Universidade de Évora - Instituto de Investigação e Formação Avançada

Programa de Doutoramento em Motricidade Humana

Tese de Doutoramento

Characterization of the prevalence of low back pain in riders – proposal of a training program

Carlota Beatriz Rico Duarte

Orientador(es) | Armando Manuel Raimundo
Orlando de Jesus Fernandes
Rute Isabel Duarte Guedes dos Santos

Évora 2025

Universidade de Évora - Instituto de Investigação e Formação Avançada

Programa de Doutoramento em Motricidade Humana

Tese de Doutoramento

Characterization of the prevalence of low back pain in riders – proposal of a training program

Carlota Beatriz Rico Duarte

Orientador(es) | Armando Manuel Raimundo
Orlando de Jesus Fernandes
Rute Isabel Duarte Guedes dos Santos

Évora 2025

A tese de doutoramento foi objeto de apreciação e discussão pública pelo seguinte júri nomeado pelo Diretor do Instituto de Investigação e Formação Avançada:

Presidente	Guida Veiga (Universidade de Évora)
Vogais	João Paulo Brites de Sousa (Universidade de Évora) Luís Miguel Antunes Gomes (Instituto Politécnico de Setúbal - Escola Superior de Saúde) Maria Dolores Apolo Arenas (Universidad de Extremadura) Maria de Fátima Florentino Gonçalves Ramalho (Instituto Politécnico de Santarém) Orlando de Jesus Fernandes (Universidade de Évora) (Orientador)

Évora 2025

"If you can't fly then run, if you can't run than walk, if you can't walk then crawl, but whatever you do you have to keep moving forward" – Martin Luther King Jr

"In order to rise

From its own ashes

A phoenix

First

Must

Burn."

Octavia E. Butler, *Parable of the Talents*

Dedication

I dedicate this thesis to my teacher, trainer, and friend, José António da Costa Freitas, who inspired me to pursue the topic of *Lower Back Pain in Equestrians*. Although this research comes too late to prevent his specific back condition from worsening, I hope it will still help him manage his pain and avoid further complications that could compromise his ability to do what he loves most – riding horses.

I also extend this dedication to all equestrian athletes suffering from lower back pain. May the findings in this thesis help them manage their pain, understand the associated risk factors, and ultimately reduce or eliminate non-specific lower back pain. I hope that this work contributes to improving their quality of life, enhancing their equestrian performance, and reducing the risk of their condition becoming career-ending.

Dedicatória

Dedico esta tese ao meu professor, treinador e amigo, José António da Costa Freitas, que me inspirou a seguir o tema de *Dor Lombar em Cavaleiros*. Embora esta pesquisa tenha vindo tarde demais para evitar o agravamento da sua condição lombar específica, espero que ainda o possa ajudar a gerir a dor e evitar complicações adicionais que possam comprometer a sua capacidade de fazer o que mais gosta – montar a cavalo.

Estendo também esta dedicação a todos os cavaleiros que sofrem de dores lombares. Que os resultados desta tese os ajudem a gerir a dor, a compreender os fatores de risco envolvidos e finalmente, a reduzir ou eliminar a dor lombar não específica. Espero que este trabalho contribua para melhorar a sua qualidade de vida, aumentar o seu desempenho equestre e reduzir o risco da condição se tornar incapacitante para as suas carreiras desportivas.

Acknowledgements

Finishing this doctorate was one of the biggest goals of my life, for the opportunities it presents and chapters it allows me to put an end to. “The difficulties and struggles of today are but the price we must pay for the accomplishments and victories of tomorrow” - William J.H. Boetcker

For the last nine years of my life my major goals were to be able to have a stable and happy life. It is my highest hope that this doctorate helps me find the stability I have desired for so long.

I have lived my share of battles in this life, most of them feeling completely alone, this was not the case during the doctorate. The biggest challenges for me in this journey were fighting self-doubt and internal pressure, and one of the happiest realizations I had was that I was not fighting these battles alone.

I would like to express my deepest gratitude to my supervisors, Professor Doctor Armando Raimundo, Professor Doctor Orlando Fernandes and Professor Doctor Rute Santos, for their unwavering support and guidance throughout this journey. Their availability, invaluable advice, and willingness to offer assistance at every step were crucial in helping me navigate the challenges of this doctorate. Their insights, encouragement, and dedication to my progress not only enriched this work but also fostered my academic growth. I truly appreciate their patience and commitment, which were instrumental in the successful completion of this thesis. To Professor Doctor João Paulo Sousa, thank you for helping me with the systematic review, one of the hardest chapters of this thesis.

A special thanks to José Freitas and Rute Santos, thank you from the bottom of my heart for helping and guiding me in my academic and professional career for the last nine years, thank you for your friendship and for having the patience to put up with me all these years, I would not be where and who I am today without you.

To my families – Duarte, Rico, Aleixo and Branco - thank you for all the support and love you have always given me. Thank you for always having an open door for me, no matter how far or distant I may be. To my parents, I owe a great deal of thanks for the opportunities they have given me in life and for helping me pursue my dreams, I hope I made you proud.

My heartfelt thanks to my dearest and closes friends that have been in my life for so long – Constança, Jorge, Troncho, Maria, Andreia, Guilherme e Francisco – thank you for the long talks, the motivation, the support and all the happy moments we have lived together. I wish to extend my deepest gratitude to my friend Elizabeth Fraser-Hitch for always being available to help me learn and improve my technical English. To my neighbors – Ana, José and Jorge - that have become a family to me thank you for all companion, readiness to help and support.

I would like to acknowledge the invaluable support of my students that have helped me throughout this journey with my horses and in data collections of the doctorate, thank you for the patience and volunteering. To Luciana Lourenço thank you for the long hours and kilometers spent with me doing data collections, building dossiers and organizing data.

I am deeply grateful to the organizations and people that helped me gather participants for my study – Polytechnic Institute of Portalegre, Mafra School of Arms, Alter Real Stud, Portuguese Dressage Academy, Colonel Manuel Teles Grilo, António Pinto, Pedro Manso, Raquel Falcão and Diogo Lima Mayer. And to the participants thank you for volunteering your time, thank you for your patience when things and gadgets did not work as expected, thank you for participating, without you all this would not be possible.

Finally, I would like to thank my dogs for time they spent lying next to me, all the companion and support they provided through the long hours I spent on my computer during this doctorate, so even when I was lonely, I was never really alone.

Agradecimentos

Fazer este doutoramento foi um dos maiores objetivos da minha vida, pelas oportunidades que me apresenta e capítulos que me permite encerrar. "As dificuldades e batalhas de hoje são nada mais que o preço que temos que pagar pelas conquistas e vitórias de amanhã" – William J-H- Boetcker

Nos últimos nove anos da minha vida os meus maiores objetivos foram conseguir ter uma vida estável e feliz. Espero honestamente que este doutoramento me ajude a encontrar a estabilidade que desejei durante tanto tempo.

Já vivi a minha cota de batalhas nesta vida, muitas delas a sentir-me completamente sozinha, o que não foi o caso durante o doutoramento. Os maiores desafios desta jornada, para mim, foram lutar contra autocrítica e pressão interna, e uma das mais felizes realizações que tive foi não estar a enfrentar estas batalhas sozinha.

Gostaria de expressar a minha mais profunda gratidão aos meus orientadores, Professor Doutor Armando Raimundo, Professor Doutor Orlando Fernandes e Professora Doutora Rute Santos, pelo seu incansável apoio e orientação ao longo desta jornada. A sua disponibilidade, conselhos inestimáveis e disposição para oferecer assistência em cada etapa foram cruciais para me ajudar a superar os desafios deste doutoramento. Os seus *insights*, encorajamento e dedicação ao meu progresso não só enriqueceram este trabalho, mas também promoveram o meu crescimento académico. Agradeço imensamente a paciência e o compromisso de cada um, que foram fundamentais para a conclusão bem-sucedida desta tese. Ao Professor Doutor João Paulo Sousa, obrigada por me ajudar na revisão sistemática, um dos capítulos mais desafiadores desta tese.

Um agradecimento especial os professores, José Freitas e Rute Santos, agradeço do fundo do coração por me ajudarem e guiarem na minha carreira académica e profissional nos últimos nove anos, obrigada pela vossa amizade e por terem tido paciência para me aturar durante este tempo, não estaria onde estou nem seria quem sou hoje sem vocês.

Às minhas famílias – Duarte, Rico, Aleixo e Branco – obrigada por todo o apoio e amor que sempre me deram. Obrigada por terem sempre as portas abertas para mim, independentemente de quão longe ou distante eu possa estar. Aos meus pais, devo um agradecimento imenso pelas oportunidades que me deram na vida e por me ajudarem a perseguir os meus sonhos, espero ter-vos deixado orgulhosos.

O meu sincero agradecimento aos meus queridos e mais próximos amigos que têm estado na minha vida por tanto tempo – Constança, Jorge, Troncho, Maria, Andreia, Guilherme e Francisco – obrigada pelas longas conversas, pela motivação, pelo apoio e por todos os momentos felizes que vivemos juntos. Quero estender a minha mais profunda gratidão à minha amiga Elizabeth Fraser-Hitch por estar sempre disponível para me ajudar a aprender e melhorar o meu inglês técnico. Aos meus vizinhos – Ana, José e Jorge – que se tornaram uma família para mim, obrigada por toda a companhia, prontidão para ajudar e apoio.

Gostaria de reconhecer o apoio inestimável dos meus alunos que me ajudaram ao longo desta jornada com os meus cavalos e nas recolhas de dados do doutoramento, obrigada pela paciência e voluntariado. À Luciana Lourenço, obrigada pelas longas horas e quilómetros passados comigo a recolher dados, a construir dossiês e a organizar informação.

Estou profundamente grata às organizações e pessoas que me ajudaram a reunir participantes para o meu estudo – Instituto Politécnico de Portalegre, Escola de Armas de Mafra, Coudelaria de Alter, Academia Portuguesa de Dressage, Coronel Manuel Teles Grilo, António Pinto, Pedro Manso, Raquel Falcão e Diogo Lima Mayer. E aos participantes, obrigada por dedicarem o vosso tempo, pela paciência quando as coisas e aparelhos não funcionaram como esperado, obrigada por participarem, sem vocês tudo isto não seria possível.

Finalmente, gostaria de agradecer aos meus cães pelo tempo que passaram deitados ao meu lado, por toda a companhia e apoio que me deram nas longas horas que passei no computador durante este doutoramento, mesmo quando estava sozinha, nunca estive realmente só.

Characterization of the prevalence of low back pain in riders – proposal of a training program

Abstract

Lower back pain (LBP) is a prevalent musculoskeletal disorder that significantly impacts quality of life, particularly among equestrian athletes (EA), due to the physical demands of the sport. Despite its high prevalence, research on LBP in this population remains limited.

This thesis aimed to assess the prevalence and risk factors (RF) of LBP in Portuguese EA and to evaluate the effectiveness of a 12-week specific training program (STP) designed to reduce LBP symptoms. The objectives included identifying LBP prevalence in EA, RF for LBP, determining the prevalence among Portuguese EA, and assessing the efficacy of the STP across multiple variables, including pain intensity, disability, functional movement, and muscle activation.

The hypothesis posited that LBP prevalence in EA would be higher than in other populations, and the 12-week STP would significantly reduce pain intensity, perceived disability, and improve functional movement and muscle activation.

The thesis includes a systematic review, a cross-sectional study on the prevalence and RF of LBP in Portuguese EA, and two intervention studies assessing the STP's effectiveness. The results revealed a high prevalence of LBP in this population, with significant risk factors such as increased weekly riding workloads, stable duties, and equestrianism as a primary occupation. The STP, specifically designed for equestrian athletes, led to significant reductions in LBP intensity and disability. Additionally, improvements were observed in muscle activation, particularly in the lumbar muscles, and functional movement, supporting the effectiveness of structured exercise interventions in managing LBP.

In conclusion, this thesis demonstrates that tailored exercise programs, like the STP developed here, are an effective strategy for managing non-specific LBP in EA. The intervention not only alleviated pain but also enhanced muscle efficiency and functional movement, contributing to improved performance and injury prevention in equestrian athletes.

Caracterização da prevalência de dor lombar em cavaleiros – efeitos de um programa de treino na redução de dor Lombar

Resumo

A dor lombar (DL) é um distúrbio musculoesquelético prevalente que impacta significativamente a qualidade de vida, particularmente entre os atletas equestres (AE), devido às exigências físicas do desporto. Apesar da sua elevada prevalência, evidencias científicas sobre DL nesta população ainda são limitadas.

Esta tese teve como objetivo avaliar a prevalência e os fatores de risco (FR) da DL nos AE portugueses e avaliar a eficácia de um programa de treino específico (PTE) de 12 semanas, desenhado para reduzir os sintomas de DL. Os objetivos incluíram identificar a prevalência de DL nos AE, os FR para a DL, determinar a prevalência entre os AE portugueses e avaliar a eficácia do PTE em várias variáveis, incluindo intensidade da dor, incapacidade, movimento funcional e ativação muscular.

A hipótese postula que a prevalência de DL nos AE seria superior à das outras populações e que o PTE de 12 semanas reduziria significativamente a intensidade da dor, a incapacidade sentida e melhoraria o movimento funcional e a ativação muscular.

A tese inclui uma revisão sistemática, um estudo transversal sobre a prevalência e os FR da DL nos AE portugueses e dois estudos de intervenção para avaliar a eficácia do PTE. Os resultados revelaram uma alta prevalência de DL nesta população, com fatores de risco significativos, como as grandes cargas semanais de treino, os trabalhos de manutenção de equinos e a prática de equitação como ocupação principal. O PTE, especificamente desenhado para os AE, levou a reduções significativas na intensidade da DL e na incapacidade. Além disso, foram observadas melhorias na ativação muscular, particularmente nos músculos lombares, e no movimento funcional, apoiando a eficácia das intervenções de exercício estruturado na gestão da DL.

Em conclusão, esta tese demonstra que programas de exercício personalizados, como o PTE desenvolvido aqui, são uma estratégia eficaz na gestão da DL não específica nos AE. A intervenção não só aliviou a dor, como também melhorou a eficiência muscular e o movimento funcional, contribuindo para um melhor desempenho e prevenção de lesões nos atletas equestres.

Papers included in this thesis

Paper 2

Duarte C, Santos R, Fernandes O, Raimundo A. Prevalence of Lower Back Pain in Portuguese Equestrian Riders. *Sports*. 2024; 12(8):207. https://doi.org/10.3390/sports12080207

Paper 1

Duarte C, Raimundo A, Sousa JP, Fernandes O, Santos R. Prevalence of lower back pain and risk factors in equestrians: a systematic review. Accepted by *Sports* – In final stage of review process.

Index

List of tables

List of figures

Abbreviations and acronyms

ACC - Accelerometry

AIC - Akaike Information Criteria

BC – Before Christ (before common era)

BF% - Body fat percentage

BM – body mass

BMI – Body mass index

BMR – basal metabolic rate

BP – Back pain

CEA – Child equestrian athletes

CER - control event rate

CLBP – Chronic low back pain

CT – clearing test

DS – deep squat

EA – Equestrian athlete

ED – Equestrian discipline

EMG - Electromyography

EMMs - Estimated Marginal Means

ES – Equestrian sports

ESI – Erector Spinae (iliocostalis)

FEI – Fédération Équestre Internationale

FEP – Portuguese equestrian federation

FMS – functional movement screening tests

GenLM - Generalized Linear Models

HAB – Hip abduction with hip neutral test (adductors)

HAB-HF – Hip abduction with flexed hip (monoarticular adductors)

HAD-HF – Hip adduction with hip flexed test (piriformis)

HE – hip extension test (iliopsoas)

HF-KF – Hip flexion with knee flexed test (gluteus maximus)

HIR – Hip internal rotation test (external rotators)

HTR – Hip total rotation (hip rotators)

IMUs – Inertial measurement units

ISBE – Isometric side bridge endurance (trunk lateral flexors)

ISBE-ND – Isometric side bridge endurance in non-dominant side (trunk lateral flex-ors)

KF – Flexion of knee (quadriceps)

LBP – Lower back pain

LTAD - Long Term Athlete Development

MCD - meaningful change definition

MF – Multifidus muscle

MMI – muscle mass index

MRI – Magnetic resonance imaging

N - number

NMQ – Nordic Musculoskeletal questionnaire

NRS – Numeric rating scale

NSAIDs – nonsteroidal anti-inflammatory drugs

NSQ – Not standardized questionnaire tool

ODI – Oswestry Disability Index/ Oswestry Low Back Pain Disability Questionnaire

OR – Odds ratio

OSQE - Observational Study Quality Evaluation tool

PE – perceived exertion

PES – Borg’s perceived exertion scale

PSEQ – Pain Self-efficacy questionnaire

Q – Question

RMDQ – Roland Morris disability questionnaire

RMDS – Roland Morris disability score

RM-Square – Root Mean Square

ROM – Range of motion

sEMG – Surface electromyography

SF-MPQ – Short form McGill pain questionnaire

STP – Specific training program

TPU – trunk push-up

VAS – visual analog scale

VFI – visceral fat index

W – week

WSP – Warm-up and stretching program

Chapter I

General Introduction

Objectives

Hypothesis

Chapter I
General introduction

Lower back pain (LBP) is the most prevalent musculoskeletal disorder affecting people worldwide, it affects individuals of all ages and represents a significant cause of disability and diminished quality of life. In 2020, approximately 1 in 13 people had experienced LBP at some point in their lives, making it a major public health concern with substantial socioeconomic impact. Non-specific LBP – defined as cases where no identifiable disease or structural cause can be found to explain the pain - is the most common presentation of LBP, affecting 90% of people experiencing LBP. LBP can be classified as acute - lasting less than 6 weeks - sub-acute - lasting 6 to 12 weeks- or chronic - lasting more than 12 weeks. This condition leads to a reduction in physical activity, loss of work productivity, and increased healthcare utilization, posing a burden not only on individuals but also on healthcare systems worldwide.[1,2]

In the context of sports, LBP is particularly prevalent among athletes [3] due to the physical demands, repetitive movements, and specific biomechanical stresses associated with different sporting activities. In the context of equestrian sports (ES), LBP is identified as the most common musculoskeletal complaint among equestrian athletes (EA),[4] and is especially concerning due to the unique physical and biomechanical challenges of this particular sport, which involves maintaining balance, postural control, and repeated exposure to impact forces. ES require a high degree of core stability, muscular endurance, and symmetrical movement to ensure optimal performance and minimize occurrences of traumatic incidents. Riders often experience LBP due to factors such as poor posture, muscular imbalances, or inadequate training regimens that fail to address these specific demands. Despite the widespread occurrence of LBP among EA, research on its prevalence and underlying risk factors remains limited. This underscores the need for targeted studies to better understand LBP in this population, aiming to guide the development of effective preventive measures, management techniques and rehabilitation strategies.

Existing literature suggests that the prevalence of LBP in EA is higher than in other sports,[5] likely due to prolonged periods of riding, the vibration and shock absorption experienced while on horseback, and the physical requirements for maintaining control of the horse.[6] These challenges can contribute to the development of both acute and chronic LBP. Although numerous studies have investigated LBP-specific risk factors in EA, there is still no consensus on which risk factors are the most relevant or their precise impact on functional performance. Understanding these elements is crucial for tailoring interventions that not only alleviate symptoms but also enhance riders' ability to train and compete safely.

Implementing appropriate training interventions to address LBP can reduce pain, improve functional movement patterns, enhance overall performance in EA, and ultimately improve quality of life in this population. Specific training programs focused on core stability, flexibility, mobility, and muscular endurance could be particularly beneficial for this population. Recent evidence from various athletic disciplines supports the efficacy of such interventions in reducing LBP and associated disability.[7] While research on exercise-based interventions for LBP in EA has shown encouraging outcomes,[8-10] studies tend to focus on a limited set of variables. There is still a need for more comprehensive investigations that encompass various factors, such as perceived disability in daily life, perceived disability during equestrian activities, body composition, functional movements, and pain intensity. Expanding the scope of research in this way could provide a clearer understanding of the most effective approaches for this population.

This thesis aims to fill this gap by investigating the prevalence of LBP in EA, identifying relevant risk factors, and evaluating the impact of a specialized 12-week training program on LBP symptoms and functional outcomes. The findings will provide valuable insights into the management of LBP in ES, potentially leading to more informed guidelines for training, injury prevention, and rehabilitation within this unique athletic population.

1.1. Pertinence of the thesis, main objectives and hypothesis

1.1.1. Pertinence of the thesis

Low back pain is a significant health issue among EA, leading to reduced performance, limitations in daily activities, and an increased risk of chronic pain. Despite the high prevalence of LBP in this population, evidence-based training programs specifically tailored to EA are scarce. The need for targeted strategies to address LBP in equestrians is crucial, as general recommendations may not account for the unique demands of the sport, such as maintaining posture and stability during riding.

Portugal, with its well-established equestrian culture and diverse population of riders, provides a fitting context for this research. The nationwide participation allows for a more representative sample, encompassing various equestrian disciplines, skill levels, and regional differences. The findings aim to inform the development of specialized training programs that could help reduce LBP symptoms, improve functional performance, and enhance the quality of life for EA.

This study is pertinent because it addresses a gap in the existing literature, contributing to a better understanding of the factors associated with LBP in equestrians and providing evidence for the effectiveness of specific training interventions. Moreover, the results could guide coaches, clinicians, and sports professionals in implementing more precise and effective rehabilitation and prevention strategies.

1.1.2. Objectives of the thesis

1. Identify the real prevalence of lower back pain in EA:
    - 1.1. Determine the prevalence of LBP specifically among Portuguese EA.
2. Identify risk factors for LBP in EA:
    - 2.1. Determine which risk factors are associated with LBP in the overall equestrian population.
    - 2.2. Explore specific risk factors within the Portuguese equestrian community.
3. Design and evaluate a specific training program aimed at reducing LBP symptoms:
    - 3.1. Assess the program’s efficacy across several variables:
        - 3.1.1. Perceived disability in daily life.
        - 3.1.2. Perceived disability during equestrian activities.
        - 3.1.3. Body composition, focusing on relevant variables.
        - 3.1.4. Functional movement patterns.
        - 3.1.5. LBP intensity.
        - 3.1.6. Muscle activation.
        - 3.1.7. Athlete movements while riding.
    - 3.2. Compare the results of the specific training program intervention with those of a control group.

1.1.3. Hypothesis

1. The prevalence of LBP in EA will be higher than that reported in the general population and other athletic populations, with a significant proportion of Portuguese riders affected.

2. The 12-week training program will significantly reduce LBP intensity and perceived disability, with improvements noted across various outcomes, including functional movements and body composition.

3. There will be a positive correlation between changes in muscle activation, improved functional movement, and reduced LBP symptoms following the intervention.

1.2. Contribution in academic and practical terms

1.2.1. Academic Contributions

1. Advancement in knowledge of LBP in EA: This thesis will add to the existing literature by providing a comprehensive assessment of LBP prevalence and risk factors in EA, a group that is relatively underrepresented in sports science research. The thesis data can help bridge gaps in understanding the unique demands and risks associated with ES.
2. Multidimensional Approach to LBP Assessment: By evaluating multiple variables - such as perceived disability in and of ES, functional movement patterns, body composition, muscle activation, and riding biomechanics – the present research promotes a holistic view of LBP management. This approach can influence future studies to adopt more comprehensive methodologies when investigating equestrian sports-related musculoskeletal issues.
3. Contribution to Evidence-Based Interventions: By assessing the efficacy of a 12-week specific training program for LBP, the present research provides empirical support for structured interventions. This could guide future studies in the development of tailored exercise protocols and serve as a foundation for systematic reviews and meta-analyses focusing on LBP in EA.
4. Guidance of Further Research: The study's findings on risk factors and intervention outcomes can help identify areas where further research is needed,

such as longitudinal studies on injury prevention, the effects of different training modalities, or specific biomechanical analyses.

1.2.2. Practical Contributions

1. Development of Tailored Training Programs for riders: The thesis findings can directly inform the design of specific training programs for EA, targeting LBP prevention and rehabilitation. These programs can be utilized by coaches, trainers, and sports therapists to implement scientifically supported strategies that are customized to the needs of riders.
2. Enhanced Rider Performance and Quality of Life: By addressing LBP through tailored training interventions, this research can contribute to the improvement of riders' functional performance, pain management, and overall quality of life. The implications extend to promoting longer, healthier careers in ES by minimizing the risk and impact of chronic LBP.
3. Improvement of Clinical Practices for LBP Management: The thesis provides valuable insights for physiotherapists and healthcare providers, supporting the adoption of sport-specific rehabilitation techniques for riders experiencing LBP. This can lead to more effective treatment plans that consider the unique physical requirements of ES.
4. Informing Policies and Guidelines in ES: The results of the study could inform health and safety guidelines, training standards, and preventive measures within ES organizations. This may include advocating for the integration of LBP-focused training programs as part of routine conditioning for riders to ensure safer practice.
5. Educational Value for Sports Professionals: The findings and methodologies utilized in this research can be integrated into sports science and physiotherapy curricula to educate future professionals on LBP management, injury prevention, and the development of sport-specific training interventions.

1.3. Structure of the thesis

The present thesis follows the Scandinavian model – divided in scientific papers – and is divided into six chapters. The general outline of the thesis and paper division is shown in **Figure I.1**.

Theoretical and conceptual framework	**Chapter I**		**General Introduction**
	Chapter II	**Literature review**	Equestrian sports The equestrian athlete Equestrian sports science
	Chapter III	**Paper 1**	Prevalence of lower back pain and risk factors in equestrians: a systematic review
Lower back pain in Portuguese Equestrians	**Chapter IV**	**Paper 2**	Prevalence of Lower Back Pain in Portuguese Equestrian Riders
Effects of specific training program in LBP in Equestrians	**Chapter V**	**Paper 3**	Effects of a 12-week specific training program on lower back pain symptoms in equestrian athletes
	Chapter VI	**Paper 4**	The effect of an intervention on activation levels across four lower back muscles and lower back pain symptoms of equestrian athletes
Closure	**Chapter VII**		**Discussion and conclusions of the thesis**

Figure I.1. *Outline of the thesis*

1.4. References

1. World Health Organization. Low back pain [Internet]. Geneva: WHO; 2023 Jun 19 [cited 2024 Oct 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/low-back-pain

2. World Health Organization. WHO releases guidelines on chronic low back pain [Internet]. Geneva: WHO; 2023 Dec 7 [cited 2024 Oct 16]. Available from: https://www.who.int/news/item/07-12-2023-who-releases-guidelines-on-chronic-low-back-pain

3. Trompeter K, Fett D, Platen P. Prevalence of Back Pain in Sports: A Systematic Review of the Literature. *Sports Med*. 2017; 47: 1183-1207. https://doi.org/10.1007/s40279-016-0645-3

4. Quinn S, Bird S. Influence of saddle type upon the incidence of lower back pain in equestrian riders. *Br J Sports Med*. 1996; 30(2): 140-144. https://doi.org/10.1136/bjsm.30.2.140

5. Wilson F, Ardern CL, Hartvigsen J, Dane K, Trompeter K, Trease L, et al. Prevalence and risk factors for back pain in sports: a systematic review with metanalysis. *Br J Sports Med*. 2021; 55(11): 601-607. https://doi.org/10.1136/bjsports-2020-102537

6. Pugh TJ, Bolin D. Overuse Injuries in Equestrian Athletes. *Curr Sports Med Rep*. 2004; 3(6): 297-303. https://doi.org/10.1007/s11932-996-0003-67.

7. Thornton JS, Caneiro JP, Hartvigsen J, Ardern CL, Vinther A, Wilkie K, et al. Treating low back pain in athletes: a systematic review with meta-analysis. *Br J Sports Med*. 2021; 55(12):656-662.

8. Weeks RA, McLaughlin PA, Vaughan BR. The efficacy of an eight-week exercise program for the management of chronic low back pain in the equestrian population. The Journal of sports medicine and physical fitness. 2024. 10.23736/S0022-4707.24.15830-6

9. Biau S, Le Navenec C, Pycik E, Noury B. Un cycle de dix semaines d'étirement et de renforcement des muscles du tronc impacte l'activité équestre et diminue les

douleurs lombaires des futurs cavaliers professionnels. Sci Sports. 2024; 39(1):36-42. https://doi.org/10.1016/j.scispo.2023.02.002

10. Siedlecka M, Aniśko B, Placek K, Wójcik M. Low back pain occurrences and gynecological disorders in female equestrians and strengthening of core stability muscles lumbar spine. Fizjoterapia Polska. 2023; 23(4). 10.56984/8zg20a371

Chapter II

Literature review

Paper 1 – Title systematic review

Chapter II
Literature review

2.1. Equestrian sports

2.1.1. Equestrian sports characterization

The horse - Equus caballus - has captivated human attention for millennia, as evidenced by its prominent depiction in Western European cave art from the Stone Age [1]. “Horses are the animal that has changed history” - Ludovic Orlando - the role of the horse has varied greatly throughout history – food source, warfare, agricultural work, transport, leisure, sport and therapy [2,3] - however, its impact on human cultural and economic development throughout history is undeniable.

The earliest recorded interaction between humans and horses dates back to 1350 BC, when horses were being trained for warfare [2]. Equestrian sports (ES) later emerged as part of the ancient Olympic Games in 680 BC [4]. ES can be very complex due to the wide variety of sports categories, characteristics, discipline formats and styles.

In ES, men and women compete on equal terms, making it the only sport at the Olympic level that is truly mixed [5], the sex of the horse is also irrelevant in competition. A unique feature of ES is the exceptionally long athletic careers it allows. Riders can begin competing in pony divisions as early as age five [6], and many continue to compete at the Olympic level well into their 60s and 70s [7]. This longevity makes equestrianism an "early start-late specialization" sport within the Long-Term Athlete Development model [8].

ES are uniquely complex, requiring a partnership between two athletes—horse and rider—working together toward a common goal. It's essential to remember that one of these athletes is an animal [9]. Horses are herbivorous herd animals with a natural instinct to flight rather than fight, and their senses, particularly eyesight, differ significantly from those of humans [9]. Their natural instincts shape their behaviour and responses [9]. Horses also possess strong memories and are shaped by their past experiences [9], which may be unknown or misunderstood by their human partner.

In ES, it is normal for a single rider to work with and ride more than one horse, regardless of their skill level. For inexperienced riders, “to develop a feel for riding, it is necessary to ride as many different horses as possible”[9] and professional riders train and compete with various horses. This highlights another important notion: while the human athlete remains the same, there can be many different equine athletes being worked and trained.

In ES the relationship trainer-trainee in the combination horse-rider varies depending on the rider experience and skill level (**Figure II.1**). In Portugal there is a proverb that says "Young horse, old rider. Young rider, old horse", meaning the schooled horse - schoolmaster - is the best teacher and the young horse should only be ridden by experienced riders [9]. Nonetheless, every equestrian athlete (EA), regardless of skill level, requires an experienced trainer[9] – instructor - who assists them in developing their skills, enhancing communication with the horse and elevating their performance [10].

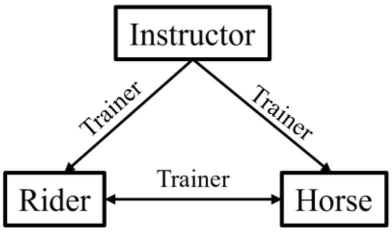


Figure II.1. *Triad instructor-rider-horse and trainer role.*

The daily training of the EA combination, regardless of skill level and equestrian discipline (ED) – on horseback – is holistic, meaning, a rider that competes in show jumping does not limit the riding work to only jumping the horse, he also works on flatwork on all three gaits, hacks out among other activities.

2.1.2. Equestrian disciplines overview

Nowadays there are more than 50 ED [11] recognized by various national and international federations worldwide, the Fédération Équestre Internationale (FEI) regulates eight disciplines – jumping, dressage, para-dressage, eventing, driving, para-driving, endurance and vaulting [12]. In various disciplines, horse-human interaction can differ, ranging from handling the horse on the ground, performing gymnastics on horseback, riding in a wheeled chariot pulled by the horse, to the most common form - riding directly on horseback. **Table II.1** provides a simple overview of how horse-human interactions, sport category and sport characteristics can vary throughout different ED and styles.

Table II.1. *Horse-human interactions, sport category and sport characteristics in different equestrian disciplines and styles.*

Discipline/ style	Horse-human interaction	Sport category	Competition characteristics
Dressage	Horseback	Individual	Three gaits Flatwork
Show Jumping	Horseback	Individual	Canter Jumping
Eventing	Horseback	Individual	Three gaits Flatwork Canter Jumping
Endurance	Horseback	Individual	Mainly trot and canter Flatwork
Vaulting	Gymnastics on horseback	Individual Team	Canter Gymnastic movements on horseback
Fox hunting	Horseback	Team	Mainly canter Flatwork Jumping
Western style	Horseback Ground handling	Individual Team	Three gaits Flatwork
Racing	Horseback Harness	Individual Team	Canter Flatwork Jumping
Harness racing	Harness	Individual	Trot Flatwork
Polo	Horseback	Team	Mainly canter Flatwork
Horseball	Horseback	Team	Mainly canter Flatwork
Driving	Harness	Team	Three gaits Flatwork

			Mainly trot and canter
Para-dressage	Horseback	Individual	Three gaits Flatwork
Para-driving	Horseback	Individual	Three gaits Flatwork Mainly trot and canter
Showing	Horseback Ground handling	Individual	Tree gaits Flatwork

Note: Flatwork – the horse does not perform any intentional jumping.

Additionally, each discipline can have different formats with varying rules and objectives, regardless of level of competition. For example, in jumping competitions the objectives may vary depending the format, in the puissance the objective is to jump increasingly higher fences, with the highest faultless jump winning, in hunting competitions the style and technic of the combination is what is judged, in jumping competitions not against the clock the objective is to jump the course faultless regardless of time, in competitions against the clock the objective is to clear the course in the shortest amount of time possible.

2.1.3. Age categories

Being ES always reliant on a combination – horse and rider – there exist different age categories - that determine the competition level - focusing on the horse or on the rider specifically, **Tables II.2** and **II.3** describe age categories of the rider and the horse in competition.

Table II.2. *Age category of equestrian athletes in competition*

Level of competition	Age category	Description (years old)
National competition	Infant Pony	6 to 8
National competition	Novice	8 to 12
	Novice pony	
National competition	Youth	12 to 14
National competition	Youth pony	12 to 16
International competition	Children	12 to 14
National competition	Junior	14 to 18
International competition		

National competition	Young rider	16 to 21
International competition		
International competition	Under 25	16 to 25
National competition	Senior	Over 19
International competition		Over 18
Level of competition	Competition category	Description (years old)
National competition	Veteran	Over 45
International competition		

Note: National competition as in Portuguese equestrian federation (FEP) rules [13]. International competition as in FEI rules [14]. The veteran age category may vary among disciplines in FEI and FEP, retrieved from jumping rules [13,14].

The rider age category is flexible when overlapped, depending on competition level and discipline rules – meaning (depending on the competitions) a rider aged 19 can choose to register as young rider or under 25 or senior during that competition season.

Table II.3. *Age category of equine athletes in competition*

Level of competition	**Age of Young horses competition**
National competition	4 years old
National competition	5 years old
International competition	
National competition	6 years old
International competition	
National competition	7 years old
International competition	
International competition	8 years old

Note: National competition as in FEP jumping rules [13]. International competition as in FEI jumping rules [14].

Rider under the age of 12 cannot participate in young horses competitions [13]. The age categories exist to regulate the national championships and international competition level of horse or rider and are dependent on ED rules.

2.1.4. Level of competition and skill level of the rider

Each ED or discipline format has different levels of competition, generally levels can vary among – non-federated competitions, national competitions, national championships, international events, official international events, continental international competitions, world championships and Olympic. The level of competition one chooses to enter can vary with horse, rider or combination skill level and horse or rider age category.

Rider skill level is a concept that lacks consensus and a standardized definition, especially in ES sciences. Some equestrian federations have created affiliation systems sensitive to the different competition levels of riders. While skill level may vary based on affiliation status and competition level, it is not solely determined by these factors. Williams and Tabor[15] proposed a detailed taxonomy of rider status categories for ES (**Table II.4**).

Table II.4. *Taxonomy of rider status categories in equestrian sports*

Category	Description
Leisure rider	Rider that engages in hacking and unaffiliated equestrian events
Novice rider	Rider that is inexperienced and has less than 3,000 hours of riding experience.
Experienced rider	Rider that has over 3,000 hours of riding experience, demonstrating an independent seat and competent ability in flatwork (up to and including lateral work) and jumping (≥1.00 m), with some competitive experience in affiliated equestrian events.
Amateur rider	Experienced riders who regularly participate in affiliated equestrian events but do not rely on equestrianism as their primary source of income.
Professional rider	Experienced riders whose primary occupation involves working with or riding horses, or coaching riders.
Elite rider	Experienced riders who have competed at the national or international level in a specific ED.
Expert rider	Elite riders who have represented their country in the Olympics or the highest level of competition in non-Olympic ED.
Para-rider	A rider, whether experienced or novice, who participates in para-equestrian events as defined by the FEI.

Adapted from Williams, Tabor [15].

2.2. The Equestrian athlete

The millennia-long history of ES has brought a consensus on how riders should sit on a horse[2] – the standard position[16] (**Figure II.2**). A correct seat is described as upright, balanced, elastic, solid, interactive[17] and aligned with the horse's center of gravity[18] and allows the rider to absorb the natural and special reactions of the horse[16]. Different types of seats – light or deep - can only be developed from a secure, basic and correct seat [9]. The standard position in described as having an imaginary vertical line running through the ear, tip of the shoulder, tip of the hip, and the heel. The feet should be parallel to the horse (with the toes possibly slightly turned outward), with the stirrup positioned on the front third of the foot, and the ankles relaxed (heels naturally down), creating a "shock-absorbing angle". The head should be straight, with the gaze parallel to the ground. The forearm (elbow, arm, and wrist) and the reins should form a straight, uninterrupted line to the horse's mouth. The hands should be positioned with the nails facing each other, thumbs pointing up, placed above and in front of the horse's withers, with a hand's width of space between them. [2'9'16]

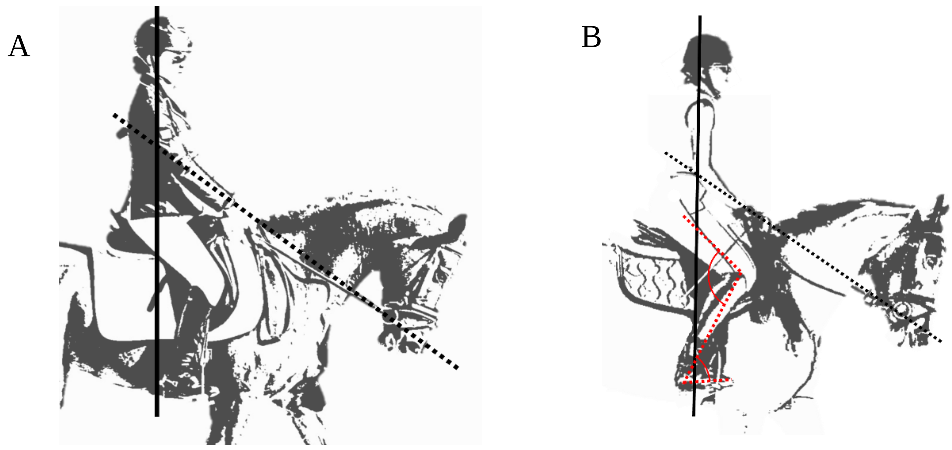


Figure II.2. *Rider standard position*
A – Dressage seat (longer stirrup leathers); *B – Jumping seat (shorter stirrup leathers)*

In different ED the stirrup length can vary to help the rider connect to the horses movements, these variations do not alter the standard seat definitions, the length of the stirrup leathers will only vary the angles of the riders thigh-leg and leg-foot as shown in **Figure II.2B**.

The rider seat has some variations according to the discipline practiced, these variations help the rider adapt to special reactions of the horse – when jumping, racing and others. The most common seats in English riding are the dressage seat (**Figure II.2A**), light seat (**Figure II.3A**) and jumping seat (**Figure II.3B**).[9] **Figure II.3C** also shows the racing seat where the rider angles – trunk-thigh, thigh-leg and leg-foot – are as closed as possible.

Figure II.3. *Rider standard position with a light seat*

A – The light seat; B – Rider seat over a jump (jumping seat); C – Rider seat racing.[59]

2.2.1. Training of the rider

Rider training follows a training scale (**Figure II.4**) focused on the development of the seat and the aids - cues used by the rider to communicate with the horse.

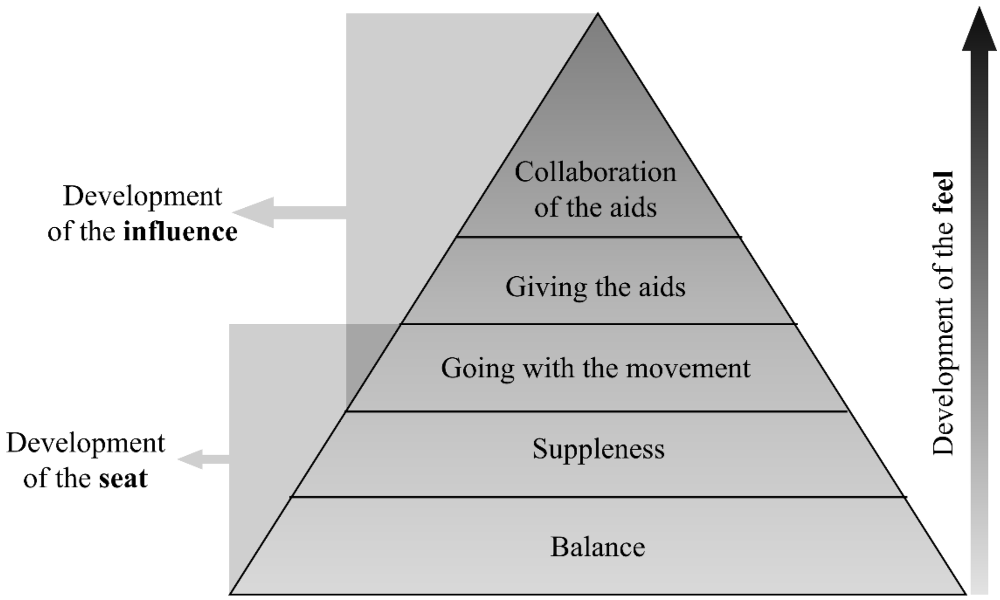


Figure II.4. *Rider training scale*

Note: Adapted from - The principles of riding [9]

A correct seat forms the foundation of a rider's influence over the horse. A supple and elastic seat enables the rider to move harmoniously with the horse's motion. A balanced seat is both a prerequisite for effective influence and a result of mastering riding techniques. Early in their training, riders must develop this balance, which evolves through the gradual refinement of leg, weight, and rein aids. An understanding of body mechanics and riding theory enhances sensitivity in riding. Establishing this foundation is crucial for developing confidence and control at the outset of a rider's equestrian education.

2.3. Biomechanics and physical demands of horse riding

2.3.1. Equestrian athlete posture and horse movement

Horse gaits – walk, trot and canter - vary in limb coordination, speed and center of gravity trajectories and riders must follow the horse's motion primarily through controlled pelvic movements. This requires supple hip joints and maintaining a vertical body alignment.[18] Synchronizing the rider movements with the horse is crucial for achieving harmony.[19] Sudden changes in the horse speed, like rapid acceleration or deceleration, can disrupt the rider's position due to inertia and momentum. Anticipating the horse movement direction helps reduce unbalancing effects, such as leaning forward when a racehorse starts or maintaining a neutral position when riding a cutting horse – western style discipline - to stay balanced during unpredictable movements. [20]

2.3.2. Equestrian athlete pelvic movement patterns

The rider's pelvic movements—pitch, roll, and yaw—are essential for following the horse's motion. Pitch involves forward (anterior) or backward (posterior) rotation around the horizontal axis, affecting the rider's posture: anterior pitch creates a hollow back (lordosis), while posterior pitch flattens the back (kyphosis). Roll refers to the side-to-side tilt of the pelvis, and yaw involves rotation around the vertical axis, turning the pelvis left or right. The structure of the pelvis differs between male and female riders, influencing riding position and stability. Female riders, with wider and shorter pelvises, have a broader base of support and exhibit more pelvic and trunk roll. Additionally, the female pelvis has a greater posterior pitch, resulting in a more kyphotic posture compared to male riders. [20]

2.3.3. Equestrian athlete symmetry and balance

Riders often exhibit structural and functional asymmetries between the left and right sides of the body, some of these asymmetries are inherent and others developed during riding career. [21'22'23] While studies on leg length differences yield conflicting results, right-handed dressage riders show greater rein tension on the dominant side, indicating differences in stability between hands. [18'21'22] Despite inherent asymmetry, riders are trained to sit symmetrically to help horses move evenly. Pelvic asymmetry, especially in experienced riders, complicates this balance as both rider and horse exhibit their own patterns of laterality. [24,25] Rider asymmetric postures also affect saddle forces on the horse's back. [26]

Riders' arm and leg asymmetries have been observed during movement, with novice riders displaying larger ranges of motion and professional riders showing more consistent movement patterns. [23,27] Misalignment in one body segment leads to compensation in others, such as collapsing through one hip. [28]

Several studies have examined riders' movement patterns off the horse, revealing a tendency to load more weight on one side of the body. [25,29,30] Asymmetries in foot pronation affect pelvic movement and tests with Swiss balls have shown that riders often make compensatory movements when controlling pelvic rotation. [31,32]

Off-horse assessments can help identify asymmetries and guide therapeutic exercises to improve rider symmetry. According with Clayton, MacKechnie-Guire and Hobbs[20] further research is needed to develop effective testing and exercises to address these rider asymmetries and their impact on equestrian performance, with the objective of ensuring that riders are dynamically stable and functionally symmetrical while managing the forces and movements transmitted from the horse.

Evident progress has been made in understanding horse-rider biomechanics, nonetheless, much remains to be explored regarding how rider movements affect horse performance and vice versa. According with Wolframm[2] research has focused on isolated kinematic and kinetic variables and a more comprehensive approach is needed to study rider-horse coordination across different gaits and skill levels. Analyzing these interactions could improve rider training, motor control and address physical asymmetries. In the long term, research could benefit talent identification, coaching, rider safety, and horse welfare. [2]

Biomechanics is crucial in ES, as experienced riders demonstrate more efficient movement patterns and better synchronizing with the horse. Understanding motor learning stages helps riders develop automatic and effective responses, improving their performance and stability. Future studies could provide valuable feedback to enhance training and overall equestrian performance. [2]

2.3.4. Muscle activity of the equestrian athlete – surface electromyography

Surface electromyography (sEMG) has become an important tool in understanding the neuromuscular demands placed on EA. By measuring muscle activation patterns, sEMG allows for the analysis of how riders engage various muscle groups during different gaits, horse movements and skill levels. This research provides valuable insights into muscle coordination, strength and fatigue, which are critical for optimizing rider performance and preventing injuries. Several studies have explored muscle activity in EA, highlighting key differences between novice and advanced riders as well as the effects of different riding conditions.

Gonzalez and Šarabon[33] compared novice and advanced riders' neuromuscular control. Novice riders showed more reciprocal muscle activation, while advanced riders exhibited better intermuscular coordination, higher core engagement and efficient muscle control, highlighting superior neuromuscular control in advanced riders.

Guillaume, Laroche and Babault [34] analysed muscle activity and kinematics of amateur riders during cross-country jumps. Similar muscle activation was found across obstacles versus cross-country jumps, with minor kinematic differences. No significant changes in muscle strength were noted and different obstacle configurations – jumping or cross-country - did not greatly affect muscle or kinematic responses.

Funakoshi, Masuda, Uchiyama and Ohta[35] assessed trunk alignment improvement in horseback riding compared to a simulator. Horseback riding sessions showed reduced erector spinae activity and better trunk alignment due to coordinated rider and horse movements, this effect was not seen in the horse simulator.

In 2012, Douglas, Price and Peters[36] undertook a systematic review that found that as horses progress through gaits, riders' heart rate, oxygen consumption, and muscular contraction increase. The review called for more research, especially on competitive performance, to inform the development of equestrian-specific strength and conditioning programs.

In 2021, González and Šarabon[37] conducted a study investigating shock attenuation mechanisms in novice and advanced riders, linking neuromuscular control to low back pain. Advanced riders had better shock attenuation and muscle tone, particularly in trunk stabilizers, suggesting the importance of muscular anticipation in preventing LBP.

Pantall, Barton and Collins[38] explored iliocostalis lumborum and rectus abdominis activation during rising trot. Novice riders coactivated both muscles, while experienced riders displayed phase shifts, with rectus abdominis acting as an agonist, underscoring the need for targeted abdominal training in experienced riders.

In 2022, Legg, Cochrane, Gee, Macdermid and Rogers[39] designed a study that measured physiological demands and body movement of jockeys – racing EA - during trials and races. Races required higher cardiovascular effort and hamstring activation, emphasizing the need for race-specific off-horse training to improve jockey fitness, stability and horse welfare.

In summary, advanced riders show superior neuromuscular control, better shock attenuation, and improved trunk stabilization, highlighting the importance of muscular anticipation for injury prevention. Horseback riding improves dynamic trunk alignment, an effect not replicated by simulators. While different riding conditions do not significantly alter muscle activation, tailored training programs, are essential for enhancing performance. Further research is needed to develop equestrian-specific strength and conditioning programs, especially for competitive riders.

2.3.5. Horse-Rider Interaction Through Accelerometry

In recent years, the use of accelerometry and other wearable sensor technologies has gained attention as a valuable tool for analyzing and enhancing the performance of EA. These methods provide insights into rider biomechanics, horse-rider coordination and the physical demands of ES, offering new perspectives on training and injury prevention. Several studies have explored the application of accelerometers and inertial measurement units (IMUs) to quantify and assess rider movement and interaction with the horse across various gaits and skill levels.

Eckardt and Witte[40] assessed horse–rider interaction using inertial measurement techniques, revealing better horse-rider coordination in the sagittal plane compared to the frontal plane. Differences were found across equine gaits, though no significant differences were observed between skill levels.

Wang et al[41] created a method for analyzing rider posture with body sensor networks, highlighting real-time posture updates based on inertial sensor data. The method was validated with an optical system and identified key differences in exercise intensity and joint angles, providing useful data for coaches to improve rider skills.

Izzo, Convertini, D'isanto, Cejudo-Palomo and Varde’i[42] used inertial sensors to examine spinal impact during ES, finding no significant impacts during walk but high-impact events during trot and canter. The findings suggest the need for training adjustments to include spine mobilization and strengthening exercises to prevent localized trauma.

Wilkins, Mulloy and Camomilla[43] explored trunk-pelvis acceleration attenuation in sitting trot using IMUs. Findings showed that riders significantly reduced the horses accelerations between their trunk and pelvis, with attenuation closely linked to horse acceleration. These findings highlight the need for further investigation into the factors influencing this attenuation.

Wolframm, Bosga and Meulenbroek[44] studied horse-rider coordination across gaits – walk, rising trot, sitting trot and canter - using accelerometers. Canter showed the highest synchronicity between horse and rider. The study concludes that accelerometers are effective in identifying distinct coordination patterns, which vary by gait.

Funakoshi, Masuda, Uchiyama and Ohta[35] analyzed trunk alignment improvement from horseback riding, comparing it to a horse-riding simulator. Exploratory analysis found associations between the rider's neck acceleration and the horse's saddle angular velocity, as well as between the rider's pelvis and the saddle's angular velocity. Riding also improved the rider's trunk alignment, an effect not seen with the simulator, indicating a distinct underlying mechanism.

González and Šarabon[37] analyzed neuromuscular mechanisms for shock attenuation in novice and advanced riders. Analyses of variance showed that advanced riders had better shock attenuation and higher overall muscle tone. Cross-correlation analysis revealed that the main difference between groups – novice and advanced - was in the timing, and not the intensity of muscle activation. This highlights the importance of training muscular anticipation in trunk stabilizers, which is more crucial than focusing solely on muscle activation intensity for EA and coaches.

Overall studies show better horse-rider coordination in the sagittal plane, highlighting the importance of real-time posture updates, and the need for spinal mobilization to prevent trauma from high-impact gaits. Research also highlights the significant role of trunk-pelvis acceleration attenuation, the variability of coordination across gaits, and the necessity of improving muscular anticipation in riders for superior shock attenuation and overall performance.

2.4. Exercise Interventions, Core Stability and Training Program Development for Equestrian Athletes

The development of effective exercise training programs for EA is crucial for optimizing both rider performance and horse welfare. A systematic review[36] on physical fitness, physiological demands, and biomechanical performance in EA highlights the significant impact of riding on the rider's body. As riders progress through different gaits, particularly during faster movements like canter and jumping, the physical demands increase, requiring higher levels of muscle engagement, particularly in the trunk. These demands suggest that targeted strength and conditioning programs are necessary, particularly in competitive settings.

Additionally, as stated before the horse-rider partnership is complex, with rider fitness, balance, and decision-making playing key roles in influencing good performance. An unbalanced or physically unfit rider not only struggles to communicate effectively with their horse but also increases the physiological demands on the horse by forcing it to compensate for the rider’s unbalanced movements. Responsible riders must understand the impact their physical condition and decisions have on their equine partners, and training programs should be designed to promote both rider fitness and informed decision-making to safeguard the horse’s health and welfare.[15]

Furthermore, exercise programs are not only essential for enhancing performance but also play a significant role in preventing injury, by improving function and can help reduce pain in athletes[45]. Research shows that tailored exercise rehabilitation programs can improve trunk muscle activation, leading to better muscle function and reduced pain[46]. Strengthening core stability and addressing muscle imbalances through targeted exercises helps reduce the strain on both rider and horse, promoting longevity in the sport. Integrating therapeutic interventions that focus on core stability, flexibility, and balance into training programs is vital for injury prevention and performance enhancement, ensuring that riders maintain physical resilience while minimizing the risk of overuse injuries. These programs should be adaptive, addressing both rehabilitation needs and performance goals, enabling riders to remain competitive while safeguarding their health and the well-being of their horses.

Recent studies have explored various training interventions, including core fitness, strength, and stretching programs, aimed at improving rider biomechanics, symmetry, and managing chronic conditions like low back pain. These studies highlight the importance of targeted exercise regimens in reducing asymmetrical loading, enhancing muscular endurance, and alleviating pain, all of which contribute to better riding performance and overall rider life quality.

Hampson and Randle[47] investigated the effect of an 8-week core fitness program on rider symmetry and pressure distribution on the equine back. Dressage horse-rider pairs showed significant improvements in left-right symmetry and increased stride length after the implementation of the program. The study suggests that core fitness programs can reduce asymmetrical loading and improve performance in both rider and horse.

Lee, Soboleswki, Story, Shields and Battaglini[48] tested the feasibility and effects of an 8-week home-based isometric strength training program for equestrians. After program completion riders improved muscular endurance and riding performance. Results show a significant correlation between improved endurance and better riding test scores.

Weeks, McLaughlin and Vaughan[49] implemented an 8-week exercise intervention targeting equestrians with low back pain. Nine participants experienced significant reductions in pain severity and improved riding functionality. Study findings suggest that specific exercise programs can effectively manage chronic low back pain in equestrians.

Biau, Le Navenec, Pycik and Noury[50] constructed a 10-week stretching and strengthening program targeting trunk muscles in future professional riders. The program significantly improved rider movements and reduced low back pain during riding. Riders who participated in the program experienced better functionality compared to the control group, demonstrating the benefits of targeted training for EA.

Siedlecka, Aniśko, Placek and Wójcik[51] explored the impact of a six-week lumbar stabilizing exercise program on spine pain and gynecological issues in female amateur riders. The results showed a reduction in lumbar pain and slight improvement in gynecological complaints, highlighting the benefits of strengthening exercises for improving rider health and well-being.

In conclusion, targeted exercise programs focusing on core stability, strength, and flexibility are essential for optimizing rider performance, preventing injuries, and enhancing horse welfare. Research shows that such programs improve rider biomechanics, reduce pain, and address muscular imbalances, ultimately leading to better communication between rider and horse. Whether designed for improving symmetry, endurance, or managing chronic conditions like low back pain, these interventions are crucial for promoting long-term health, well-being and success in EA. Adaptive training regimens ensure both rehabilitation and performance goals are met.

2.4.1. Sensorimotor Training

"Neuromuscular Training" and "Sensorimotor Training", terms proposed by Fernandes & Pezarat-Correia[52], refer to training protocols designed to enhance balance and postural control. Over the past few decades, scientific literature has introduced various terms to characterize these protocols, commonly employing concepts such as "Balance Training" and "Proprioceptive Training".[52]

Initially, sensorimotor training was utilized for injury prevention and functional rehabilitation; however, it has since gained significance in strength training. It is now applied across diverse populations, including adults, youth, children, the elderly, athletes, and individuals with disabilities. Currently, sensorimotor training is emphasized for improving individual functionality, particularly in injury recovery and prevention, as well as in enhancing motor and sports performance.[52]

The quality of exercise execution is vital in sensorimotor training, emphasizing correct posture. A primary objective is to create and consolidate unconscious movement control mechanisms that activate deep muscles, ensuring stabilization of the body axis. Progressions should only occur once the individual demonstrates sufficient mastery of balance and task control, allowing advancement to more challenging exercises without compromising posture. Supervision and intervention from the training supervisor are essential to ensure that proper coordination patterns are consolidated.[52]

Sensorimotor training has evolved into a critical component for enhancing balance and postural control across various populations. Through a structured approach to exercise types, progression, and load dynamics, this training method not only aids in rehabilitation and injury prevention but also enhances overall motor performance.[52]

2.4.1.1. Postural Control

Postural control refers to an individual's ability to manage body sway while maintaining their center of gravity within the base of support, thereby preserving balance and preventing falls. This capability relies on an adequate balance between joint mobility and stability, ensured by the neuromuscular system and based on the integration of multiple sensory inputs by the central nervous system. Control can be reactive, utilizing feedback mechanisms, or anticipatory, employing feedforward mechanisms when disturbances are predicted.[52]

The sensory information supporting postural control primarily originates from proprioceptors, cutaneous receptors (especially those located on the soles of the feet), vestibular inputs, and visual cues. Among these, proprioceptive information is crucial as it provides data regarding the position and acceleration of body segments, as well as variations in muscle length and tension. Among proprioceptors, muscle receptors such as the muscle spindle and the Golgi tendon organ are particularly important, as they initiate reflex mechanisms that rapidly respond to unexpected changes. The muscle spindle, which is sensitive to muscle stretch, is fundamental in reflexively regulating balance and posture, while the Golgi tendon organ, which is sensitive to muscle tension, is associated with the inverse myotatic reflex, inhibiting muscle activation and modulating muscle tension swiftly.[52]

Sensorimotor training aims to enhance the efficacy of these reflexive processes in postural control, optimizing neuromuscular responses among agonist, antagonist, and stabilizing muscles. Initially, voluntary control of movement predominates, requiring significant cortical involvement and concentration from participants. As training progresses, task learning allows for the programming of new movement patterns, controlled at subcortical levels, facilitating quicker adjustments and anticipatory activation of deep stabilizing muscles before extremity movements.[52]

2.4.1.2. Methodology of Sensorimotor Training

Developing a sensorimotor training plan requires consideration of various components, including exercise types, progression, and load dynamics.[52]

2.4.1.2.1. Exercise Types

Exercises can be adjusted using different materials, and it is crucial to define the type of support (bipodal/unipedal), the type of support surface (stable/unstable, rigid/soft, textured/smooth), and the sensory channels involved in balance regulation (eyes open/eyes closed).[52]

2.4.1.2.2. Exercise Progression

Progression can be organized into four phases [52]:

<u>Static Phase</u>: The focus is on developing appropriate activation patterns of deep stabilizing muscles, including the multifidus, transverse abdominis, internal oblique, diaphragm, and pelvic floor muscles. Exercises should involve static or quasi-static balance tasks, with adjustments made slowly to stimulate mechanoreceptors.

<u>Dynamic Phase</u>: This phase introduces progressively wider movements of the lower and upper extremities, requiring greater stabilization capacity from the core musculature. Various training accessories, such as instability platforms, elastic bands, and BOSU balls, can be utilized.

Functional Phase: Exercises should be performed on increasingly unstable surfaces and incorporate more natural movement patterns like walking, running, jumping, or lunges.

Dynamic Functional Phase: This phase is specific for advanced individuals or athletes, selecting exercises based on the specific tasks of the sport, replicating characteristic movement patterns.

2.4.1.2.3. Load Dynamics

Consideration must be given to factors such as the number of sets, repetitions, and duration of breaks. A typical sensorimotor training session lasts about 60 minutes and includes four to six different exercises, each with approximately four repetitions, interspersed with 40-second breaks.[52]

2.4.2. Sensorimotor training in equestrian athletes

Sensorimotor training is vital for equestrian athletes, particularly those experiencing lower back pain, as it enhances balance, postural control, and overall functional performance. The demands of equestrian sports require riders to maintain stability while navigating dynamic movements, making effective postural control essential for injury prevention (e.g. preventing falls).

For equestrians with LBP, sensorimotor training improves proprioceptive awareness and muscle activation patterns, promoting better neuromuscular responses to destabilizing forces. This training strengthens deep stabilizing muscles, which are critical for spinal stability and effective riding posture. As a result, riders experience reduced pain and improved control over their movements.

The structured progression of sensorimotor training builds physical and psychological confidence, allowing athletes to safely increase training intensity. This proactive approach not only aids in rehabilitation but also helps prevent LBP by addressing underlying deficits that may contribute to pain, such as asymmetries while riding.

Incorporating sensorimotor training into the conditioning programs of equestrian athletes can lead to enhanced performance, reduced injury risk, and improved quality of life, particularly for those dealing with lower back pain.

2.5. Lower back pain

Lower back pain (LBP) is the most widespread musculoskeletal condition globally, affecting people of all ages and contributing significantly to disability and reduced quality of life. The lifetime prevalence of LBP is estimated to affect around 84% of adult population,[53] underscoring its status as a major public health issue with considerable socioeconomic consequences. LBP is categorized as acute (lasting less than 6 weeks), sub-acute (6 to 12 weeks), or chronic (more than 12 weeks). The condition leads to decreased physical activity, diminished work productivity, and increased healthcare demands, imposing a substantial burden on both individuals and healthcare systems worldwide.[54’55] Appropriate treatment for LBP may reduce the risk of patients developing chronic pain, a condition that can be challenging to reverse.[53]

2.5.1. Musculoskeletal causes for LBP

In 2020, Popescu and Lee[53] listed the main known musculoskeletal causes for LBP:

- Discogenic Pain: Caused by vascular ingrowth into the disc, disc uncovering due to spondylolisthesis, or exposure of nerve endings to inflammatory mediators. Typically worsens with lifting, twisting, or bending forward.
- Herniated Intervertebral Disc: Occurs when the disc compresses nearby neural structures, leading to lumbar radiculopathy with leg pain and possible myotome weakness. Severe cases may cause central stenosis, potentially resulting in cauda equina syndrome, which requires emergency surgical evaluation.
- Lumbar Zygapophyseal (Facet) Joint Pain: Often associated with degenerative disc disease and joint cartilage degeneration. Involves inflammation, increased vascularization, and subchondral bone changes, potentially contributing to spinal stenosis.
- Spondylolysis and Spondylolisthesis: Spondylolysis is a defect in the pars interarticularis, which can lead to the slippage of adjacent vertebrae (spondylolisthesis).
- Sacroiliac Joint Pain: May result from sacroiliitis, trauma, falls, or motor vehicle accidents.

- Lumbar Spinal Stenosis: Characterized by lower back and radicular limb pain, which is alleviated by sitting and often presents with the "shopping cart sign" (pain relief with leaning forward).

Nonetheless, in many cases, the underlying cause of LBP cannot be precisely determined, despite thorough clinical evaluation and diagnostic testing. When a specific disease, injury, or structural abnormality cannot be identified as the source of the pain, it is classified as non-specific LBP. Non-specific LBP, accounts for 90% of cases, being the most prevalent form, and occurs when no specific disease or structural cause can be identified to explain the pain.[54'55]

2.5.2. Physical aspects of LBP

Lower back pain is a complex condition with significant physical consequences that can disrupt daily life, sporting performances and reduce overall quality of life. understanding these physical aspects is essential for effective diagnosis and management.

The key physical outcomes associated with LBP and suggested assessment tools, outlined by Delitto et al.[56], are:

- Pain and Impairment: LBP often presents with varying levels of pain intensity and discomfort, affecting both physical function and mobility. This impairment is commonly assessed using self-reported measures, such as the Oswestry Disability Index and the Roland-Morris Disability Questionnaire, which evaluate the degree of disability and limitations in daily activities.

- Mobility Limitations: Patients with LBP frequently experience restricted lumbar range of motion, making activities like bending, lifting, or prolonged sitting difficult. Lumbar mobility can be measured through flexion, extension, and side bending assessments using inclinometers, providing valuable data on functional impairments.

- Muscle Weakness: Chronic LBP can lead to muscle weakness, particularly in the trunk and hip regions. Evaluating muscle performance, such as trunk endurance and hip abductor strength, helps identify deficits that may contribute to ongoing pain or functional limitations.

- Functional Limitations: LBP may significantly impact daily activities, leading to reduced physical capabilities and participation restrictions. Functional assessments, including Functional Capacity Evaluations, are employed to measure the extent of activity limitations, aiding in determining the appropriate interventions.

- Centralization and Pain Provocation: Evaluating pain response to specific movement tests, such as the prone instability test or centralization judgments, can help classify the severity and nature of LBP. These assessments guide clinical decision-making and facilitate tailored treatment approaches.

2.5.3. Psychological aspects of lower back pain

LBP is not only a physical condition but also has significant psychosocial dimensions that can influence its development, persistence, and management. Understanding the psychosocial aspects is crucial for a comprehensive approach to diagnosis and treatment.

The key psychological factors related to LBP and assessment tools, as identified by Delitto et al.[56], include:

- Depression: Depression often accompanies chronic LBP, intensifying pain, disability, and medication use, while affecting quality of life. Routine screening, using tools like the Primary Care Evaluation of Mental Disorders questionnaire, is crucial for identifying depressive symptoms and guiding effective intervention.
- Fear-Avoidance Beliefs: Fear-avoidance beliefs involve the fear of pain impacting physical activity and work, potentially leading to chronic LBP. The Fear-Avoidance Beliefs Questionnaire (FABQ) assesses these fears, helping clinicians identify risks and promote strategies for safe movement to prevent disability.

- Pain Catastrophizing: Pain catastrophizing is the expectation of the worst outcome during pain, marked by rumination, helplessness, and pessimism. It is associated with chronic pain development and can predict future disability in LBP. The Pain Catastrophizing Scale (PCS) measures these negative thoughts, highlighting recovery barriers.

- Psychosocial Distress: Screening for psychosocial distress is crucial in LBP management. Tools like the Orebro Musculoskeletal Pain Questionnaire (OMPQ) and STarT Back Screening Tool help identify patients at risk for long-term pain and functional limitations, enabling early intervention to improve outcomes.

2.6. Lower back pain and equestrian athletes

Equestrian athletes face unique challenges that make them particularly susceptible to the various aspects of lower back pain (LBP). The demands of this high-risk sport [57], which include maintaining specific postures, performing repetitive movements, and managing high-impact forces from riding, contribute to both musculoskeletal and psychosocial factors associated with LBP.

2.6.1. Musculoskeletal Factors

LBP is a common musculoskeletal injury in equestrian athletes, with various causes linked to the particular characteristics and physical demands of the sport. Equestrian sports pose a risk for traumatic injuries, such as fractures or sprains, due to accidents handling equines or falls. While overuse injuries play a subordinate role compared to traumatic injuries, the nature of the sport still makes athletes susceptible to them.[58] Repetitive movements and continuous strain can result in cumulative stress on the lower back, aggravating existing conditions or causing new musculoskeletal issues. The repetitive bending, twisting, lumbar hyperextension, and impact absorption during riding can contribute to the development and exacerbation of musculoskeletal issues in the lower back. Additionally, the prolonged seated position in the saddle, often accompanied by asymmetrical posture, increases stress on the lower back structures, leading to pain or muscle imbalances.

2.6.2. Physical Aspects

The physical consequences of LBP, such as pain, restricted mobility, and muscle weakness, can significantly impact an equestrian athlete’s performance. Pain and functional limitations can hinder an athlete’s ability to maintain a stable seat, effectively communicate with the horse, or perform technical movements, all of which are critical for success in equestrian sports. Additionally, reduced trunk or hip strength may impair the rider's ability to absorb shock and maintain balance, leading to increased risk of falls and severe injury. Evaluating mobility, strength, and functional limitations through targeted assessments can help guide individualized rehabilitation and conditioning programs to restore optimal function.

2.6.3. Psychological Factors

Psychosocial elements such as depression, fear-avoidance behaviours, and pain catastrophizing can also affect equestrian athletes with LBP. The pressure to perform, fear of re-injury, or anxiety about disappointing oneself or others may intensify depressive symptoms or contribute to maladaptive beliefs about pain. Fear-avoidance behaviours can be particularly problematic, as riders may reduce their riding frequency or avoid specific movements due to fear of worsening pain, leading to deconditioning and prolonged recovery. Moreover, pain catastrophizing may exacerbate the perception of pain and create barriers to effective rehabilitation.

2.6.4. Implications for Management

Given the multifaceted nature of LBP in equestrian athletes, a comprehensive approach focusing on physical rehabilitation is essential. Targeted exercise therapy to address specific musculoskeletal issues, such as mobility limitations, muscle imbalances, and pain management, can help optimize recovery and enhance performance. If left untreated or inadequately managed, LBP may not only become chronic but also force equestrian athletes to suspend their activities or even give up the sport entirely. Early physical intervention aimed at restoring function and preventing further disability is crucial for minimizing the impact of LBP on an athlete's career and overall quality of life.

2.7. References

1. Sauvet G. The hierarchy of animals in the Paleolithic iconography. *J Archaeol Sci Re*p. 2019; 28: 102025. https://doi.org/10.1016/j.jasrep.2019.102025

2. Wolframm I. The science of equestrian sports. 1. Oxfordshire, Great Britan: Routledge; 2014.

3. Hausberger M, Roche H, Henry S, Visser EK. A review of the human–horse relationship. *Appl Anim Behav Sci*. 2008; 109: 1-24. https://doi.org/10.1016/j.applanim.2007.04.015

4. FEI. History [Internet]. FEI. 2020. Available from: https://inside.fei.org/fei/about-fei/history

5. Arachtingi D. Foster the Gender Equality in the context of horse-riding. An Olympic Value which reveals a path from domination to emancipation. *Daigoras*

Int Acad J Oly Stud. 2020; 4: 60-74. Retrieved from: http://diagorasjournal.com/index.php/diagoras/article/view/90

6. Pugh T J, Bolin D. Overuse Injuries in Equestrian Athletes. *Curr Sports Med Rep*. 2004; 3(6): 297-303. https://doi.org/10.1007/s11932-996-0003-6

7. de Haan D, Henry I, Sotiriadou P. Evaluating the place of equestrian sport in the Long-Term Athlete Development (LTAD) and the Sport Policy factors that Lead to International Sporting Success (SPLISS) models. In: SPLISS conference, 2015, Melbourne, Australia.

8. Lewis V, Douglas JL, Edwards T, Dumbell L. A preliminary study investigating functional movement screen test scores in female collegiate age horse-riders. *Comp Exerc*. 2019; 15(2): 105-112. https://doi.org/10.3920/CEP180036

9. The principles of riding. eBook edition ISBN 978 1 910016 13 8. Warendorf, Germany: FNverlag der Deutschen Reiterlichen Vereinigung GmbH; 2017.

10. Dashper K. Learning to communicate: The triad of (mis) communication in horse riding lessons. In: Davis D, Maurstad A. The meaning of horses: Biosocial encounters. 1. London: Routledge; 2016. 87-101.

11. 58 Horse Disciplines: Discover a World of Equestrian Sports! [Internet]. Joyful Equestrian. 2023 [cited 2024 Sep 21]. Available from: https://www.joyfulequestrian.com/horse-disciplines/?utm_content=cmp-true

12. Discipline [Internet]. FEI.org. 2022. Available from: https://www.fei.org/disciplines

13. Federação equestre portuguesa. Regulamento geral. Portugal; 2015.

14. Fédération Équestre internationale. FEI General regulations; 2024.

15. Williams J, Tabor G. Rider impacts on equitation. *Appl Anim Behav Sci*. 2017; 190: 28-42. https://doi.org/10.1016/j.applanim.2017.02.019

16. Veloso M. Manual do monitor de equitação geral. 1. Lisboa, Portugal: Escola Nacional de Equitação. 2009.

17. Blokhuis MZ, Aronsson A, Hartmann E, Van Reenen CG, Keeling L. Assessing the rider's seat and horse's behavior: difficulties and perspectives. *J Appl Anim Welf Sci*. 2008; 11(3): 191-203. https://doi.org/10.1080/10888700802100876

18. Marlin D, Fisher FM, Fisher D, MacKechnie-Guire R. Stirrup and rein forces do not show left-right differences in advanced dressage riders and horses. 8(Supplement 1):S1–S121. 11th International Conference on Equine Exercise Physiology, Uppsala, Sweden. *Comp Exerc Physiol*. 2022; 18: S1–S121

19. Lagarde J, Kelso JAS, Peham C, Licka T. Coordination dynamics of the horse-rider system. *J Mot Behav*. 2005; 37:418–424. https://doi.org/10.3200/JMBR.37.6.418-424

20. Clayton HM, MacKechnie-Guire R, Hobbs. Riders' Effects on Horses—Biomechanical Principles with Examples from the Literature. *Animals*. 2023; 13(24): 3854. https://doi.org/10.3390/ani13243854

21. Roepstorff L, Egenvall A, Rhodin M, Byström A, Johnston C, van Weeren, P.R, Weishaupt M. Kinetics and kinematics of the horse comparing left and right rising trot. *Equine Vet J*. 2009; 41:292–296. https://doi.org/10.2746/042516409X397127

22. Licka T, Kapaun M, Peham C. Influence of rider on lameness in trotting horses. *Equine Vet J*. 2004; 36:734–736. https://doi.org/10.2746/0425164044848028

23. Symes D, Ellis R. A preliminary study into rider asymmetry within equitation. *Vet J*. 2009; 181:34–37. https://doi.org/10.1016/j.tvjl.2009.03.016

24. Bye TL, Martin R. Static postural differences between male and female equestrian riders on a riding simulator. *Comp Exerc Physiol*. 2021:1–8. https://doi.org/10.3920/CEP210003

25. Hobbs SJ, Baxter J, Broom L, Rossell LA, Sinclair J, Clayton HM. Posture, flexibility and grip strength in horse riders. *J Hum Kinet*. 2014; 42:113–125. doi:10.2478/hukin-2014-0066

26. Gunst S, Dittmann MT, Arpagaus S, Roepstorff C, Latif SN, Klaassen B, et al. Influence of Functional Rider and Horse Asymmetries on Saddle Force

Distribution During Stance and in Sitting Trot. *J Equine Vet Sci*. 2019; 78:20–28. https://doi.org/10.1016/j.jevs.2019.03.21

27. Eckardt F, Witte K. Kinematic Analysis of the Rider According to Different Skill Levels in Sitting Trot and Canter. *J Equine Vet Sci*. 2016; 39:51–57. https://doi.org/10.1016/j.jevs.2015.07.022

28. Engell MT, Byström A, Hernlund E, Bergh A, Clayton H, Roepstorff L, Egenvall A. Intersegmental strategies in frontal plane in moderately-skilled riders analyzed in ridden and un-mounted situations. *Hum Mov Sci*. 2019; 66:511–520. https://doi.org/10.1016/j.humov.2019.05.021

29. Guire R, Mathie H, Fisher M, Fisher D. Riders' perception of symmetrical pressure on their ischial tuberosities and rein contact tension whilst sitting on a static object. *Comp Exerc Physiol*. 2017; 13: 7–12. https://doi.org/10.3920/CEP160026

30. Uldahl M, Christensen JW, Clayton HM. Relationships between the Riders Pelvic Mobility and Balance on a Gymnastic Ball with Equestrian Skills and Effects on Horse Welfare. *Animals*. 2021; 11:453. https://doi.org/10.3390/ani11020453

31. Mackechnie-Guire R, Mackechnie-Guire E, Fairfax V, Fisher M, Hargreaves S, Pfau T. The Effect That Induced Rider Asymmetry Has on Equine Locomotion and the Range of Motion of the Thoracolumbar Spine When Ridden in Rising Trot. *J Equine Vet Sci*. 2020; 88:102946. https://doi.org/10.1016/j.jevs.2020.102946

32. Engell MT, Hernlund E, Egenvall A, Bergh A, Clayton HM, Roepstorff L. Does foot pronation in unmounted horseback riders affect pelvic movement during walking? *Comp Exerc Physiol*. 2015; 1:231–237. https://doi.org/10.3920/CEP150019

33. González Me, Šarabon N. Muscle modes of the equestrian rider at walk, rising trot and canter. *PloS one*. 2020; 15(8): e0237727. https://doi.org/10.1371/journal.pone.0237727

34. Guillaume J F, Laroche D, Babault N. Kinematics and electromyographic activity of horse riders during various cross-country jumps in equestrian. *Sports Biomech*. 2021. https://doi.org/10.1080/14763141.2019.1597154

35. Funakoshi R, Masuda K, Uchiyama H, Ohta M. A possible mechanism of horseback riding on dynamic trunk alignment. *Heliyon*. 2018; 4(9). 10.1016/j.heliyon.2018.e00777

36. Douglas JL, Price M, Peters DM. A systematic review of physical fitness, physiological demands and biomechanical performance in equestrian athletes. *Comp exerc physiol*. 2012; 8(1): 53-62. https://doi.org/10.3920/CEP12003

37. González ME, Šarabon N. Shock attenuation and electromyographic activity of advanced and novice equestrian riders' trunk. *Appl Sci*. 2021; 11(5): 2304. https://doi.org/10.3390/app11052304.

38. Pantall A, Barton S, Collins P. Surface electromyography of abdominal and spinal muscles in adult horseriders during rising trot. In: *ISBS-Conference Proceedings Archive*. 2009.

39. Legg K, Cochrane D, Gee E, Macdermid P, Rogers C. Physiological demands and muscle activity of jockeys in trial and race riding. *Animals*. 2022; 12(18):2351. https://doi.org/10.3390/ani12182351

40. Eckardt F, Witte K. Horse–rider interaction: A new method based on inertial measurement units. *J Equine Vet Sci*. 2017; 55:1-8. https://doi.org/10.1016/j.jevs.2017.02.016

41. Wang Z, Li J, Wang J, Zhao H, Qiu S, Yang N, Shi X. Inertial sensor-based analysis of equestrian sports between beginner and professional riders under different horse gaits. *IEEE Trans Instrum Meas*. 2018; 67(11):2692-2704. 10.1109/TIM.2018.2826198

42. Izzo R, Convertini A, D'isanto T, Cejudo-Palomo A, Varde'i CH. Study and evaluation of the impacts on the saddle in the L4-L5 and S1 lumbar area during horse riding training session through the use of the last generation inertial sensor. In: http://hdl.handle.net/10045/110813. 2020. 10.14198/jhse.2020.15.Proc4.16

43. Wilkins C, Mullo F, Camomilla V. Exploring the attenuation interaction between horse and rider in sitting trot using inertial measurement units. *ISBS Proceedings Archive*. 2024; 42(1):1022. Available at: https://commons.nmu.edu/isbs/vol42/iss1/237

44. Wolframm IA, Bosga J, Meulenbroek RG. Coordination dynamics in horse-rider dyads. *Hum Mov Sci*. 2013; 32(1):157-170. https://doi.org/10.1016/j.humov.2012.11.002

45. Thornton JS, Caneiro JP, Hartvigsen J, Ardern CL, Vinther A, Wilkie K, et al. Treating low back pain in athletes: a systematic review with meta-analysis. *Br J Sports Med*. 2021; 55(12):656-662.

46. Marshall PW, Murphy BA. Muscle activation changes after exercise rehabilitation for chronic low back pain. *Arch Phys Med Rehabil*. 2008; 89(7):1305-1313. https://doi.org/10.1016/j.apmr.2007.11.051

47. Hampson A, Randle H. The influence of an 8-week rider core fitness program on the equine back at sitting trot. *Int J Perf Anal Spor*. 2015; 15(3):1145-1159. https://doi.org/10.1080/24748668.2015.11868858

48. Lee JT, Soboleswki EJ, Story CE, Shields EW, Battaglini CL. The feasibility of an 8-week, home-based isometric strength-training program for improving dressage test performance in equestrian athletes. *Comp Exerc Physiol*. 2015; 11(4):223-230. https://doi.org/10.3920/CEP150018

49. Weeks RA, McLaughlin PA, Vaughan BR. The efficacy of an eight-week exercise program for the management of chronic low back pain in the equestrian population. *The Journal of sports medicine and physical fitness*. 2024. 10.23736/S0022-4707.24.15830-6

50. Biau S, Le Navenec C, Pycik E, Noury B. *Un cycle de dix semaines d'étirement et de renforcement des muscles du tronc impacte l'activité équestre et diminue les douleurs lombaires des futurs cavaliers professionnels*. A ten weeks program of stretching and strengthening core muscles improves performance and reduces lower back pain of future professional riders. *Sci Sports*. 2024; 39(1):36-42. https://doi.org/10.1016/j.scispo.2023.02.002

51. Siedlecka M, Aniśko B, Placek K, Wójcik M. Low back pain occurrences and gynecological disorders in female equestrians and strengthening of core stability muscles lumbar spine. *Fizjoterapia Polska*. 2023; 23(4). DOI:10.56984/8zg20a371

52. Fernandes O, Pezarat-Correia P. Treino sensoriomotor. In: Mil-Homens P, Pezarat-Correia P, Vilhena de Mendonça G, editors. Treino da força: princípios biológicos e métodos de treino. Volume 1. Cruz-Quebrada: Faculdade de Motricidade Humana; 2015. p. 213-25.

53. Popescu A, Lee H. Neck pain and lower back pain. *Med Clin (North Am)*. 2020; 104(2): 279-92. 10.1016/j.mcna.2019.11.003

54. World Health Organization. Low back pain [Internet]. Geneva: WHO; 2023 Jun 19 [cited 2024 Oct 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/low-back-pain

55. World Health Organization. WHO releases guidelines on chronic low back pain [Internet]. Geneva: WHO; 2023 Dec 7 [cited 2024 Oct 16]. Available from: https://www.who.int/news/item/07-12-2023-who-releases-guidelines-on-chronic-low-back-pain

56. Delitto A, George SZ, Van Dillen L, Whitman JM, Sowa G, Shekelle P, et al. Low back pain: clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *J Orthop Sports Phys Ther*. 2012;42(4). https://www.jospt.org/doi/10.2519/jospt.2012.42.4.A1

57. Krüger L, Hohberg M, Lehmann W, Dresing K. Assessing the risk for major injuries in equestrian sports. *BMJ Open Sport Exerc Med*. 2018; 4(1). 10.1136/bmjsem-2018-000408

58. Meyer, H.-L, Scheidgen, P, Polan, C, Beck, P, Mester, B, Kauther, M.D, Dudda, M, Burggraf, M. Injuries and Overuse Injuries in Show Jumping—A Retrospective Epidemiological Cross-Sectional Study of Show Jumpers in Germany. Int. J. Environ. Res. Public Health 2022, 19, 2305. https://doi.org/10.3390/ijerph19042305.

59. Image retrieved and adapted from: Bing Images. Picture of horse racing [Internet]. Available on: https://www.bing.com/images/search?view=detailV2&ccid=VDh%2fwTue&id=70B1DA5B97236A9A96EC46C9451A01139A5222AA&thid=OIP.VDh_wTue4_x5VrPXm-

D0eAHaDB&mediaurl=https%3a%2f%2fi.pinimg.com%2foriginals%2fd5%2fca%2fa2%2fd5caa212a46a0eebef7efb0ed4cebcab.jpg&cdnurl=https%3a%2f%2fth.bing.com%2fth%2fid%2fR.54387fc13b9ee3fc7956b3d79be0f478%3frik%3dqiJSmhMBGkXJRg%26pid%3dImgRaw%26r%3d0&exph=2154&expw=5285&q=picture+of+horse+racing&simid=608049769483622270&FORM=IRPRST&ck=BFA04F4E546B9BF2D0A1CD5AED4C0F79&selectedIndex=19&itb=0&ajaxhist=0&ajaxserp=0 . Accessed 24 Sept 2024.

Chapter III

Paper1: Prevalence of lower back pain and risk factors in equestrians: a systematic review

Chapter III

3. Paper 1 – Systematic review

Prevalence of lower back pain and risk factors in equestrians: a systematic review

Carlota Duarte [1,2 *], Armando Raimundo [2,3 *], João Paulo Sousa [2,3], Orlando Fernandes [2,3] and Rute Santos [1,4]

1 - Escola Superior de Biociências de Elvas, Instituto Politécnico de Portalegre, 7300-110 Portalegre, Portugal;
carlotaduarte@ipportalegre.pt
2 - CHRC—Comprehensive Health Research Centre, Universidade de Évora, 7004-516 Évora, Portugal
3 - Escola de Saúde e Desenvolvimento Humano, Universidade de Évora, 7004-516 Évora, Portugal;
orlandoj@uevora.pt (O.F.); ammr@uevora.pt (A.R.)
4 - VALORIZA—Research Centre for Endogenous Resource Valorization, Instituto Politécnico de Portalegre,
7300-555 Portalegre, Portugal
*Correspondence: carlotaduarte@ipportalegre.pt (C.D.); ammr@uevora.pt (A.R.).

Abstract

This systematic review aimed to determine the prevalence of lower back pain (LBP) in equestrian athletes (EA) and identify associated risk factors. Following PRISMA guidelines, observational studies published between 2004 and 2024 in English, Portuguese, Spanish, and German were included. The review identified relevant studies through Web of Science, EBSCO, MEDLINE, and SCOPUS (last search 30 October 2024), yielding 14 studies with a total of 4,527 participants. The question format for the included studies specified the population as equestrian athletes, the exposure as equestrian sports, and the outcome as lower back pain. The risk of bias was evaluated using the Observation Study Quality Evaluation tool, and six studies were deemed high-quality. LBP prevalence in EA was higher than in the general and athlete population, with point prevalence ranging from 27.9% to 87.9%. Sport-specific factors, including workload and stable duties, were significant risk factors. Methodological inconsistencies, such as varying definitions of LBP and a lack of standardized exposure assessment, and overall low quality of studies, limited the comparability of findings. This review underscores the need for more high-quality research and tailored interventions addressing both riding and off-horse activities in EA.

Keywords

Back pain; Equestrian athlete; Equestrian sports; Musculoskeletal disorders; Prevalence; Risk factors; Systematic review.

List Abbreviations

BF% - Body fat percentage

BMI – Body mass index

BP – Back pain

CEA – Child equestrian athletes

CLBP – Chronic low back pain

EA – Equestrian athletes

ED – Equestrian disciplines

ES – Equestrian sports

FEI – Fédération Équestre Internationale

HAB – Hip abduction with hip neutral test (adductors)

HAB-HF – Hip abduction with flexed hip (monoarticular adductors)

HAD-HF – Hip adduction with hip flexed test (piriformis)

HE – hip extension test (iliopsoas)

HF-KF – Hip flexion with knee flexed test (gluteus maximus)

HIR – Hip internal rotation test (external rotators)

HTR – Hip total rotation (hip rotators)

ISBE – Isometric side bridge endurance (trunk lateral flexors)

ISBE-ND – Isometric side bridge endurance in non-dominant side (trunk lateral flexors)

KF – Flexion of knee (quadriceps)

LBP – Lower back pain

MRI – Magnetic resonance imaging

NMQ – Nordic Musculoskeletal questionnaire

NRS – Numeric rating scale

NSQ – Not standardized questionnaire tool

ODI – Oswestry Disability Index/ Oswestry Low Back Pain Disability Questionnaire

OSQE - Observational Study Quality Evaluation tool

PSEQ – Pain Self-efficacy questionnaire

RMDQ – Roland Morris disability questionnaire

ROM – Range of motion

SF-MPQ – Short form McGill pain questionnaire

VAS – Visual Analog scale

3.1. Introduction

Lower back pain (LBP) is a prevalent musculoskeletal disorder affecting the general population [1], particularly athletes [2]. While regular exercise can mitigate the risk of LBP, high levels of physical activity can paradoxically increase it [3,4]. In the context of equestrian sports (ES), back pain is frequently identified as the most common overuse injury among equestrian athletes (EA) [5], with a notably high prevalence in this population[6].

ES are unique in that they depend on the intricate interaction between horse and rider. Historically, scientific literature has primarily focused on the equine athlete, often overlooking the human athlete's role [7]. However, recent research has begun to address this gap, emphasizing the physical demands placed on the rider. ES are characterized by long career spans, with athletes often beginning competitive riding as early as 6 years old[8] and continuing to compete at the highest levels, such as the Olympics, well into their 60s and 70s [9,10].

Given that previous episodes of LBP are a strong predictor of future occurrences[11], the potential impact of LBP on an EA's career is concerning. This matter is particularly true considering the rider's reliance on clear and balanced physical communication with their horse [12] - a crucial aspect of performance when dealing with a 500kg prey animal.

Over the past two decades, efforts have been made to identify the musculoskeletal complaints most affecting EA and to understand the risk factors contributing to their development. Given the distinctive nature of equestrian sports and the high prevalence of LBP among riders, it is crucial for the equestrian community to fully understand the impacts of LBP and identify potential risk factors. However, existing studies have reported varied findings regarding the prevalence and underlying causes of LBP in this population, highlighting the complexity of establishing clear risk factors. This knowledge is essential for developing targeted, evidence-based prevention and management strategies.

The objectives of this systematic review were to determine the prevalence of LBP among EA and identify the specific risk factors contributing to LBP in this population. By addressing these objectives, the review aimed to provide a comprehensive understanding of LBP within equestrian sports, offering informed guidance for future research in the development of effective prevention and management strategies to enhance the well-being and performance of EA.

3.2. Materials and Methods

3.2.1. Research design

A detailed review of observational epidemiological studies on LBP in EA was conducted using the PRISMA statement guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analysis [13]. The only significant amendment to the original protocol was the substitution of the tool used for assessing the risk of bias and quality of the included studies with a more suitable evaluation tool, ensuring a better fit for the specific study designs analyzed. Methods of the analysis and inclusion criteria were prespecified and documented in a protocol (PROSPERO database ID: CRD42024568577). The question format used for the present review is PEO: EA is the population, equestrian sports are the exposure, and LBP is the main outcome.

3.2.2. Types of studies

The studies considered for this systematic review were published in English, Portuguese, Spanish (linguistic proficiency of the research team) and German (translated for the team by a native speaker and specialist in equine sciences). The review included studies published between January 1, 2004, and August 30, 2024. Eligible studies were fully published observational studies, encompassing cohort, case-control, cross-sectional, and survey-based designs, published in scientific journals.

To qualify for inclusion, studies needed to employ descriptive and analytical observational designs that provided data on the incidence of LBP in EA. Data collection was confined to primary sources, utilizing tools such as questionnaires, interviews, and physical assessments.

3.2.3. Types of participants and exposure

The review encompassed EA: individuals of any age or sex that engage in equestrian sports, defined as activities involving horseback riding at all three gaits: walk, trot, and canter. All levels of competition and practice, ranging from leisure to professional, were included. The review considered all recognized equestrian disciplines, apart from studies focusing on driving, vaulting, para-equestrian sports, rodeo, or therapeutic use of horses, due to the specific characteristics inherent to these activities.

3.2.4. Types of outcome measures

The main outcome measure of the study was the prevalence of LBP among EA, encompassing non-specific, acute, and chronic LBP (LBP characteristics like frequency, severity, and disability were also retrieved). Additionally, the research considered secondary outcomes, including exposure data and various risk factors associated with LBP in this population. No restrictions were placed on the definitions of LBP, methods of pain reporting, and verification.

3.2.5. Information sources and search

Relevant papers were identified through a comprehensive search of four electronic databases: Web of science, EBSCO, MEDLINE/PUBMED and SCOPUS (last search on 30 October 2024). Additionally, other sources, such as reference lists of included studies, review articles, and websites (e.g. ResearchGate) were searched to obtain further relevant papers.

All search strategies are summarized in **Supplementary Material I – Tables III.3 and III.4**. Keywords for the database search were defined using terms related to the population and exposure, combined with keywords related to outcomes of interest. These keywords were combined using “OR” and “AND” operators. When possible, re-strictions were applied to search terms to include only titles, abstracts, and keywords. An example of a research phrase used in PUBMED was (“horseback rid*” OR “equestrian athlete”

OR “horse rid*” OR “equitation”) AND (“Back pain” OR “Lumbar” OR “Spinal injuries” OR “Back injuries” Or “Overuse injuries”).

No filters were applied to the study design to ensure all relevant studies were included for abstract screening. The study design was identified by analysing full papers, looking for terms such as “epidemiology”, “retrospective”, “prospective”, “longitudinal”, “survey”, “questionnaire”, “cross-sectional”, “case-control”, and “cohort”.

3.2.6. Study selection

To assess eligibility, two reviewers (R.S. and O.F.) with a background in equestrian sports sciences, equine sciences, health and sports sciences, and training in scientific investigation were involved in the search strategy and identification of relevant records. When discrepancies existed, they were resolved by achieving consensus. The opinion of experts in epidemiology (J.P.S.) or in the field of sports sciences (A.R.) was sought when required.

No attempt was made to rectify the reported study design. Priority was given to the design obtained from each paper title, abstract, and methods section. However, whenever it was not mentioned in the paper, the study design was defined based on the definitions given by Carlson & Morrison [14].

3.2.7. Data collection process

A data extraction form was developed to summarize the evidence and was pilot tested on three randomly selected papers by one reviewer (C.R.D.). The data extraction was then verified by a second reviewer (O.F.), with any disagreements resolved through discussion. This approach enhanced the quality of data extraction and helped identify additional items to be collected. To ensure consistency and comprehensive-ness, all reported characteristics of each study were considered during data extraction, even when matched with other papers.

3.2.8. Assessment of methodological quality and risk bias

The quality and risk of bias – and reporting bias - of the studies were assessed using the Observational Study Quality Evaluation (OSQE) tool [15], which has distinct versions for cohort, case-control, and cross-sectional studies, each with its own scoring system. The OSQE cross-sectional version is a subset of items from the OSQE cohort version. Specifically, the OSQE cohort and case-control versions include 14 mandatory items and 2 optional items, while the OSQE cross-sectional version comprises 7 mandatory items and 3 optional items. Higher scores indicate better study quality. Two authors (C.D. and J.P.S.) independently conducted the quality assessments of the selected studies, and consensus on the scores was achieved through meetings. A cut-off of 65% was selected, as previously reported [1’6], with studies scoring above this threshold considered to be of high quality.

For prevalence studies, the Critical Appraisal Checklist for Prevalence Studies [16] was used to assess the methodological quality and to determine the extent to which a study has addressed the possibility of bias in its design, conduct and analysis. To assess the quality of the studies, the same cut-off value of 65% was used. High-quality studies are those that get a score over 65%, low-quality studies score under 65%, and any study receiving a 'no' in any item, was not considered as a prevalence study and was excluded from the population prevalence analysis and was only considered for study-specific prevalence.

3.2.9. Data items and analysis

When a paper lacked complete information, no assumptions were made. If supplementary material was provided this information was also analyzed. The review team did not contact authors for confirmation or additional details. The primary focus was on reporting data directly available to readers. Eligible papers were coded for data extraction. The collected data items, summarized in **Supplementary Materials I – Table S3**, include details on (i) study characteristics, (ii) data collection, (iii) sample details, (iv) pain details, and (v) risk factors.

Microsoft Excel [17] spreadsheets were used to organize data and for basic calculations: sums, means and proportions. SCALEX SP [18] calculator and Epitools [19] were used to calculate sample sizes and confidence limits for sample proportions, with the level of confidence set at 95%; these calculations were done for studies that did not provide such information.

3.3. Results

3.3.1. Study selection

A total of fourteen papers were identified for inclusion in the review. **Figure III.1** presents detailed information of the study selection process. The search of the electronic databases provided a total of 545 citations. After du-plication removal and language restriction, the final number of citations was 197. Of these, 96 were eliminated after screening the title, abstract, and keywords. 101 full-text papers were examined for final confirmation of eligibility criteria. Additionally, three records were identified outside of the databases through citation tracking and relevant websites (e.g. ResearchGate). In total, 90 studies did not meet the inclusion criteria.

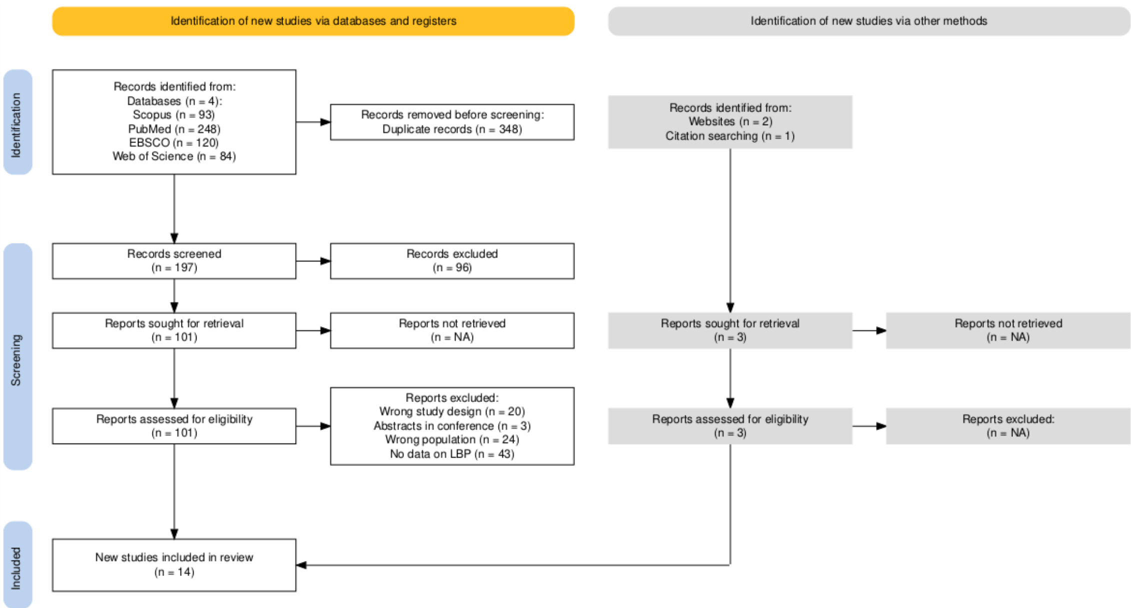


Figure III.1. *Study selection process*

3.3.2. Characteristics of included studies

Over the past 20 years, there has been a significant increase in the number of published observational epidemiological studies on LBP in EA (**Supplementary Material II – Figure III.8**). The design details of these studies and outcomes are summarized in **Tables III.6** and **III.7 in Supplementary Material II**. Notably, 89.3% of the study samples originated in Europe, with a wide range of sport levels and competition statuses. However, all but one study [20] failed to clearly define rider status/ skill level. A diverse array of equestrian disciplines was represented, with only four studies [21’22’23’24] focusing on a single discipline (**Table III.8 Supplementary Material II**). Across the 14 included studies, the total number of participants was 4527 (range: 19 – 2185). Questionnaires were the predominant data collection method (N=14), with recall periods ranging from point to lifetime. **Tables III.8**, **III.9** and **III.10 in Supplementary Material II** provide detailed summaries of the data collection tools, procedures, recall periods, sample sizes, and participant demographics.

3.3.3. Methodological quality

The methodological quality assessment of 14 studies is available in **Supplementary Material II Table III.11**. All studies were evaluated using the OSQE spreadsheet for cross-sectional studies, as it was the most appropriate for all study designs, despite two studies being reported as cohort [28'29] and one as case-control [20]. Only six studies achieved a score above 65%, indicating high quality (**Supplementary Material II Table III.12**). Common deficiencies across the studies included the representativeness of the sample (21.4%), assessment of the independent variable (21.4%), declaration of conflict of interest (50%), control for confounders (57.1%), reporting of results following a protocol (100%), reporting on missing data (7.1%), analysis of effect modifiers (21.4%) and calculation of sample size (85.7%). Notably, all studies received full scores for reporting. Recall periods for pain, back pain (BP) and/ LBP were only clearly stated and/or understandable in seven studies [20'26'27'28'29'30]. Although only six of the fourteen studies met high-quality criteria, all studies were included in the review due to the limited availability of research on this topic. Study quality is addressed in the results and discussion sections to aid in interpreting findings.

The results of the Critical Appraisal Checklist for Prevalence Studies [16] can be found in **Supplementary Material II Table III.13**. Two studies were excluded as prevalence studies; the Lewis and Baldwin [21] study did not have an adequate sample size for precise results, and Lewis and Kennerley [22] did not have an appropriate sample to represent the target population. Of the remaining seven studies, three [26'27'33] were evaluated as high-quality prevalence studies and the remaining four [23'24'25'31] as low-quality prevalence studies. Sample sizes and confidence limits for sample proportions of prevalence studies can be found in **Supplementary Material II Table III.14**.

3.3.4. Demographic and anthropometric characteristics of the sample

Most of the samples were dominated by female athletes (77% female average among all papers), except for 4 papers [21'26'28'32] (56.2% average) where the female and male samples were very even and one paper with an all-female sample [22]. In most of the studies, apart from two regarding child EA (CEA) [28'29] (mean age 14.5 years), and one that included populations of all ages [33] (mean age 33.6 years), the sample included adult EA ranging from 18 to over 70 years of age. Seven papers did not report on height, weight, and BMI of EA [20'21'22'23'30'31'33]. Two papers reported on height [27'32], weight [27'32] and BMI [32] of female and male EA. Four papers report-ed on average height, weight, and BMI of all participants [24'26'28'29]. Kraft et al. [25] only presented data on average weight and BMI with a cut-off value. Cejudo et al. [28'29] presented in both papers the body fat percentage (BF%) average value for female and male athletes.

3.3.5. Equestrian sports

3.3.5.1. Discipline

There are six different equestrian disciplines (ED) recognized by the FEI, and at least 50 more recognized nationally and/or internationally by different Federations. The three Olympic ED are Dressage, Show Jumping and Eventing. The heterogeneity of ED is visible in the selection of papers in this review, as is shown in **Figure III.2**. The ED most represented in the papers and by the number of participants is Dressage, followed by Show Jumping and Eventing (**Table III.1**). It is important to note that in some studies, participants could report practicing more than one discipline at a time.

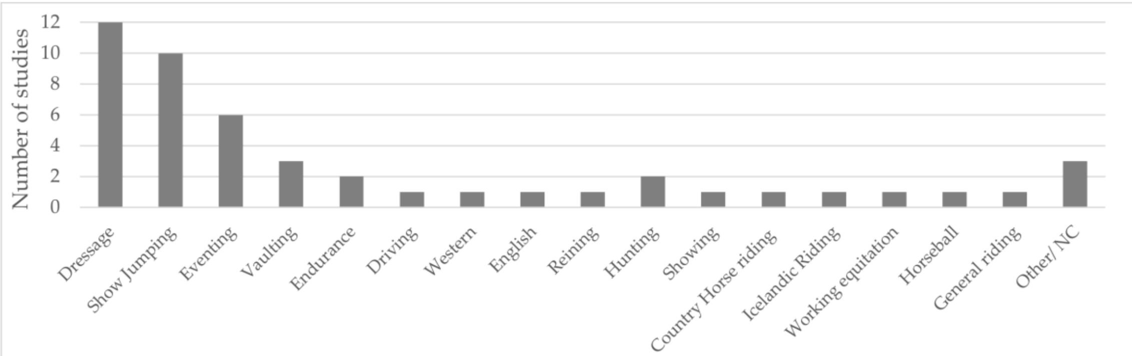


Figure III.2. *Equestrian disciplines represented in the studies and number of studies with population practicing each discipline*
Note: NC – Non-competitive. More details in ***Supplementary Material I Table III.8****.*

Table III.1. *Number and percentage of papers and participants represented in each equestrian Olympic discipline.*

	Papers (N, %)	Participants (N, %)
Dressage	12, 85.7	2310, 51
Show Jumping	10, 71.4	1996, 44.1
Eventing	6, 42.9	644, 14.2

3.3.5.2. Level of sport

Comparing the level of sport was hindered by inconsistent classification systems across the studies. Some studies categorized riders by status without providing clear definitions, while others used competition levels or simply defined athletes as competitive or non-competitive, as shown in **Table III.2**.

Table III.2. *Rider status, level of competition and competition status of participants in each study.*

	Rider status	Level of competition	Competitive/ non-competitive
Deckers et al. [20]	Professional & Amateur	National	Competitive
Lewis & Baldwin. [21]	-	International	Competitive
Lewis & Kennerley. [22]	Elite	International	Competitive
Lewis, Dumbell & Magnoni. [23]	Recreational, Amateur & Professional		Competitive
Hobbs et al. [24]	-	-	Competitive
Kraft et al. [25]	Elite	National/ International/ Olympic	Competitive
Duarte et al. [26]	Hobby & Profession	-	-
Ferrante et al. [27]	-	Sport license *	Competitive/ non-competitive
Cejudo et al. [28]	-	-	Competitive
Cejudo et al. [29]	-	-	Competitive
Pilato et al. [30]	-	Intercollegiate	Competitive
Lewis et al. [31]	Leisure, Amateur & Professional	-	Competitive/ non-competitive
Puszczałowska-lizis et al. [32]	Amateur	-	-
Kraft et al. [33]	-	Performance classes **	Competitive

*Note: *As defined by the Italian National Equestrian Federation; **As defined by the German equestrian federation.*

3.3.5.3. Sport practice

Measuring exposure to sports practice is crucial in these studies. For injuries, risk factors, or pain, exposure is generally quantified by the duration during which athletes are at risk. Understanding this workload, including the number of years spent riding and the time spent riding per week or per day, is of utmost importance. All studies, apart from three [21'22'23], had information on the time of equestrian sport practice (in years). One of the studies that did not provide data on years spent riding provided a statistical analysis with this variable [23]. Only eight of the studies [20'25'26'27'28'29'30'33] had data on equestrian sports practice weekly or daily.

3.3.5.4. Equestrian related activities

Of all fourteen papers included in this review, nine [20'24'27'28'29'30'32'33] did not provide any information on daily practices in the yard and equestrian sports secondary activities (mucking out, stable yard chores, and other activities inherent with keeping horses). Three [22'23'25] mentioned in the description of the questionnaire asking if participants needed to perform other intensive activities associated with keeping horses and what factors contributed to increased levels of pain (e.g. yard work), but did not present any data or analysis for this variable.

3.3.6. Other sporting activities

Four studies [26'27'30'31] collected information regarding practices in other sporting activities and reported that 79% [31], 91% [30] and 55.9 % [26] exercised or practiced other sports, and 35% [27] had a physical training program for EA. In two studies, 34.2% of equestrians [31] and 25% of competitive showjumpers [23] used an exercise program to manage/ treat pain felt.

3.3.7. Anatomic location and nature of injury

Pilato et al. [30] wrote a paper about injury history in collegiate EA. They reported different types of injuries (fracture, pain/arthritis, sprain, disk injury and others), and injuries to the spine (40.96% in the lumbar, 34.94% in the thoracic). 6.85% of the participants suffered a fracture to the lumbar spine. Kraft et al. [25] used MRI of the lumbar spine to look for possible disk degeneration. All remaining studies [20'21'22'23'24'25'26'27'28'29'30'31'32'33] focused on pain in different bodily locations (**Figure III.3**).

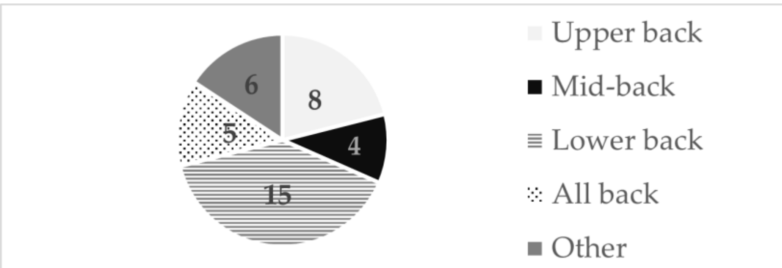


Figure III.3. *Number of studies reporting on pain in different trunk and body locations.*
Note: Upper back [20'21'23'30'31'32'33]; Mid-back [20'24'30'32]; Lower back [20'21'22'23'24'25'26'27'28'29'30'31'32'33]; All back [20'22'32'33]; Other [21'22'23'24'31].

In a study about Eventing riders [21], 96% of the participants reported competing with pain. Ferrante et al. [27] also reported some different musculoskeletal disorders (scoliosis, fractures, and others). 57% of the riders who experienced pain in Lewis & Kennerly's [22] study felt that pain was not associated with an old injury resulting from a fall. Three studies reported on chronic pain [22'23'31] and chronic LBP (CLBP) [27], with an incidence of 62% [22], 67% [23], 83% [31] and 23.9 % [27].

3.3.8. Tools and methods for measurement of LBP

Tools and methods used to measure LBP (frequency, location, severity, and disability) are represented in **Figure III.4**. The SF-MPQ is a tool used to measure the intensity of pain; it includes the present pain intensity (PPI) index and the VAS. The ODI is used to measure disability and quality of life impairment for adults with LBP. NMQ is used to compare low back, neck, shoulder and general complaints, especially musculoskeletal complaints, in epidemiological studies. NRS and VAS are used to measure pain in-tensity. PSEQ is used for people with chronic pain to rate self-efficacy beliefs. The RMDQ is used to evaluate LBP-related disability.

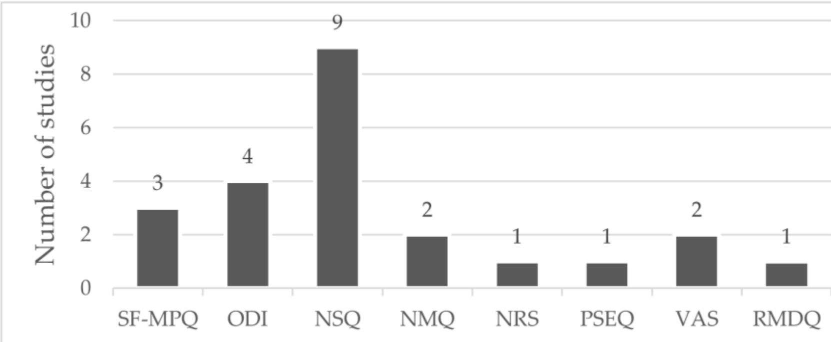


Figure III.4. *Tools and methods used to measure LBP - frequency, location, severity and disability*

Note: SF-MPQ – Short Form McGill Pain Questionnaire [21,23,31]*; ODI – Oswestry Disability Index (or the Oswestry Low Back Pain Disability Questionnaire)* [20,25,31,32]*; NSQ – Not standardized questionnaire tool* [20,22,24,26,27,28,29,30,32,33]*; NMQ – Nordic Musculoskeletal Questionnaire* [27]*; NRS – Numeric Rating Scale* [27] *for severity of pain; PSEQ – Pain Self-efficacy Questionnaire* [27] *only for those reporting CLBP; VAS – Visual Analog Scale* [25,33] *to measure intensity of pain; RMDQ – Roland Morris Disability Questionnaire*[26].

3.3.9. Lower back pain

Figure III.5 shows LBP prevalence within sample populations with different re-call periods, and **Figure III.6** shows the LBP prevalence in equestrians - with confidence limits.

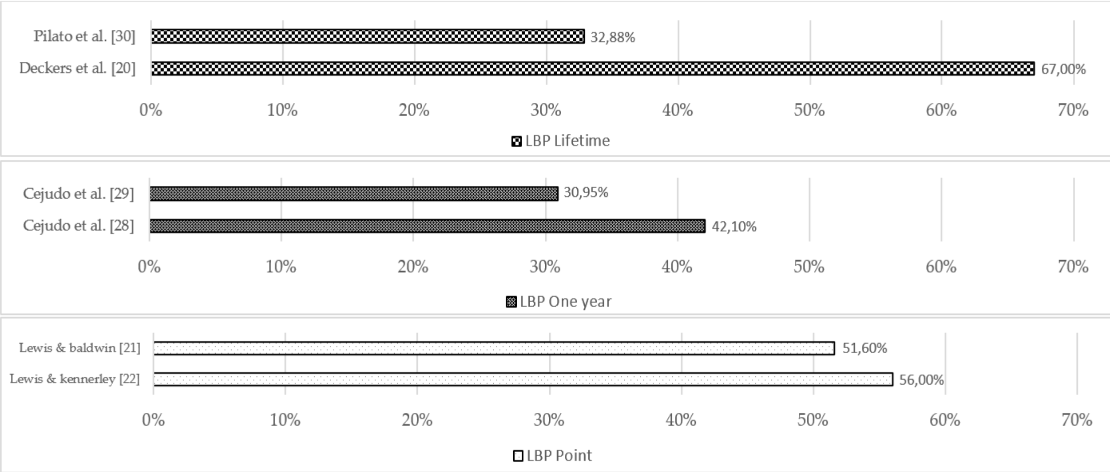


Figure III.5. *Prevalence of LBP within study population, results of included studies divided into different recall periods*

Four studies measured LBP prevalence with a one-year recall period ranging from 61.7% to 74.3% in prevalence studies and 30.95% to 74.3% when considering all studies. Seven studies measured LBP point prevalence; it ranged from 27.9% to 87.9% in all studies. Ferrante et al. [27] also measured LBP prevalence with a recall period of a lifetime (91.6%), 6-months (64.8%), one month (46.2%) and CLBP (23.9%) defined as LBP that which was present for most days in the last three months. The point prevalence within the study population of LBP in the two studies was 51.6% [21] and 56% [22].

Of all studies, only four provided a definition for LBP. Duarte et al. [26] defined LBP as pain, discomfort, or numbness in the lower back area. Ferrante et al. [27] defined LBP as pain and discomfort localized below the costal margin and above the inferior gluteal folds, with or without referred leg pain. Cejudo et al. [28'29] gave the same definition for LBP in both studies, as pain in the lower back that lasted for more than one week or missed training due to LBP in the previous 12 months. The period of 1 week for LBP was chosen to exclude muscle soreness. Pilato et al. [30] reported the number of episodes: 15.07% of the collegiate EA had one episode, 2.74% complained of 2 episodes, and 15.07% had more than 2 episodes of pain/ arthritis in the lumbar spine. Hobbs et al. [24] categorized participants with lumbar pain by posture type, and the most frequent posture types of participants with LBP were normal, kyphotic/lordotic and swayback. In Kraft et al. [25], the study EA had a significantly higher intensity of LBP than controls; the prevalence of LBP in the control group was 33%.

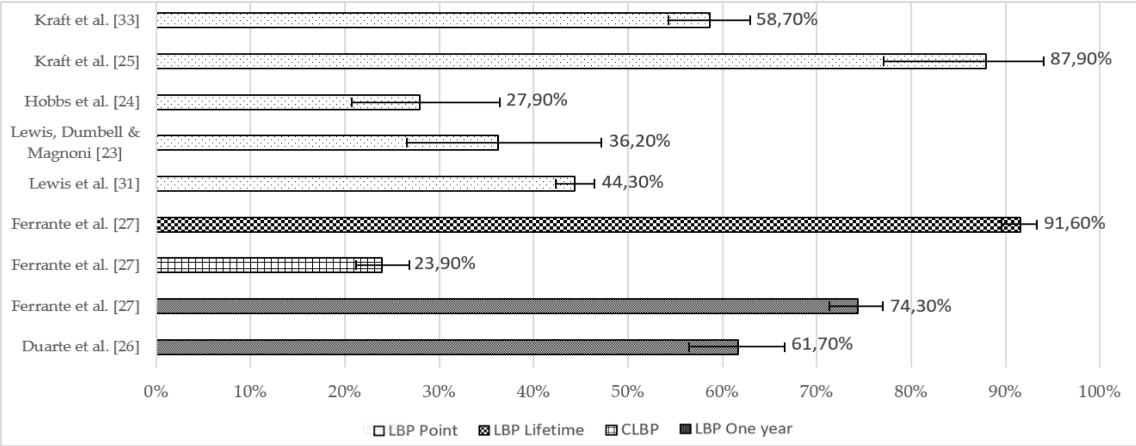


Figure III.6. *Prevalence, with confidence limits, of LBP in EA, results of included prevalence studies, divided in different recall periods*

Note: When not provided, confidence limits were calculated by the review team; more details are in ***Table III.14, Supplementary material II****.*

3.3.10. Duration and frequency of symptoms

Only five studies published information on the duration and/or frequency of symptoms. 54% of the participants in the Lewis et al.[31] study experienced pain (regardless of location and intensity) for over 6 years. A study on LBP in Italian EA [27] reported that participants who experienced LBP during their lifetime had an average of 15 episodes, and participants with LBP in the last year had an average of 5 episodes. The average length of episodes (regardless of time prevalence) was 3 days. Pilato et al. [30] divided injury frequency into one, two, or more than two episodes and presented data on spine and pelvis injury frequency; the type of injury with a higher number of responses of 2 or more episodes was pain/ arthritis located in the thoracic spine, followed by lumbar spine and cervical spine. The median LBP duration in a study of competitive show jumpers [23] was 2 to 3 years. Kraft et al. [33] reported data on the frequency of participants' BP: 59.3% had BP occasionally, 25.2% daily, and 15.6% never had BP.

3.3.11. Consequences of pain

The main consequence of pain [21'22'23'31], LBP [26] and CLBP [27] is limitation in performance whilst riding 72.7% [31], $p<0.05$ [27], 85% [23], 63.1% [26] or competing 55% [21], 59% [22]. Lewis & Kennerly [22] found a statistically significant association between those experiencing pain and the perceptions of pain negatively affecting performance. The rider's perception of how pain affects performance is reported in four studies [21'22'23'31]. Common effects felt by EA are postural asymmetry, limited and reduced ROM, irritability, earlier onset of fatigue, lack of concentration and anxiety. A study about

Italian EA [27] found that CLBP was associated with time loss in the sport (p<0.001), medication consumption (p<0.001) and restriction in participation (p<0.001). Hobbs et al. [24] stated that pain avoidance during riding could increase the prevalence of postural defects and muscle imbalances in higher-level riders. Furthermore, Cejudo et al. [28] results suggest that LBP impacts trunk proprioception and stability in CEA.

3.3.11.1. Levels of pain, severity, and levels of disability

Eight studies reported on the level of pain experienced by the participants based on results of the VAS [20’21’23’25’31’33], NRS [27] and ODI [32] (question one of the ODI questionnaire). Levels of pain experienced are represented in **Figure III.7**. Most equestrians in these studies felt mild and moderate levels of pain in general, as well as LBP and mild BP. Kraft et al. [25] found significant differences in the intensity of LBP between riders and controls. Deckers et al. [20] and Ferrante et al. [27] pain intensity levels are for all athletes with pain in all recall periods – lifetime, one-year, one month, chronic – the remaining papers measured pain levels in present LBP.

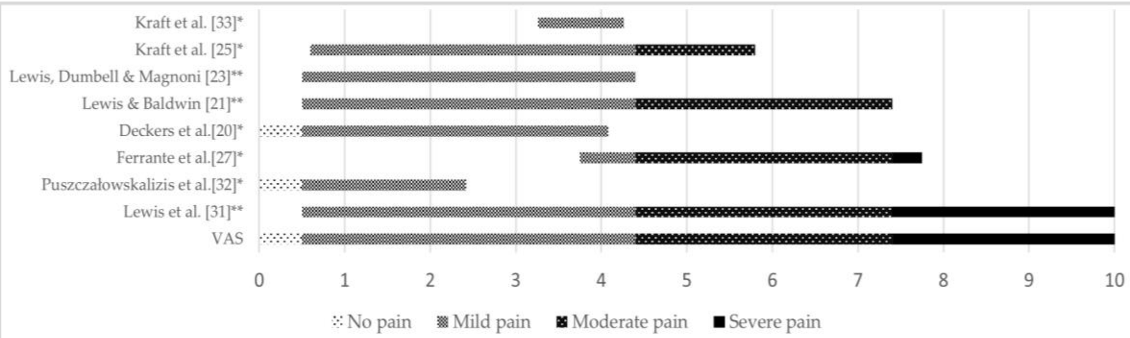


Figure III.7. *Levels of pain felt by equestrians based on VAS ratings [34].*
*Note: Location of pain: LBP [23’25’27’31’32]; BP [20’33]; Pain in general [21]. *Values of intensity of pain given as a quantitative variable (median with standard deviation above and below); ** Values of intensity of pain given as a qualitative variable.*

Five studies measured disability caused by BP [20], LBP [25’26’27’32] and CLBP [27]. 26.4% of the respondents in the Ferrante et al. [27] survey had a disability in daily living activities, and athletes with CLBP had higher values of disability than those with LBP. These authors did not find any correlations between the severity of pain and self-efficacy in participants with LBP. Levels of disability ranged from no disability [20’25’32], minimal disability [20’25’32] and moderate disability [32]. Duarte et al. [26] used a cut-off value to determine functionality or dysfunctionality in RMDQ results. Of the participants with LBP, 49.5% had dysfunctionality; nevertheless, the RMDQ mean score was 5.39 – higher than the cut-off value of ≥ 4 for dysfunctionality. Two [23’31] studies mentioned in their methodology using the ODI to measure the impact of pain on equestrians' general life and well-being, but the results of the ODI could not be found by the review team.

3.3.11.2. Time loss

In Lewis et al.'s [31] survey, a total of 42% of participants reported that pain or injury had stopped them from riding at some point in life. Time off riding due to pain ranged from a few days to 15 years and even prevented some from returning to riding permanently. Another survey [27] concluded that 28.5 % of EA with LBP or CLBP had suspended sporting activities and that athletes with CLBP suspended sporting activities more frequently. In a study on competitive showjumpers [23], 15% reported that pain had prevented them from riding; time off ranged from one day periodically to one year.

3.3.11.3. Pain management techniques

The pain management techniques reported in studies were medication, consultation with a physician and various types of therapies (e.g., physical therapy, therapy, osteopathy, massage). Equestrians with pain who used medication were 75% [31], 96% [21], and 37.2% [27]. EA that used over-the-counter medication were 51.1% [31], 93% [21], 67% [23] and 51.4% [22]. EA using medication with medical prescription were 23.9% [31], 3%[21], 9% [23] and 16.2% [22]. In a study on collegiate EA [30], 16.44% regularly used pain medication. Of the equestrians who had pain and sought treatment to help manage it, 33%[32], 36.7% [27] and 49.6% [33] had visited a physician. The most common therapies used by equestrians with pain were physical therapy: 47.7% [31], 38.5% [32], 61.69% [27], 19% [21], 47% [23] and 18.9% [22] and massage 12% [32] and 29% [23].

3.3.12. Risk factors, associations and contributing factors for LBP

Tables III.15, III.16, III.17 and III.18 (**Supplementary Material III**) report data on risk factors, associations, and contributing factors for pain, BP, and LBP. Variables with statistically significant associations were classified as "risk factors", those without significant associations were classified as "not risk factors", while those without significant statistical analysis were considered "contributing factors" or "not contributing factors". The data is categorized into population characteristics (**Tables III.15** and **III.16**) and exposure characteristics (**Tables III.17** and **III.18**). Due to the variability in data analysis, population characteristics and reporting methods, it was not possible to combine findings for most variables.

Two studies [26'27] found that sex was not a risk factor for the one-year prevalence of LBP [26], LBP incidence over a lifetime or one-year period [27], CLBP incidence [27], or LBP-related disability and functionality issues [26]. However, Puszczałowska-Lizis et al. [32] reported that women had a higher risk of experiencing pain in the lumbar back pain compared to men. Regarding anthropometric characteristics, height [27'28'29], weight [27'28'29], and BMI [25'26'27'28'29] were not identified as risk or contributing factors for one-year LBP incidence [26'27'28'29], CLBP [27], dysfunctionality due to LBP [26], or disc degeneration disease[25]. However, Duarte et al. [26] observed that higher BMI scores were significantly correlated with increased disability scores. Ferrante et al. [27] identified weight as a substantial risk factor for lifetime LBP prevalence. Only two studies [28'29] investigated BF% and yielded opposing conclusions despite having similar populations and methodologies. One study found no correlation between BF% and LBP [29], while the other identified BF% as a prominent risk factor for LBP in CEA, with a cutoff value of BF% > 23% [28]. Two high-quality studies provided somewhat contradictory results concerning age as a risk factor. Ferrante et al. [27] found that younger age was a risk factor for LBP with both lifetime and one-year incidence. In contrast, Duarte et al. [26] found that older age was a risk factor for LBP-related dysfunctionality. No significant associations were found between age and CLBP [27], disability scores [26], LBP in CEA [28'29], or one-year LBP incidence [26]. Kraft et al. [25], using MRI imaging, concluded that incipient disc degeneration was not a risk factor for LBP point prevalence and found no relationship between trunk/leg-length co-efficient and disc degeneration disease. Engaging in sports other than equestrian activities did not pose a risk factor for lifetime [27] or one-year [26'27] LBP incidence, nor for LBP-related disability [26]. Two studies on CEA populations [28'29], which had similar characteristics, found significant asymmetries in range of motion (ROM) (more information in **Table III.15, Supplementary Material IV**) and trunk muscle endurance (ISBE)[28] between dominant and non-dominant limbs in all participants, regardless of LBP incidence. Nonetheless, these studies determined that higher values in ROM (hip total rotation)[28], lower values in ROM (hip adduction with hip flexed-HAD-HF, flexion of knee-KF)[29], and lower trunk muscle endurance (isometric side bridge endurance (ISBE) and ISBE in non-dominant side)[28] were risk factors for LBP incidence, with cutoff values of HAD-HF ≤ 26º, KF ≤ 128º, and ISBE ≤ 65s.

Practicing equestrian sports professionally, rather than as a hobby, was identified as a strong risk factor for LBP incidence, disability, and dysfunctionality caused by LBP[26]. Additionally, 43% of the equestrian population [26] considered riding a contributing factor to the intensity of pain experienced. In contrast, Kraft et al. [25] found that being an equestrian athlete did not pose a risk for T2-weighted signal alterations of the lumbar spine (disc degeneration), and Duarte et al. [26] did not find a significant correlation between LBP prevalence and the level of equestrian sports practiced, whether professionally or as a hobby. Equestrian discipline was not a risk or contributing factor for LBP prevalence [26], intensity, disability, disc degeneration disease [25], or CLBP incidence [27]. However, Kraft et al. [25] noted that practicing dressage might contribute to T2-weighted signal alterations in the lumbar spine. Ferrante et al. [27] found a significant relationship between equestrian discipline and lifetime LBP prevalence, but this result should be interpreted cautiously due to the small sample sizes in some disciplines and discipline characteristics. No correlations were found between the level of riding (as indicated by sport license) and LBP or CLBP incidence [27].

Workload was a significant risk factor for LBP [26] and CLBP [27] incidence when it reached 5 to 6 hours/week [27], exceeded 7 hours/week [26], or surpassed 13 hours/week [27]. Other studies did not find correlations between workload and point [25], lifetime [27] or one-year LBP incidence [27’28’29], LBP intensity [25], or LBP-related disability [26]. The duration of equestrian sports practice (in years) was not identified as a risk or contributing factor for LBP incidence [26’27], or LBP-related disability [26].

One high-quality study found that performing stable duties was a major risk factor for LBP incidence, though it did not affect functionality [26]. Specifically, stable du-ties like mucking out appeared to be contributing factors to higher disability scores and LBP intensity. Grooming activities and lunging horses also contributed to LBP intensity in 27% and 26% of equestrians [26].

3.4. Discussion

This systematic review aimed to clarify the prevalence and risk factors associated with LBP in equestrian athletes, as this population is uniquely exposed to physical demands distinct from those in other sports. Equestrian sports combine high-intensity activities with repetitive motion and prolonged postures, placing specific biomechanical stresses on the lower back. Given these unique demands, understanding the prevalence of LBP in equestrians compared to the general and athletic populations provides insight into the potential need for targeted interventions. The findings of the present review indicate that the prevalence of LBP in equestrians is higher than in the general population [1] across all recall periods - lifetime, one-year, and point. The lifetime prevalence of LBP in EA was measured in only one high-quality study [27], which is higher than the pooled prevalence for athletes [2,6]. One-year LBP prevalence in equestrians, reported by all prevalence studies, is higher than the pooled one-year prevalence in athletes [2,6], yet lower than the prevalence range for horse-riding athletes reported by Wilson et al. [6]. Regarding point prevalence of LBP in equestrians, based on both high- and low-quality studies, it is generally higher than the pooled point prevalence in athletes [2,6], except for one low-quality study [24] where the point prevalence is lower than the pooled values in athletes [6]. Given this, although the prevalence of LBP is high in athlete populations - particularly since athletes are less likely to have comorbidities compared to the general population [6] - it generally appears to be even higher among equestrians. Similarly, this pertains to CLBP prevalence being higher in EA [27] in comparison to the general population [1] with different physical activity levels – low, moderate, and high [35]. Additionally, incidence could not be established since studies did not report a minimum symptom period or whether LBP episodes were recurrent or not. In the present review, 57.1% of the studies – high and low-quality – used validated tools or at least clear definitions to identify LBP. Furthermore, as only 28.6% of the studies provided a definition of LBP, attention must be given to the definition of BP since variations in definitions can result in different prevalence estimates [2]. Wilson et al. [6] highlighted an urgency to create a definition of LBP for athletes - for use in re-search. Additionally, in the present review, the team noted that the terms BP and LBP were used interchangeably at times. The same was noted in other reviews [6].

It has been determined that a prominent risk factor for LBP is a previous LBP episode [6], that is, a history of LBP. The present review’s findings cannot support this conclusion; only 35.7% of studies published data on the duration or frequency of symptoms, and this variable was not comparable due to methodological heterogeneity. The reported levels of pain in equestrians ranged from none to severe, yet most pain was mild and moderate, a finding in line with adolescent athletes [36], elite athletes [37,38] and non-athletes [37] population with LBP. Research has proven that intensity and disability caused by LBP are correlated [39]. The most common levels of disability caused by LBP in equestrians were no disability and minimal disability, which seems to be similar in the athlete population [38]. On the other hand, EA [26] seem to be more prone to dysfunctionality than elite athletes [38]. The disability results could be lower than expected due to the lack of sensitivity of the tools used in the assessment of disability in athletes – in their sports and exercise activities [40] – athletes could have limitations to their athletic performance and yet have little or no disability in their daily activities [38]. A systematic review of instruments used to assess BP in athletes [41] published in 2023 suggested that future research on BP in athletes should use the Athlete Disability Index [38].

The results of the present review show that more equestrians tend to use medication to manage pain than other non-pharmacological therapies. Pain is commonly self-managed by athletes using over-the-counter pain medications or supplements, suggesting that information specifically aimed at athletes on the safe and efficacious use of pain medications is necessary [42]. Managing pain in elite athletes must balance the tension between ignoring or masking pain and recognizing its protective role in the presence of injury [42]. The mission of the World Anti-Doping Agency is to promote clean sport, and to support this goal, understanding the prevalence of LBP among equestrians is crucial. This knowledge can help evaluate treatment strategies to ensure that EA have access to therapists and other pain management methods, reducing the reliance on self-medication [22].

Living, training, and competing in pain can carry significant consequences. Most EA in pain – general, in the back or in the lower back - feel limitations in their performance riding and competing. Literature has shown that LBP and BP reduce athletic performance in training and competition [43'44'45'46]. Moreover, performance is not limited to sports. A study characterizing injuries suffered by mounted and non-mounted police officers [47] concluded that the most common injuries in mounted police officers were to the lower back and musculoskeletal in nature. Given their responsibility to protect the public, a decline in police officers' performance could lead to serious injury or even death for themselves, their fellow officers, or members of the community they serve (Orr et al. 2017 & Simas et al. 2022 cited in [47]). Other consequences of LBP are effects on participation [6] – in training and competition, high costs of treatment, decreased quality of life [46] and functional impairment [6]. Furthermore, it is known that asymmetry has an impact on equestrian performance [12]. Significant asymmetries of ROM and ISBE have been detected in EA [28], and pain avoidance in riding can increase the prevalence of asymmetry [24]. Further research focusing on LBP and asymmetry in EA is needed to help understand if asymmetry is a consequence of pain or if pain is a consequence of underlying asymmetries. A systematic review and meta-analysis on postural asymmetries and LBP concluded that lumbopelvic mechanisms may be altered in individuals with LBP, yet no definitive conclusions could be drawn [48].

As in the present review, results regarding the risk anthropometric parameters pose to LBP tend to be inconsistent and inconclusive, especially in the athletic population. In the general population, LBP can be experienced at any age, but prevalence and incidence are higher in older individuals [49]. However, Shiri et al. [50] found that LBP slightly declined with increasing age, while lumbar radicular pain increased with age. In sports, the evidence was insufficient and inconsistent, making it impossible to establish any associations between age and LBP [2'6'51]. The same seems to be true for sex. In the general population, LBP and lumbar radicular pain affect more women [49'50], yet in sports, evidence is inconsistent [2'6'51]. In the present review, there is strong evidence indicating that height is not a risk factor for LBP in the general population [50] and athletes [51]. Weight, BMI, and BF% seem to be consistent risk factors for LBP across the literature [6'50'51'52]. In EA, there was inconsistent evidence to demonstrate an increased risk. Other associations, such as the practice of other sporting activities (differing from the main sport) and disc degeneration in athletes and EA were also in-consistent [6'51'53]. Altered lumbar ROM – flexion and extension – have been considered strong risk factors for LBP [51]. In the present review, altered ROM have been considered predictive factors for LBP in CEA, yet it is not possible to compare these findings due to assessment heterogeneity.

Considering all this information, it can be assumed that the higher prevalence of LBP in equestrians is more closely related to sport-specific variables than to the anthropometric characteristics of the riders. In the present work, there is strong evidence that the type of equestrian discipline does not significantly impact LBP. While disciplines differ in nature and biomechanical demands on both horse and rider, the daily work of the equine and equestrian athlete is similar across them. Training sessions of-ten overlap, sharing common characteristics, and the widely accepted correct rider position remains consistent across all disciplines, varying only with specific training or tasks. Competition level, skill level, years of sport and workload are exposure variables that correlate – an athlete at a higher skill and competition level naturally has more experience coming from more years and a higher workload in the sport. Although there is strong evidence that years of exposure to sport and high volume of training are risk factors for LBP prevalence[6], other authors could not find evidence for these as-sociations [2'51]. This inconsistency is also reflected in the present review, where findings for these variables – competition level, skill level, years of sport and workload - were inconsistent. However, this may be attributed to poor assessment stemming from the lack of standardized tools for measuring exposure in equestrian sports. Future re-search on EA should focus on developing and validating survey tools specifically designed for this population.

Horse-riding is one of the sports with the highest prevalence of LBP in elite athletes [6], implying that the functional characteristics of equestrian sports may be a key factor in the high prevalence of LBP. Horse riding appears to generate whole-body vibrations [54], which in turn increases the risk of LBP [55]. Moreover, the present review indicated that activities related to the maintenance and management of the equine partner appear to increase the risk of LBP. Literature has found that bent and twisted back positions—common in some of these activities—create harmful stress loads [56] and increase the risk of musculoskeletal problems [57]. Additionally, heavy workloads, repeated lifting, and the accumulation of stress from flexed, rotated, and awkward lumbar spine positions were identified as moderate to strong risk factors for LBP [58]. Future research should make a concerted effort to include, rather than over-look, the off-horse workloads inherent in equestrian sports.

No definitive risk factors for LBP in EA have been identified yet, highlighting the need for further scientific research on this topic. To advance our understanding, it is crucial to focus on the following areas:

• Study Quality: Conducting higher-quality studies is essential to provide more substantial evidence regarding which variables pose risk factors for LBP and which do not.

• Research Tools: There is a pressing need to develop standardized questionnaires that address key questions, enabling researchers to better understand the prevalence of LBP in EA and the factors contributing to its existence.

Improving these aspects will help clarify the underlying causes of LBP in this population and inform more effective prevention and treatment strategies.

3.5. Limitations

This systematic review has several limitations that should be acknowledged. First, the review process was not blinded, which could introduce bias, as reviewers were aware of study authors and affiliations. This issue is particularly pertinent given that one of the included studies shares the same main author as this review. To minimize potential bias, the quality assessment for all studies, including this one, was also conducted by a reviewer not involved with the article in question. Another limitation lies in the tools used to assess study quality and prevalence, which were originally developed for medical and health studies. These tools may lack the sensitivity required to accurately evaluate research specific to athlete populations, potentially affecting the reliability of the quality assessments. Additionally, the interchangeable use of the terms "back pain" and "lower back pain" in some studies complicates data interpretation, as these terms were sometimes conflated. During the full-text screening and data extraction, judgments had to be made regarding whether the studies specifically addressed LBP, introducing a degree of subjectivity. Furthermore, there was a challenge with the definition of "point prevalence," as several studies did not clearly report the specific time window in which athletes were asked about their pain. In many instances, the review team had to infer that the reported prevalence referred to point prevalence based on the context, but this was not explicitly stated. This assumption may have led to inconsistencies in the reported prevalence estimates. Lastly, the review was limited to peer-reviewed articles, excluding other sources like abstracts, reports, and theses. A notable limitation in the present review was the challenge of accurately assessing exposure to risk factors due to the absence of standardized tools specific to equestrian sports. Proper exposure assessment is crucial for understanding injury and illness risk, yet current tools are generally designed for other sports contexts and may not capture the unique demands of equestrian activities. In equestrian sports, where training often includes holistic routines beyond discipline-specific sessions, exposure factors like hours spent riding, type of horse, and regular stable management tasks (e.g., grooming, mucking out) are critical but inconsistently recorded. This lack of standardized, equestrian-specific exposure measures likely influenced the precision of risk estimates across studies, limiting the comparability of findings and the review's ability to quantify risk factors effectively. Developing tailored tools for equestrian contexts is essential to advance accuracy in future research and foster evidence-based prevention strategies in the field. A further limitation encountered was the methodological heterogeneity across studies, particularly concerning rider status and skill level. These variables were challenging to categorize consistently, as competition level alone does not fully capture rider expertise. The absence of standardized clear definitions meant that the skill levels and competitive statuses of equestrian athletes could not be uniformly assessed. Future research would benefit from clearer definitions regarding skill level, affiliation status, and competition specifics to improve comparability and ensure that samples accurately represent different experience levels. Despite these limitations, the review provides valuable insights into the prevalence of LBP in EA and highlights the necessity for further, more precise research in this area. Future studies should prioritize the development and validation of sport-specific tools for assessing LBP risk factors in equestrian athletes. By focusing on sport-specific variables and improving research quality, the equestrian community can better understand and mitigate LBP risks, ultimately enhancing athlete well-being and performance.

3.6. Conclusions

This systematic review underscores the heightened prevalence of LBP among equestrian athletes compared to the general population and other athletic groups. While some evidence points to sport-specific factors - such as the physical demands of riding and associated tasks - as potential contributors to this increased prevalence, definitive risk factors remain elusive due to methodological inconsistencies and a lack of standardized assessment tools. The findings highlight the need for higher-quality re-search focused on the unique characteristics of equestrian sports.

3.7. Paper back matter

3.7.1. Supplementary materials

Supplementary materials I - Table III.3: Search strategy performed in all databases, number of articles found in each search; Table III.4: Key words selected regarding population & exposure, and out-come of interest; Table III.5: Summary of data items collected from included studies; Table III.6: Study design features (n=14); Table III.7: Study outcomes (n=14); Table III.8: Sample details of included studies; Table III.9: Data collection tools, dissemination procedure and sample size with details; Table III.10: Detailed data collection tools of included studies; Figure III.8: Number of publications per period. Supplementary materials II – Table III.11: Detailed information of OSQE tool – cross-sectional studies, with comments and explanation; Table III.12: Quality score of all included studies and quality taxonomy; Table III.13: JBI critical appraisal checklist for included studies reporting prevalence data; Table III.14: Confidence intervals of LBP prevalence. Supplementary materials III – Table III.15: Population characteristics (demographic and anthropometric) that do not pose a risk or do not contribute to pain; Table III.16: Exposure characteristics (related with Equestrianism) that do not pose a risk or do not contribute to pain; Table III.17: Population characteristics (demographic and anthropometric) that pose a risk or contribute to pain. Table III.18: Exposure characteristics (related with Equestrianism) that pose a risk or contribute to pain.

3.7.2. Author contributions

Conceptualization, C.D. A.R. and J.P.S.; literature search and study selection, R.S. and O.F.; data extraction, C.D. and O.F.; data analysis and interpretation, C.D., R.S. and J.P.S.; writing—original draft preparation, C.D.; writing—review and editing, C.D. and A.R.; supervision, A.R., J.P.S., R.S. and O.F.; project administration, A.R.; funding acquisition, A.R. All authors have read and agreed to the published version of the manuscript.

3.7.3. Funding

The APC was funded by FCT—Fundação para a Ciência e a Tecnologia, through Comprehensive Health Research Center (CHRC) grant number UIDP/04923/2020.

3.7.4. Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon request.

3.7.5. Acknowledgements

The research team would like to extend their sincere gratitude to Elisabeth Fraser-Hitch for her meticulous proofreading of this work. Her expertise not only in technical terminology but also in ensuring grammatical accuracy and clarity has greatly enhanced the quality of the manuscript. Her contributions have ensured that the English language throughout the review is precise and professionally presented.

3.7.6. Conflicts of interest

The authors declare no conflicts of interest related to the publication of this systematic review. While one of the included studies shares the same main author as this review, all efforts were made to minimize bias. The quality assessment for all studies, including the one authored by a member of this review team, was independently conducted by another reviewer who was not in-volved with the respective study. Additionally, no external funding or influences affected the outcomes or interpretations presented in this review.

3.9. References

1. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, Woolf A, Vos T, Buchbinder R. A systematic review of the global prevalence of low back pain. *Arthritis rheum*. 2021; 64(6): 2028-2037. https://doi.org/10.1002/art.34347

2. Trompeter K, Fett D, Platen P. Prevalence of Back Pain in Sports: A Systematic Review of the Literature. *Sports Med*. 2017; 47: 1183-1207. https://doi.org/10.1007/s40279-016-0645-3

3. Huang R, Ning J, Chuter VH, Taylor JB, Christophe D, Meng Z, Jiang L. Exercise alone and exercise combined with education both prevent episodes of low back pain and related absenteeism: systematic review and network meta-analysis of randomised controlled trials [RCTs] aimed at preventing back pain. *Br J Sports Med*. 2020; 54(13): 766-770. https://doi.org/10.1136/bjsports-2018-100035

4. Heneweer H, Picavet H, Staes F, Kiers H, Vanhees L. Physical fitness, rather than self-reported physical activities, is more strongly associated with low back pain: evidence from a working population. *Eur Spine J*. 2012; 21: 1265-1272. https://doi.org/10.1007/s00586-011-2097-7

5. Keener MM, Tumlin KI. Self-reported acute injury and chronic pain in American equestrian athletes. *Comp Exerc Physiol*. 2023; 1: 1-14. https://doi.org/10.1163/17552559-20230021

6. Wilson F, Ardern CL, Hartvigsen J, Dane K, Trompeter K, Trease L, et al. Prevalence and risk factors for back pain in sports: a systematic review with meta-analysis. *Br J Sports Med*. 2021; 55(11): 601-607. https://doi.org/10.1136/bjsports-2020-102537

7. Williams J. Performance analysis in equestrian sport. *Comp Exerc Physiol*. 2013; 9(2): 67-77. https://doi.org/10.3920/CEP13003

8. Pugh TJ, Bolin D. Overuse Injuries in Equestrian Athletes. *Curr Sports Med Rep*. 2004; 3(6): 297-303. https://doi.org/10.1007/s11932-996-0003-6

9. Dumbell LC, Rowe L, Douglas JL. Demographic profiling of British Olympic equestrian athletes in the twenty-first century. *Sport Soc*. 2018; 21(9): 1337-1350. https://doi.org/10.1080/17430437.2017.1388786

10. Haan D. A Review of the Appropriateness of Existing Micro- and Meso-level Models of Athlete Development within Equestrian Sport. *Int J Hum Mov Sports Sci*. 2017; 5(1): 1-8. doi:10.13189/saj.2017.050101

11. Hoy D, Brooks P, Blyth F, Buchbinder R. The epidemiology of low back pain. *Best Prat Res Clin Rheumatol*. 2010; 24(6): 769-781. https://doi.org/10.1016/j.berh.2010.10.002

12. Lewis V, Douglas JL, Edwards T, Dumbell L. A preliminary study investigating functional movement screen test scores in female collegiate age horse-riders. *Comp Exerc Physiol*. 2019; 15(2): 105-112. doi:10.3920/CEP180036

13. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021; 372. doi:10.1136/bmj.n71

14. Carlson MD, Morrison RS. Study Design, Precision, and Validity in Observational Studies. *J Palliat Med*. 2009; 12(1): 77-82. doi:10.1089/jpm.2008.9690

15. Drukker M, Weltens I, van Hooijdonk C, Vandenberk E, Bak M. Development of a methodological quality criteria list for observational studies: the observational study quality evaluation. *Front Res Metr Anal*. 2021; 6: 675071. doi:10.3389/frma.2021.675071

16. Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Chapter 5: Systematic reviews of prevalence and incidence. In: Aromataris E, Munn Z. JBI Reviewer's Manual. South Australia: JBI; 2020. 177-217. https://doi.org/10.46658/JBIMES-20-06

17. Corporation, Microsoft. Microsoft Excel [computer program]. Version 2021. Available online: https://www.microsoft.com

18. Naing L, Nordin R, Rahman H, Naing Y. Sample size calculation for prevalence studies using Scalex and ScalaR calculators. BMC Med Res Methodol. 2022; 22(1): 1-8. https://doi.org/10.1186/s12874-022-01694-7

19. Epitools Epidemiological Calculators. Ausvet [Internet]. Sergeant, ESG; Available from: https://epitools.ausvet.com.au/ciproportion [accessed on 24 August 2024]

20. Deckers I, De Bruyne C, Roussel NA, Truijen S, Minguet P, Lewis V, et al. Assessing the sport-specific and functional characteristics of back pain in horse riders. *Comp Exerc Physiol*. 2021; 17(1): 7-15. doi:10.3920/CEP190075

21. Lewis V, Baldwin K. A preliminary study to investigate the prevalence of pain in international event riders during competition, in the United Kingdom. *Comp Exerc Physiol*. 2018; 14(3): 173-181. https://doi.org/10.3920/CEP180006

22. Lewis V, Kennerley R. A preliminary study to investigate the prevalence of pain in elite dressage riders during competition in the United Kingdom. *Comp Exerc Physiol*. 2017; 13(4): 259-263. doi:10.3920/CEP170016

23. Lewis V, Dumbell L, Magnoni F. A Preliminary Study to Investigate the Prevalence of Pain in Competitive Showjumping Equestrian Athletes. *J Phys Fitness Med Treat Sports*. 2018; 4(3). doi:10.19080/JPFMTS.2018.04.555637

24. Hobbs S.J, Baxter J, Louise B, Laura-An R, Jonathan, S, Hilary CM. Posture, Flexibility and Grip Strength in Horse Riders. *J Hum Kinet*. 2014; 42(1): 113-125. doi:10.2478/hukin-2014-0066

25. Kraft CN, Peter PH, Ute B, Mei Y, Oliver D, Christian L, Makus FV. Magnetic Resonance Imaging Findings of the Lumbar Spine in Elite Horseback Riders: Correlations With Back Pain, Body Mass Index, Trunk/Leg-Length Coefficient, and Riding Discipline. *Am J Sports Med*. 2009; 37(11): 2205-2213. doi:10.1177/0363546509336927

26. Duarte C, Santos R, Fernandes O, Raimundo A. Prevalence of Lower Back Pain in Portuguese Equestrian Riders. *Sports*. 2024; 12(8): 207. doi:10.3390/sports12080207

27. Ferrante M, Bonetti F, Quattrini M, Mezzetti, M, Demarie S. Low Back Pain and Associated Factors among Italian Equestrian Athletes: a Cross-Sectional Study. *MLTJ*. 2021; 11(2): 344. doi:10.32098/mltj.02.2021.19

28. Cejudo A, Ginés-Díaz A, Rodrígues-Ferrán O, Santonja-Medina F, Sainz De Baranda P. Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes. *Children*. 2020; 7(10): 172. doi:10.3390/children7100172

29. Cejudo A, Ginés-Días A, Sainz De Baranda P. Asymmetry and Tightness of Lower Limb Muscles in Equestrian Athletes: Are They Predictors for Back Pain? *Symmetry*. 2020; 12(10): 1679. doi:10.3390/sym12101679

30. Pilato M, Henry T, Malavase D. Injury History in the Collegiate Equestrian Athlete: Part I: Mechanism of Injury, Demo-graphic Data and Spinal Injury. *J Sports Med Allied Health Sci*. 2017; 2(3): 3. doi:10.25035/jsmahs.02.03.03

31. Lewis V, Nicol Z, Dumbell L, Cameron L. A Study Investigating Prevalence of Pain in UK Horse Riders over Thirty-Five Years Old. *Int J Equine Sci*. 2023; 2(2): 9-18.

32. Puszczałowska-Lizis E, Szymański D, Pietrzak P, Wilczyński M. Incidence of back pain in people practicing amateur horse riding. *Fizjoterapia polska*. 2022; 22. doi.org/10.56984/8ZG1A68mY

33. Kraft C, Urban N, Ilg A, Wallny T, Scharfstädt A, Jäger M, Pennekamp P. *Einfluss der Reitdisziplin und -intensität auf die Inzidenz von Rückenschmerzen bei Reitsportlern*. Influence of the riding discipline and riding intensity on the incidence of back pain in competitive horseback riders. *Sportverletz Sportschaden*. 2007; 21(1): 29-33. doi:10.1055/s-2007-963038

34. Jensen M, Chen C, Brugger A. Interpretation of visual analog scale ratings and change scores: a reanalysis of two clinical trials of postoperative pain. *J Pain*. 2003; 4(7): 407-414. doi:10.1016/s1526-5900(03)00716-8

35. Heneweer H, Vanhees L, Picavet H. Physical activity and low back pain: A U-shaped relation? *Pain*. 2009; 143(1-2): 21-25. doi:10.1016/j.pain.2008.12.033

36. Schmidt C, Zwingenberger S, Walther A, Reuter U, Kasten P, Seifert J, et al. Prevalence of Low Back Pain in Adolescent Athletes – an Epidemiological Investigation. *Int J Spots Med*. 2014; 35(8): 684-689. http://dx.doi.org/10.1055/s-0033-1358731

37. Catalá M, Schroll A, Laube G, Arampatzis A. Muscle Strength and Neuromuscular Control in Low-Back Pain: Elite Athletes Versus General Population. *Front Neurosci*. 2018; 12. https://doi.org/10.3389/fnins.2018.00436

38. Noormohammadpour P, Khezri AH, Farahbakhsh F, Mansournia MA, Smuck M, Kordi R. Reliability and Validity of Athletes Disability Index Questionnaire. *Clin J Sport Med*. 2018; 28(2): 159-167. doi:10.1097/JSM.0000000000000414

39. Shafshak TS, Elnemr R. The visual analogue scale versus numerical rating scale in measuring pain severity and predicting disability in low back pain. *JCR J Clin Rheumatol*. 2021; 27(7): 282-285. doi:10.1097/RHU.0000000000001320

40. Zamani E, Kordi R, Nourian R, Noorian N, Memari AH, Shariati M. Low back pain functional disability in athletes; conceptualization and initial development of a questionnaire. *Asian J Spots Med*. 2014; 5(4). doi:10.5812/asjsm.24281

41. Azevedo VD, Silva RF, Borges S, Fernandes M, Miñana-Signes V, Monfort-Pañego M, et al. Instruments for assessing back pain in athletes: A systematic review. *Plos one*. 2023; 18(11). https://doi.org/10.1371/journal.pone.0293333

42. Hainline B, Derman W, Vernec A, Budget R, Deie M, Dvořák J, et al. International Olympic Committee consensus statement on pain management in elite athletes. *Br J Sports Med*. 2017; 51(17): 1245-1258. http:// dx. doi. org/ 10. 1136/bjsports- 2017- 097884

43. Noormohammadpour P, Rostami P, Mansournia M, Farahbakhsh F, Pourgharib Shahi MH. Kordi R. Low back pain status of female university students in relation to different sport activities. *Eur Spine J*. 2016; 25: 1196-1203. https://doi.org/10.1007/s00586-015-4034-7

44. Wernli K, Tan J, O'Sulliva P, Smith, A, Campbell A, Kent P. Does movement change when low back pain changes? A systematic review. *J Orthop Sports Phys Ther*. 2020; 50(12): 664-670. https://www.jospt.org/doi/10.2519/jospt.2020.9635

45. Nadler S, Moley P, Malanga G, Rubbani M, Prybicien M, Feinberg JH. Functional deficits in athletes with a history of low back pain: a pilot study. *Arch Phys Med Rehabil*. 2002; 83(12): 1753-1758. https://doi.org/10.1053/apmr.2002.35659

46. Mortazavi J, Zebardast J, Mirzashahi B. Low back pain in athletes. *Asian J Sports Med*. 2015; 6(2). doi:10.5812/asjsm.6(2)2015.24718

47. Orr R, Canetti E, Pope R, Lockie R, Dawes J, Schram B. Characterization of Injuries Suffered by Mounted and Non-Mounted Police Officers. *Int J Environ Res Public Health*. 2023; 20(2): 1144. https://doi.org/10.3390/ijerph20021144

48. Sugavanam T, Sannasi R, Anand P, Ashwin Javia P. Postural asymmetry in low back pain–a systematic review and meta-analysis of observational studies. *Disabil Rehabil*. 2024: 1-18.https://doi.org/10.1080/09638288.2024.2385070

49. World health organization: Low back pain [Internet]. Available from: https://www.who.int/news-room/fact-sheets/detail/low-back-pain#:~:text=LBP%20can%20be%20experienced%20at%20any%20age%2C%20and,years.%20LBP%20is%20more%20prevalent%20in%20women%20%282%29. [accessed on 21 August 2024]

50. Shiri R, Falah-Hassani K, Heliövaara M, Solovieva S, Amiro S, Lallukka T, et al. Risk factors for low back pain: a population-based longitudinal study. *Arthritis Care Res*. 2019; 71(2): 290-299. https://doi.org/10.1002/acr.23710

51. Moradi V, Memari A, Shayestehfar M, Kordi R. Low Back Pain in Athletes Is Associated with General and Sport Specific Risk Factors: A Comprehensive Review of Longitudinal Studies. *Rehabil Res Pract*. 2015; 2015(1): 850184. https://doi.org/10.1155/2015/850184

52. Wals T.P, Arnold JB, Evans AM, Yaxley A, Damarell R, Shanahan EM. The association between body fat and musculoskeletal pain: a systematic review and meta-analysis. *BMC Musculoskelet Disord*. 2018; 19: 1-13. https://doi.org/10.1186/s12891-018-2137-0

53. Papagelopoulos P, Boscainos P, Giannakopoulos P, Zoubos A. Degenerative Spondyloarthropathy of the Cervical and Lumbar Spine in Jockeys. *Orthopedics*. 2001; 24(6): 561-564. doi:10.3928/0147-7447-20010601-12

54. Zeng X, Trask C, Kociolek AM. Whole-body vibration exposure of occupational horseback riding in agriculture: A ranching example. *Am J Ind Med*. 2017; 60(2): 215-220. https://doi.org/10.1002/ajim.22683

55. Burstrom L, Nilsson T, Wahlstrom J. Whole-body vibration and the risk of low back pain and sciatica: a systematic review and meta-analysis. *Int Arch Occup Environ Health*. 2015; 88: 403-418. doi:https://doi.org/10.1007/s00420-014-0971-4

56. Löfqvist L, Pinzke S. Working with Horses: An OWAS Work Task Analysis. *J Agric Saf Health*. 2011; 17(1): 3-14. doi:10.13031/2013.36230

57. Löfqvist L, Osvalder AL, Bligård LA, Pinzke S. An analytical ergonomic risk evaluation of body postures during daily cleaning tasks in horse stables. *Work*. 2015; 51(4): 667-682. doi:10.3233/WOR-152022

58. Heneweer H, Staes F, Aufdemkampe G, van Rijn M, Vanhees L. Physical activity and low back pain: a systematic re-view of recent literature. *Eur Spine J*. 2011; 20: 826-845. https://doi.org/10.1007/s00586-010-1680-7

Chapter IV

Paper 2: Prevalence of Lower Back Pain in Portuguese Equestrian Riders

Chapter IV

Paper 2 - Prevalence of Lower Back Pain in Portuguese Equestrian Riders

Carlota Duarte [1], Rute Santos [1,2,*], Orlando Fernandes [3,4] and Armando Raimundo [3,4]

1 - Escola Superior de Biociências de Elvas, Instituto Politécnico de Portalegre, 7300-110 Portalegre, Portugal; carlotadu-arte@ipportalegre.pt (C.D.); rutesantos@ipportalegre.pt (R.S.)
2 - VALORIZA—Research Centre for Endogenous Resource Valorization, Instituto Politécnico de Portalegre, 7300-555 Portalegre, Portugal
3 - Escola de Saúde e Desenvolvimento Humano, Universidade de Évora, 7004-516 Évora, Portugal; orlandoj@uevora.pt (O.F.); ammr@uevora.pt (A.R.)
4 - CHRC—Comprehensive Health Research Centre, Universidade de Évora, 7004-516 Évora, Portugal
* Correspondence: rutesantos@ipportalegre.pt

Abstract

Lower back pain is prevalent in equestrian athletes, but its prevalence and associated factors are unknown in the Portuguese equestrian population. A questionnaire regarding lower back pain and possible associated factors was answered by 347 respondents. Of the respondents, 214 (61,7%) stated having experienced lower back pain in the past 12 months and therefore completed the Roland Morris disability questionnaire. Among the latter, 63.1% stated that lower back pain impaired their performance. The probability of suffering from lower back pain was higher in individuals with higher weekly riding workloads, who reported equestrianism as their main occupation, and who performed daily stable duties. Considering a Roland Morris disability score of 4 as the cut-off value for dysfunction, this sample had an average score of 5.39 ± 4.42. Individuals who stated equestrianism was their main occupation showed a significantly higher risk (OR = 1.759, $p = 0.041$) of exhibiting a score ≥ 4 than those who stated equestrianism as a hobby. Age ($p = 0.029$), body mass index ($p = 0.047$), and daily performance of stable duties ($p = 0.030$) were also associated with a higher Roland Morris disability score. Further research is needed to understand the full impacts of lower back pain in Portuguese equestrian athletes.

Keywords

equestrian; lower back pain; 12-month prevalence; workload; Roland Morris disability score; body mass index; age

List abbreviations

AIC - Akaike Information Criteria

BMI – Body mass index

EMMs - Estimated Marginal Means

GenLM - Generalized Linear Models

LBP – Lower back pain

LTAD - Long Term Athlete Development

OR – Odds ratio

RMDS – Roland Morris disability score

4.1. Introduction

Equestrian sports science is an emerging field [1] that is often based on experimental learning and tradition, instead of being centered on scientific knowledge [2]. Additionally, it has been predominately focused on the horse, while the analysis of the rider has expanded only in the last two decades [2]. To understand the various demands, dangers, and opportunities riders face, it is essential to use scientific, evidence-based investigation methods [3].

Compared with other sports, the career of equestrian athletes can be very long, with children starting highly competitive pony divisions at the ages of 5 and 6 [4] and riders competing at an Olympic level in their 60's and 70's [5]. As such, according to Long Term Athlete Development, equestrianism is categorized as an "early start-late specialization" sport [6]. Furthermore, horse riding is a hazardous activity, with one-fifth of all equestrians suffering serious injuries during their riding careers. Hence, research has mainly focused on acute riding injuries, but over-use injuries, repetitive strain, and lifestyle during long equestrian careers could cause chronic pain [7].

The appropriate position of the rider on the horse is "upright, balanced, elastic, solid and interactive", the shoulder, hip, and heel should be in alignment [3], the pelvis in a neutral position, keeping a controlled upright trunk and adapting to the horse's movements [6]. Riders with a correct riding position are most likely to achieve optimal performances but also reduce the risk of falling of the horse and possible injury [3]. The horse–rider relationship requires clear communication, and the rider must maintain balance and posture to be able to administer predictable cues (called aids) to communicate with the horse [6]. However, chronic pain may impair the rider's balance and posture.

Equestrian sports entail substantial and repetitive compressive mechanical forces primarily absorbed by the vertical axis of the rider's body, notably, the lumbopelvic–hip com-plex [4'8'9]. The repetitive nature of training imposes significant demands on the musculoskeletal system, leading to muscle tightness [8'10], as the rider's postural control relies heavily on coordination and neuromuscular awareness of the core and back musculature [7'11]. Although the primary cause of injury in equestrian athletes is falling of the horse [7'12], pain due to overuse or chronic injuries can diminish balance, physical performance, and sports participation, impacting athletes' success [5'6'7]. Despite injuries and pain, equestrian athletes often continue to train and compete because of various factors, such as pressure from sponsors and horse owners [7], which in turn may contribute to aggravated injuries, impair competitive success, and compromise their overall wellbeing. Furthermore, horses are trained to recognize subtle cues; a rider overcompensating because of pain can cause training difficulties [4] and discomfort for their equine partner.

Lower back pain (LBP) can be defined as pain and/or discomfort localized below the costal margin and above the inferior gluteal folds [9]. Physical activity is both a preventive and a possible risk factor for LBP [9]. In 2020, LBP afflicted 619 million individuals world-wide, with projections suggesting an increase of up to 843 million cases by 2050, mainly due to population growth and ageing [13]. LBP is the most common chronic injury in equestrian athletes [7'8], and its incidence is higher in equestrian athletes than in other athletes and the general population [9'10]. The main risk factors that have been reported for LBP in equestrian athletes are the practice of the sport itself, because of its specific features, as described above [8], the level of expertise in the sport, consequences of acute trauma and its poor recovery [1], asymmetric posture [8'10], poor postural control [11], the cushioning and depth of the saddle seat [9'14], lack of balance, stability, and alignment at the pelvic level [10'11]. Equestrian athletes with LBP tend to have affected performance (due to distraction caused by the pain), a higher risk of falling due to earlier onset of fatigue [7'8], and a reduced ability to maintain the correct riding position and synchronize with the horse's movements [7].

Measuring the functional outcomes in individuals with LBP has been performed using a variety of validated questionnaires, of which the most widely accepted are the Roland Morris and Oswestry questionnaires [15]. The Roland Morris disability questionnaire is a tool that enables a discriminating outcome measure in LBP [16]. It has previously been used to measure the impact of LBP on everyday functioning [17] and has been translated into several languages [15] and validated for the Portuguese population [18]. Stratford and Riddle [19] defined a threshold score of 4 in the Roland Morris disability questionnaire as a reasonably accurate value to discriminate patients according to their functionality in everyday living.

The purpose of this observational cross-sectional study is to investigate the prevalence of LBP in Portuguese equestrian athletes and to gain insight into the primary factors or possible causes leading to LBP in this population.

4.2. Materials and Methods

4.2.1. Participants

An online questionnaire was designed using LimeSurvey (https://www.limesurvey.org/pt, accessed on 10 March 2023). Participants were equestrian athletes over 18 years old, federated in the Portuguese Equestrian Federation in 2022 and/ or 2023. Participation was anonymous and voluntary, and consent was given prior to opening the questionnaire. The questionnaire was disseminated using social media (Facebook, Instagram, and WhatsApp) and by asking those answering the questionnaire to share the link with other horse riders and on their social media pages (a so-called snowball sampling technique). Prior to publication, the questionnaire was submitted to a small sample of subjects and evaluated by an expert panel for validation. According to data reported by the Portuguese Equestrian Federation, in 2021, there were 8076 registered practitioners, of which about 3500 were senior-level athletes (over 18 years of age). The questionnaire was available online for two and a half months (from 10 April to 29 June 2023) when the minimum number of valid responses was obtained (347), reaching approximately 10% of the senior-level equestrian athletes enrolled in the Portuguese Equestrian Federation. The sample size was calculated with a confidence level of 95%, a confidence interval (margin of error) of 5%, and assuming a 50% response distribution using Raosoft ® sample size calculator [20].

4.2.2. Questionnaire

The questionnaire comprised 50 questions divided into 7 sections, taking approximately 10 min to complete. The first section covered demographic data (age, sex, height, and weight), while the second delved into equestrian sports practices (years of practice, weekly practice hours, and federated discipline). The third section addressed other sporting activities and routines, while the fourth focused on injuries and lower back pain, based on the questionnaire priorly used on Italian equestrians [19]. Lower back pain was defined as pain, discomfort, or numbness in the lower back area, and an accompanying illustration was provided to aid participants. The fifth section queried pain experienced during daily equestrian practices, while the sixth explored related routines and characteristics. The seventh and final section contained the Roland Morris disability questionnaire [16'18]. This tool comprises a 24-item set that patients are asked to endorse (score 1) or leave blank (score 0), and results in a total score (Roland Morris disability score, RMDS) between 0 and 24, where higher values correspond to higher levels of pain-related disability [19]. A translation of the questionnaire is presented as **Supplementary Material 1**.

A threshold value of 4 was considered to classify patients with LBP as functional or dysfunctional, according to a previous study that considered this threshold to provide reasonable accuracy in distinguishing between lower back pain adult patients who met their functionality goals and those who did not [19]. Sections five and seven were exclusively presented to respondents who reported experiencing LBP in the past 12 months. For further analysis, the Body Mass Index (BMI) was calculated by dividing the person's weight, in kilograms, by their height, in meters squared; individual BMI was classified into the following categories: underweight, normal weight, overweight, and obese [21].

4.2.3. Statistical Analysis

Statistical treatment of data was performed using SPSS version 27.0 (IBM SPSS Statistics, Armonk, NY, USA) [22]. The normality of the distribution for each continuous variable (age, height, body mass, body mass index, RMDS) was examined using the Kolmogorov–Smirnov and Shapiro–Wilk normality tests. Variables revealed a non-normal distribution and hence, non-parametric tests (Mann–Whitney U, Kruskal–Wallis, Chi-square contingency coefficient) were used.

Regression models included univariate binary logistic models (to calculate unadjusted odds ratios for categorical variables, considering the presence or absence of LBP, and a Functional/Dysfunctional RMDS, as binary categorical outcomes), multivariate binary logistic models (to calculate adjusted odds ratios for categorical variables, considering the presence or absence of LBP, and a Functional/Dysfunctional

RMDS as binary categorical outcomes), and multivariable linear regression (to calculate regression coefficients for continuous variables, considering RMDS as the dependent variable). In the multivariable models, variables were screened for independence of observations (Durbin–Watson statistic), linear relationships (observation of partial regression plots), homoscedasticity, multicollinearity, and approximate normality of residual distribution, using the multiple regression procedures in SPSS.

Taking the former regression results into account, several Generalized Linear Models (GenLM) were computed, and adjustment to the data was compared using Akaike Information Criteria (AIC) values. The GenLM that best suited the data was a main effects model that included RMDS as the dependent variable, equestrianism as the main occupation (yes/no) and daily performance of stable duties (yes/no) as predictors, and age and BMI as continuous covariates, outperforming the null (intercept) model, according to an Omnibus test ($p = 0.002$). The model considered a Gamma distribution of RMDS, and the relationship between RMDS and the predictors and covariates via a Log link function. The raw values for the co-variates age and BMI were computed in the model. Estimated Marginal Means (EMMs) were adjusted for the average covariate values, as means for the reduction in the standard error due to a significant association between the covariates and the continuous dependent variable (RMDS).

4.3. Results

4.3.1. Demographics and Anthropometric Data

Of the 347 respondents, 40.1% were enrolled as show jumping riders, 22.8% as dressage riders, and 21.9% as general riders (including equestrians not involved in national competitions, rider instructors, and other officials). The remaining disciplines had minor representation within the sample. Female and male respondents represented 58.8% and 41.2%, respectively. Male respondents were older, taller, and heavier than females, and their BMI was higher, even though the average BMI fell in the normal weight category for both sexes (see **Supplementary Material S2—Table IV.8**).

In our sample, 21.3% of respondents were 35 years old or older. This proportion was 23.1% in those who considered equestrianism their main occupation, and 19.8% in those who did not, although the difference was non-significant ($p = 0.455$).

Overall anthropometric data, years of practice (means ± standard deviations) and sex (female/male) are presented in **Table IV.1**, as well as the results of a Mann–Whitney U test and a Chi-square test (for sex) that compared the group that stated that equestrianism was their main occupation with the group that stated it was not. No significant differences were found for anthropometric data, but years of equestrian practice were significantly higher (p = 0.004) in the group that stated their main occupation was equestrianism. Of the female respondents, 41.2% stated equestrianism was their main occupation, compared with 53.1% of the male respondents (p = 0.028).

Table IV.1. *Anthropometric data and years of practice (mean ± S.D.) and comparison of respondent status (main occupation: yes/no) (p-value for Mann–Whitney U test, and for Chi-square test for sex).*

	Total (n = 347)	Equestrianism as Main Occupation		p-Value
		Yes (n = 160)	No (n = 187)	
Age (years)	28.20 ± 11.13	28.36 ± 10.29	28.07 ± 11.83	0.498
Height (cm)	169.71 ± 8.93	170.46 ± 8.91	169.07 ± 8.91	0.052
Weight (kg)	66.94 ± 12.74	67.79 ± 12.15	66.20 ± 13.21	0.166
BMI (kg/m^2)	23.12 ± 3.28	23.23 ± 3.10	23.03 ± 3.44	0.461
Years of practice	16.92 ± 10.55	18.09 ± 9.68	15.91 ± 11.16	0.004
Sex (female/male)	204/143	84/76	120/67	0.028

4.3.2. Prevalence of Lower Back Pain in the Past 12 Months

The overall prevalence of lower back pain was 61.7% (95% confidence interval: 56.5–66.6%), with no significant differences between women and men (64.2% vs. 58.0%, p = 0.243). Prevalence in the group that stated equestrianism was their main occupation was not statistically different from the one presented in the group that did not (67.5% vs. 56.7%, p = 0.087). Among the main occupation equestrians, the prevalence of LBP showed no significant differences between women and men (67.9% vs. 67.1%, p = 0.914). The same was observed in the group of hobby equestrians (female prevalence: 61.7%, male prevalence: 47.8%, p = 0.066). A significant association between lower back pain and riding discipline could not be found (p = 0.590) (see **Supplementary Material S2—Table IV.9**).

4.3.3. Factors Associated with the Presence of Lower Back Pain in the Past 12 Months

The unadjusted odds ratio (OR) and 95% confidence intervals were calculated for each variable (**Table IV.2**). The occurrence of LBP in the past 12 months was associated with a higher weekly workload (p = 0.045), equestrianism as a primary occupation (p = 0.039), and daily involvement in stable duties (p = 0.029). There was no significant association between LBP in the past 12 months and the practice of other sports or performing warm-up exercises before riding.

Table IV.2. *Odds ratios for factors associated with LBP in the past 12 months.*

n = 347	Lower Back Pain in the Past 12 Months		Odds Ratio	95% Confidence Interval	*p*-Value
	Yes	No			
Female/male	131/83	73/60	1.297	0.837–2.011	0.245
Rides 7 h or more per week/up to 6 h per week	105/109	50/83	1.599	1.028–2.487	0.045
Main occupation/hobby	108/106	52/81	1.587	1.023–2.463	0.039
Daily stable duties (yes/no)	141/73	72/61	1.636	1.051–2.548	0.029
Other sports (yes/no)	114/100	80/53	0.755	0.487–1.171	0.210
Warm-up before riding (yes/no)	40/174	17/116	1.569	0.849–2.899	0.151

Note: The reference category for each variable is underlined.

A binary logistic regression model correctly predicted 63.1% of the LBP outcomes and presented a significant Omnibus test result (p = 0.024). Adjusted ORs were non-significant for all variables (see **Supplementary Material S2—Table IV.10**).

As expected, the rate of individuals who rode 7 or more hours per week and who per-formed daily stable duties was higher in the group that considered equestrianism as the main occupation compared with the group that considered it a hobby (see **Supplementary Material S2—Table IV.11**). The results of the Mann–Whitney U tests showed no significant differences between groups with and without LBP in the past 12 months regarding age, BMI, and years of equestrian practice (see **Supplementary Material—Table IV.12**).

4.3.4. Factors Associated with the Roland Morris Disability Score (RMDS) in Individuals Who Experienced LBP in the Past 12 Months

From the 214 respondents (61.7%) who stated having felt LBP in the past 12 months and responded to the Roland Morris disability questionnaire, an RMDS of 5.39 ± 4.42 was calculated (mean ± standard deviation).

Mann–Whitney U tests and Kruskal–Wallis tests found no significant differences in RMDS due to sex (p = 0.304), age class (p = 0.309), or BMI category (p = 0.065) but found a significant difference in RMDS between riders that stated equestrianism was their main occupation and those that did not (means ± standard deviations: 6.10 ± 4.74 vs. 4.67 ± 3.97, p = 0.017). Within these respondents, 135 (63.1%) considered that LBP impaired their performance, 91 (42.5%) felt that LBP was aggravated while riding, and 58 (27.1%) and 56 (26.2%) felt that LBP was aggravated while cleaning/grooming and lunging horses, respectively, and 118 (55.1%) felt that LBP as aggravated while "mucking out" (removing manure and dirty bedding from horse stalls).

The multiple linear regression model for RMDS was statistically significant (p = 0.016) (**Table IV.3**), with higher BMI being associated with higher RMDS. The association among RMDS, age, and years of practice was non-significant.

Table IV.3. *Multiple linear regression analysis for RMDS.*

	B (SE)	Beta	t	*p*-Value
Age	0.058 (0.047)	0.134	1.235	0.218
BMI	0.204 (0.097)	0.149	2.112	0.036
Years of practice	−0.003 (0.049)	−0.007	−0.066	0.948

Note: B: unstandardized regression coefficient. SE: standard error.

The unadjusted odds ratio and 95% confidence intervals were calculated for each variable (**Table IV.4**). There was no association between a Dysfunctional score and sex, weekly riding load, daily stable duties, the practice of other sports, and warm-up exercise before riding. Nonetheless, individuals who stated that equestrianism was their main occupation showed a significantly higher risk (OR = 1.759) of an RMDS ≥ 4 (Dysfunctional) than those who did not.

Table IV.4. *Odds ratio for factors associated with Dysfunctional/Functional RMDS.*

n = 214	Roland Morris Disability Score (RMDS)		Odds Ratio	95% Confidence Interval	*p*-Value
	Dysfunctional (RMDS > 4)	Functional (RMDS ≤ 4)			
Female/Male	60/46	71/37	0.6797	0.3911–1.1.181	0.171
Rides 7 h or more per week/up to 6 h per week	56/50	49/59	1.349	0.788–2.309	0.276
Main occupation/hobby	61/45	47/61	1.759	1.024–3.023	0.041
Daily stable duties (yes/no)	76/30	65/43	1.676	0.946–2.969	0.077
Other sports (yes/no)	54/52	60/48	0.831	0.485–1.422	0.499
Warm-up before riding (yes/no)	20/86	20/88	1.023	0.515–2.035	0.948

Note: Reference category for each variable is underlined.

A binary logistic regression model correctly predicted only 58.4% of the Dysfunction-al/Functional RMDS outcomes and presented a non-significant Omnibus test result (p = 0.297). However, a similar model applied separately to equestrians in the main occupation and the hobby groups revealed different results in both groups. In the main occupation group, the model presented a non-significant Omnibus test result (p = 0.296), while in the hobby group, the same test presented a significant result (p = 0.018), and the model correctly predicted 65.1% of the outcomes. The adjusted OR for daily grooming duties was 4.335 (p = 0.001), while p-values for the remaining variables were non-significant (see **Supplementary Material S2—Table IV.13**).

The results of Mann–Whitney U tests showed no significant differences between Dysfunctional and Functional score groups for BMI (p = 0.075) and years of equestrian practice (p = 0.241). However, it showed significant differences in the age of both groups (average age of 28.88 years in the Dysfunctional score group vs. 25.54 years in the Functional score group, p = 0.022).

The effect tests of a Generalized Linear Model are summarized in **Table IV.5**, showing significant effects for performing daily stable duties (p = 0.030) and for the age (p = 0.029) and BMI (p = 0.047) covariates. The estimated marginal means (EMMs) for RMDS, with age and BMI fixed at mean values (27.19 years and 23.00, respectively) are shown in **Table IV.6**, revealing higher RMDS values for equestrianism as the main occupation and for daily per-forming of stable duties.

Table IV.5. *Parameter estimates for the GenLM main effects model.*

Parameter	B (SE)	95% Wald Confidence Interval	Wald Chi-Square	df	*p*-Value
Intercept	0.583 (0.401)	−0.203–1.369	2.116	1	0.146
Equestrianism as main occupation (yes/no)	−0.146 (0.102)	−0.347–0.054	2.044	1	0.153
Daily stable duties (yes/no)	0.249 (0.115)	0.025–0.474	4.728	1	0.030
Age	0.011 (0.005)	0.001–0.021	4.761	1	0.029
BMI	0.032 (0.016)	<0.001–0.063	3.930	1	0.047

Note: B: unstandardized regression coefficient. SE: standard error. df: degrees of freedom.

Table IV.6. *Estimated marginal means (EMMs) for the Roland Morris disability score (RMDS), with age fixed at 27.19 years and BMI fixed at 23.00.*

Predictor	Groups	EMM for RMDS	95% Confidence Interval
	Overall estimated mean (*n* = 214)	5.31	4.78–5.90
Equestrianism as main occupation	Yes (*n* = 108)	5.71	4.93–6.63
	No (*n* = 106)	4.93	4.28–5.69
Daily stable duties	Yes (*n* = 141)	6.01	5.32–6.80
	No (*n* = 73)	4.69	3.92–5.61

4.4. Discussion

4.4.1. Demographics and Anthropometrical Data

In this study, the distribution of female and male equestrian athletes (58.8% and 41.2%, respectively) was apparently more balanced than in similar studies in other countries [5'9'23]. Based on the last available report of the Portuguese Equestrian Federation [24], even though there is an overall predominance of female athletes (67.3%), there is a tendency for a reduced difference between sexes in the senior categories (riders over 20 years of age, with female athletes representing 53.7%). Our sample only included equestrians who were 18 years old or older, and this probably accounts for the balanced distribution between male and female respondents. Nevertheless, a significantly higher proportion of men considered equestrianism as their main activity.

Accordingly, reported data [24] show that 17.2% of Portuguese equestrian athletes are 36 years old or older, while 21.3% of respondents were 35 or older in our sample. This percentage rose to 23.1% in riders who considered equestrianism their main occupation. The average age of respondents was 28.20 ± 11.13 years, but the average number of years of equestrian practice was 16.92 ± 10.55, thus pointing to an early start in equestrian practice. Athletes in disciplines that engage skill (such as equestrian sports, sailing, and shooting) have longer lifespans compared with other athletes, particularly those involved in power disciplines (like boxing, weightlifting, and wrestling) [25]. Previous studies have shown that the equestrian sport does not fit a traditional Long Term Athlete Development (LTAD) model, best adapting to an “early start–late specialization” paradigm and characteristic longevity of the competitive career, even at the elite level competitions [26]. Competitive and general longevity of equestrian careers simultaneously potentiate the development of skills and expertise, but they represent an additional risk for progressive spine degeneration, resulting from repetitive trauma and physical stress on the spine [27].

Apart from the general need to avoid excessive weight because of health concerns and physical performance, equestrian athletes feel additional pressure to maintain a controlled weight because of the following two different factors: the impact of a larger body frame on equestrian performance, namely, in disciplines that convey an aesthetical, subjective judgment, such as Dressage [28], and issues associated with their equine counterpart’s welfare and performance [29]. These issues can probably contribute to justifying that, despite their expanded age span (18 to 72 years old) and the fact that to nearly half of the respondents, equestrianism was not their primary occupation, most respondents (74.1%) corresponded to normal weight or underweight categories.

4.4.2. Prevalence of Lower Back Pain in the Past 12 Months and Associated Factors

Lower back pain is highly prevalent and the leading cause of life-long disability in the adult population [13]. The previously reported prevalence of LBP in the global adult population ranged from 1.4 to 20.0% [30] with a 12-month prevalence of 38% [31]. However, the reported prevalence of LBP in athletes is higher, with a mean point prevalence of 42%, ranging from 18% to 80%, and rising to 51% when a 12-month prevalence is considered [32]. The reported values of the 12-month prevalence of LBP in equestrian athletes range from 88% to 100% [32], indicating a strong association between LBP and this sport. In this study, a 12-month prevalence of 61.7% was estimated. This value was considerably lower than those reported in previous studies [9,32], which may partially reflect the fact that half of the respondents stated that equestrianism was not their main occupation (non-professionals). In professional respondents, LBP prevalence rose to 67.5%. In this study, a significant association between LBP and riding discipline could not be found, a result consistent with some previous studies [33,34], even though a cross-sectional study in the Italian equestrian athlete population reported a higher prevalence in show jumping athletes when compared with athletes in other equestrian disciplines [9].

In the global population, risk factors for lower back pain include comorbid health conditions, increasing age, as well as obesity, smoking, lack of exercise, and other lifestyle factors [13]. In athletes, strong evidence for higher body weight and moderate evidence for high BMI as risk factors of LBP have been reported, as well as insufficient evidence to indicate age and sex as risk factors [35]. Other authors refer to a history of a previous episode of LBP, high training volumes, periods of load increase, and years of exposure to the sport as risk factors [32]. In this study, we found no significant association between sex, practicing other sports, or warming up before riding and the occurrence of LBP. Previous studies have also found no connection among sex [1,9,33], practicing other physical activity [9], and LBP in equestrians, even though other authors [5,11] have established that participating in other sporting activities and physical fitness can help equestrian athletes to prevent spinal injury. Age, BMI, and years of equestrian practice were not significantly different between groups with and without LBP in the past 12 months. Regarding the age of equestrians, previous studies report contradictory results, from a higher risk in younger ages [9] to a higher frequency of LBP in older riders [5]. Other authors also failed to find a connection between BMI [8,9,34], length of previous riding experience [8,9], and occurrence of LBP in equestrians.

On the other hand, the probability of suffering from LBP was higher when the weekly riding workload was 7 h or more, when equestrianism was the respondents' main occupation, and when they performed daily stable duties. These results seem to point to an association between the workload and parallel chores involved in professional equestrian life and 12-month LBP prevalence, in line with the results found in previous studies that reported a weekly riding period greater than 5–6 h [9] and riding professionally [1] as risk factors for LBP in equestrian athletes. Stable duties like "mucking out", "preparing the bedding", and sweeping involve a bent and twisted back position most of the time, creating harmful stress loads of the posture [36] and contributing to an increased risk of musculoskeletal problems [37]. In previous studies, riders stated that stable duties were responsible for their pain [5]. To the authors' knowledge, there is only one study regarding the injury of equestrians in Portugal. Although that study comprised all injuries, and not exclusively LBP, it reported a significant association between the occurrence of injury and the number of days of training per week, years of experience, height and weight of the rider, and practice of another sport [38].

4.4.3. Roland Morris Disability Score and Associated Factors

To our knowledge, no previous studies have specifically investigated RMDS in equestrian athletes, thus limiting the comparability of the results in this study and suggesting caution in their interpretation. Nonetheless, lower average RMDS have been reported in elite athletes from different sports, in individuals with apparently similar characteristics [39]. The RMDS was previously used to evaluate long-term functional results of equestrians who suffered spinal fractures [40], which reported an average score of 5.5 and a significant correlation between occupational disability and RMDS. In this study, the RMDS of respondents who stated equestrianism as their main occupation was significantly higher than that of those who considered it a hobby.

The results of the GenLM point to a significant effect of age ($p = 0.029$), BMI ($p = 0.047$), and daily performance of stable duties ($p = 0.030$) on the RMDS. As previously discussed, in athletes in general, there is insufficient evidence indicating that age is a risk factor for LBP [35], and some authors reported high training volumes and years of exposure to the sport as risk factors [32]. Our results, on the other hand, point to a significant effect of age but found no significant effects of the latter variables. We suggest that the longer lifespan of equestrians, when compared with other athletes, may have played a part in these results. The importance of BMI as a predictor for LBP has been previously reported in the general population [41'42], and our results suggest that appropriate BMI management is probably important in reducing LBP prevalence in equestrian athletes. As for the effect of performing daily stable duties, our results point to this being a frequent activity for Portuguese equestrians (61.4% of respond-ents), and even more so for those who considered equestrianism as their main occupation (73.1%). We also reported that within the group that considered equestrianism a hobby, the risk of an RMDS > 4 (dysfunctional) was more than 4-fold greater when daily stable duties were performed. In future works, it would be useful to introduce a measure of the physical fitness of respondents to further investigate risk factors for reduced functionality in equestrians.

Validation of an RMDS of 4 as a threshold in discriminating functionality in athletes and equestrians is advisable, as functionality goals in these populations are probably very different from those regarding LBP patients in the general population. It should also be noted that the average RMDS in the respondents experiencing LBP in the past 12 months was higher than this threshold, pointing to a relevant impact of LBP on the respondents' quality of life, ability to perform their occupational duties, and competitive performance. Considering the sportive longevity of equestrian athletes [24], it would be beneficial to conduct further research regarding the causes of LBP, as well as strategies that could help its prevention or mitigation, such as specially designed training programs, as the benefits of specific exercise in preventing and improving LBP in athletes have been established in other sports [43].

4.5. Limitations of This Study

Although the questionnaire in this study was validated prior to its publication, it was not properly validated for the population in question. The fact that it was conducted online, with no additional contact with respondents, and no measure of motivations for response, raises the possibility of some bias in the responses. Regarding the Roland Morris disability questionnaire, previous work suggests there is no difference in scores retrieved in online and paper-based responses [44]. However, the only published results found by the authors that used RMDS as a measure of the functional outcome in equestrians [40] concerned patients who suffered spinal fractures, and hence were otherwise clinically followed up, allowing for additional validation. Another limitation is the use of the cut-off value of 4 as a measure of the functional impairment of the respondents since this threshold was established in a population of adult LBP patients undergoing physiotherapy. The authors acknowledged the need for cross-validation of this estimate and evaluation of the stability in the estimated value in people with diverse functional demands [19]. These limitations suggest that the obtained results should be interpreted with caution. In addition, the reported associations cannot be considered causations.

4.6. Conclusions

For the first time, this study presents the prevalence of lower back pain (LBP) in an apparently representative sample of Portuguese equestrian athletes. A 12-month prevalence of 61.7% was estimated. The probability of suffering from LBP was higher in individuals with higher weekly riding workloads, who reported equestrianism as their main occupation, and who performed daily stable duties. To measure the impact of LBP on the daily functioning of equestrian athletes, we used the Roland Morris disability questionnaire and calculated an average score of 5.39 ± 4.42 (mean ± standard deviation). Among the riders who experienced LBP in the past 12 months, 63.1% considered that it impaired their performance, 42.5% felt that LBP was aggravated while riding, and 55.1% felt that LBP was aggravated while removing manure and bedding from horse stalls. Significant associations among RMDS, age, BMI and the daily performance of stable duties were found. Estimated marginal means, controlling for age and BMI, showed higher scores in equestrians who were involved in daily stable duties. Further investigation should be conducted on the pain assessment of LBP in equestrian athletes and its effects on functionality.

4.7. Paper back matter

4.7.1. Supplementary Materials/ Appendixes

The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Supplementary material 1 – Questionnaire; Supplementary material 2: Table IV.8: Demographic and anthropometric data of respondents, according to sex; Table IV.9: Distribution of respondents that reported feeling Lower Back Pain in the last 12 months according to the equestrian discipline Pearson's Chi-square and p-value; Table IV.10: Binary logistic regression model for 12-month Lower Back Pain (variables in the equation); Table IV.11: Odds ratio for rider status (main occupation vs. hobby), weekly riding workload and daily stable duties; Table IV.12: Age, BMI and years of equestrian practice – comparison of groups with, and without Lower Back Pain in the last 12 months (p-value for Mann-Whitney U test); Table IV.13: Binary logistic regression model for Dysfunctional RMDS according to rider status (main occupation vs. hobby) (variables in the equation).

4.7.2. Author Contributions

Conceptualization, C.D., O.F., and A.R, methodology, A.R, software, O.F. and R.S, validation, O.F. and A.R, formal analysis, R.S, investigation, C.D, resources, O.F. and A.R, data curation, C.D. and A.R, writing—original draft preparation, C.D. and R.S, writing—review and editing, O.F. and A.R, visualization, C.D, supervision, A.R., O.F., and R.S, project administration, A.R, funding acquisition, R.S. All authors have read and agreed to the published version of the manuscript.

4.7.3. Funding

The APC was funded by FCT—Fundação para a Ciência e a Tecnologia, grant number UIDB/05064/2020.

4.7.4. Institutional Review Board Statement

This study was conducted as part of Carlota Duarte's PhD thesis on Human Motricity, and the questionnaire was previously approved by the Ethics Committee of the University of Évora. The anonymity of respondents was assured by both the collecting method and the content of the questionnaire.

4.7.5. Informed Consent Statement

Informed consent was obtained from all subjects involved in this study.

4.7.6. Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors upon request.

4.7.7. Acknowledgements

The authors would like to thank the riders who voluntarily agreed to respond to the questionnaire, as well as the Portuguese Equestrian Federation for their contribution to the dissemination of the questionnaire.

4.7.8. Conflicts of Interest

The authors declare no conflicts of interest. The funders had no role in the design of this study; in the collection, analyses, or interpretation of data; in the writing of this manuscript; or in the decision to publish the results.

4.8. References

1. Deckers, I, De Bruyne, C, Roussel, N.A, Truijen, S, Minguet, P, Lewis, V, Wilkins, C, Van Breda, E. Assessing the sport-specific and functional characteristics of back pain in horse riders. Comp. Exerc. Physiol. 2021, 17, 7–15. https://doi.org/10.3920/CEP190075.

2. Williams, J. Performance analysis in equestrian sport. Comp. Exerc. Physiol. 2013, 9, 67–77. https://doi.org/10.3920/CEP13003.

3. Wolframm, I.A. Motor Control of the Rider: On moving and being moved. In The Science of Equestrian Sports: Theory, Practice and Performance of the Equestrian Rider, 1st ed, Routledge: Milton Park, Abingdon, Oxon, UK, 2014; pp. 7–14.

4. Pugh, T.J, Bolin, D. Overuse injuries in equestrian athletes. Curr. Sports Med. Rep. 2004, 3, 297–303. https://doi.org/10.1007/s11932-996-0003-6.

5. Lewis, V, Nicol, Z, Dumbell, L, Cameron, L. A Study Investigating Prevalence of Pain in Horse Riders over Thirty-Five Years Old: Pain in UK Riders Over 35 Years Old. Int. J. Equine Sci. 2023, 2, 9–18. Available online: https://rasayely-journals.com/index.php/ijes/article/view/63 (accessed on 13 July 2023).

6. Lewis, V, Douglas, J.L, Edwards, T, Dumbell, L. A preliminary study investigating functional movement screen test scores in female collegiate age horse-riders. Comp. Exerc. Physiol. 2019, 15, 105–112. https://doi.org/10.3920/CEP180036.

7. Lewis, V, Kennerley, R. A preliminary study to investigate the prevalence of pain in elite dressage riders during competition in the United Kingdom. Comp. Exerc. Physiol. 2017, 13, 259–263. https://doi.org/10.3920/CEP170016.

8. Cejudo, A, Ginés-Díaz, A, Rodríguez-Ferrán, O, Santonja-Medina, F, Sainz De Baranda, P. Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Lower back pain in Child Equestrian Athletes. Children 2020, 7, 172. https://doi.org/10.3390/children7100172.

9. Ferrante, M, Bonetti, F, Quattrini, F.M, Mezzetti, M, Demarie, S. Lower back pain and Associated Factors among Italian Equestrian Athletes: A Cross-Sectional Study. Muscle Ligaments Tendons J. 2021, 11, 344. https://doi.org/10.32098/mltj.02.2021.19.

10. Cejudo, A, Ginés-Días, A, Sainz De Baranda, P. Asymmetry and Tightness of Lower Limb Muscles in Equestrian Athletes: Are They Predictors for Back Pain? Symmetry 2020, 12, 1679. https://doi.org/10.3390/sym12101679.

11. González, M.E, Sarabon, N. Shock Attenuation and Electromyographic Activity of Advanced and Novice Equestrian Riders' Trunk. Appl. Sci. 2021, 11, 2304. https://doi.org/10.3390/app11052304.

12. Pilato, M, Henry, T, Malavase, D. Injury History in the Collegiate Equestrian Athlete: Part I: Mechanism of Injury, Demographic Data and Spinal Injury». J. Sports Med. Allied Health Sci. Off. J. Ohio Athl. Train. Assoc. 2017, 2, 3. https://doi.org/10.25035/jsmahs.02.03.03.

13. Ferreira, M.L, De Luca, K, Haile, L.M, Steinmetz, J.D, Culbreth, G.T, Cross, M, Kopec, J.A, Ferreira, P.H, Blyth, F.M, Buchbinder, R, et al. Global, Regional, and National Burden of Lower back pain, 1990–2020, Its Attributable Risk Factors, and Projections to 2050: A Systematic Analysis of the Global Burden of Disease Study 2021. Lancet Rheumatol. 2023, 5, e316–29. https://doi.org/10.1016/S2665-9913(23)00098-X.

14. Quinn, S, Bird, S. Influence of Saddle Type upon the Incidence of Lower Back Pain in Equestrian Riders. Br. J. Sports Med. 1996, 30, 140–144. https://doi.org/10.1136/bjsm.30.2.140.

15. Kopec, J.A. Measuring Functional Outcomes in Persons With Back Pain: A Review of Back-Specific Questionnaires. Spine 2000, 25, 3110–3114. https://doi.org/10.1097/00007632-200012150-00005.

16. Roland, M, Morris, R. A Study of the Natural History of Back Pain: Part I. Spine 1983, 2, 141–144. https://doi.org/10.1097/00007632-198303000-00004.

17. Burbridge, C, Randall, J.A, Abraham, L, Bush, E.N. Measuring the Impact of Chronic Lower back pain on Everyday Functioning: Content Validity of the Roland Morris Disability Questionnaire. J. Patient-Rep. Outcomes 2020, 4, 70. https://doi.org/10.1186/s41687-020-00234-5.

18. Monteiro, J, Faísca, L, Nunes, O, Hipólito, J. Roland Morris disability questionnaire-adaptation and validation for the Portuguese speaking patients with back pain. Acta Med. Port 2010, 23, 761–766. Available online: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/728 (accessed on 26 August 2023).

19. Stratford, P.W, Riddle, D.L. A Roland Morris Disability Questionnaire Target Value to Distinguish between Functional and Dysfunctional States in People with Lower back pain. Physiother. Can. 2016, 68, 29–35. https://doi.org/10.3138/ptc.2014-85.

20. Raosoft Inc. Raosoft Sample Size Calculator. 2004. Available online: http://www.raosoft.com/samplesize.html (accessed on 28 April 2024).

21. Nuttall, F.Q. Body Mass Index: Obesity, BMI, and Health: A Critical Review. Nutr. Today 2015, 50, 117–128. https://doi.org/10.1097/NT.0000000000000092.

22. IBM Corp. IBM SPSS Statistics for Windows (Version 27.0) [Computer software]; IBM Corp: Armonk, NY, USA, 2020.

23. Meyer, H.-L, Scheidgen, P, Polan, C, Beck, P, Mester, B, Kauther, M.D, Dudda, M, Burggraf, M. Injuries and Overuse Injuries in Show Jumping—A Retrospective Epidemiological Cross-Sectional Study of Show Jumpers in Germany. Int. J. Environ. Res. Public Health 2022, 19, 2305. https://doi.org/10.3390/ijerph19042305.

24. Federação Equestre Portuguesa, Relatório e Contas. 2022. Available online: https://www.fep.pt/LinkClick.aspx?fileticket=Uqa-1flrOPE%3d&tabid=85&portalid=0&mid=1188 (accessed on 28 April 2024).

25. Kovbasiuk, A, Ciechanowski, L, Jemielniak, D. A Taste of Ambrosia: Do Olympic Medalists Live Longer than Olympic Losers? Scand. J. Public Health 2024, 0(0), 1-7. https://doi.org/10.1177/14034948231219833.

26. Dumbell, L.C, Rowe, L, Douglas, J.L. Demographic Profiling of British Olympic Equestrian Athletes in the Twenty-First Century. Sport Soc. 2018, 21, 1337–1350. https://doi.org/10.1080/17430437.2017.1388786.

27. Tsirikos, A, Papagelopoulos, P.J, Giannakopoulos, P.N, Boscainos, P.J, Zoubos, A.B, Kasseta, M, Nikiforidis, P.A, Korres, D.S. Degenerative Spondyloarthropathy of the Cervical and Lumbar Spine in Jockeys. Orthopedics 2001, 24, 561–564. https://doi.org/10.3928/0147-7447-20010601-12.

28. Forino, S, Cameron, L, Stones, N, Freeman, M. Potential Impacts of Body Image Perception in Female Equestrians. J. Equine Vet. Sci. 2021, 107, 103776. https://doi.org/10.1016/j.jevs.2021.103776.

29. Challinor, C.L, Randle, H, Williams, J.M. Understanding rider:horse bodyweight ratio trends, weight management practices and rider weight perceptions within

leisure and amateur riders in the UK. Comp. Exerc. Physiol. 2021, 17, 403–420. https://doi.org/10.3920/CEP200082.

30. Fatoye, F, Gebrye, T, Odeyemi, I. Real-World Incidence and Prevalence of Lower back pain Using Routinely Collected Data. Rheu-matol. Int. 2019, 39, 619–626. https://doi.org/10.1007/s00296-019-04273-0.

31. Manchikanti, L, Singh, V, Falco, F.J.E, Benyamin, R.M, Hirsch, J.A. Epidemiology of Lower back pain in Adults. Neuromodulation: Technol. Neural Interface 2014, 17, 3–10. https://doi.org/10.1111/ner.12018.

32. Wilson, F, Ardern, C.L, Hartvigsen, J, Dane, K, Trompeter, K, Trease, L, Vinther, A, Gissane, C, McDonnell, S.J, Caneiro, J.P, et al. Prevalence and Risk Factors for Back Pain in Sports: A Systematic Review with Meta-Analysis. Br. J. Sports Med. 2021, 55, 601–607. https://doi.org/10.1136/bjsports-2020-102537.

33. Kraft, C, Urban, N, Ilg, A, Wallny, T, Scharfstädt, A, Jäger, M, Pennekamp, P. Einfluss der Reitdisziplin und -intensität auf die Inzidenz von Rückenschmerzen bei Reitsportlern. Sportverletz. Sportschaden 2007, 21, 29–33. https://doi.org/10.1055/s-2007-963038.

34. Kraft, C.N, Pennekamp, P.H, Becker, U, Young, M, Diedrich, O, Lüring, C, Von Falkenhausen, M. Magnetic Resonance Imaging Findings of the Lumbar Spine in Elite Horseback Riders: Correlations With Back Pain, Body Mass Index, Trunk/Leg-Length Coefficient, and Riding Discipline. Am. J. Sports Med. 2009, 37, 2205–2213. https://doi.org/10.1177/0363546509336927.

35. Moradi, V, Memari, A.-H, ShayestehFar, M, Kordi, R. Lower back pain in Athletes Is Associated with General and Sport Specific Risk Factors: A Comprehensive Review of Longitudinal Studies. Rehabil. Res. Pract. 2015, 2015, 850184. https://doi.org/10.1155/2015/850184.

36. Löfqvist, L, Pinzke, S. Working with Horses: An OWAS Work Task Analysis. J. Agric. Saf. Health 2011, 17, 3–14. https://doi.org/10.13031/2013.36230.

37. Löfqvist, L, Osvalder, A.-L, Bligård, L.-A, Pinzke, S. An analytical ergonomic risk evaluation of body postures during daily cleaning tasks in horse stables. Pedro Arezes (Editor). Work 2015, 51, 667–682. https://doi.org/10.3233/WOR-152022.

38. Pinto, L.V, Gouveia, F.C, Ramalho, J.F, Silva, S.R, Silva, J.R. Horseback Riding-Related Injuries in Portugal and Prevention Strate-gies. J. Sport Rehabil. 2023, 32, 409–414. https://doi.org/10.1123/jsr.2022-0101.

39. Noormohammadpour, P, Khezri, A.H, Farahbakhsh, F, Mansournia, M.A, Smuck, M, Kordi, R. Reliability and Validity of Athletes Disability Index Questionnaire. Clin. J. Sport Med. 2018, 28, 159–167. https://doi.org/10.1097/JSM.0000000000000414.

40. Siebenga, J, Segers, M.J, Elzinga, M.J, Bakker, F.C, Haarman, H.J, Patka, P. Spine fractures caused by horse riding. Eur. Spine J. 2006, 15, 465–471. https://doi.org/10.1007/s00586-005-1012-5.

41. Stienen, M.N, Joswig, H, Smoll, N.R, Corniola, M.V, Schaller, K, Hildebrandt, G, Gautschi, O.P. Influence of Body Mass Index on Subjective and Objective Measures of Pain, Functional Impairment, and Health-Related Quality of Life in Lumbar Degenerative Disc Disease. World Neurosurg. 2016, 96, 570–577.e1. https://doi.org/10.1016/j.wneu.2016.09.070.

42. Teck, T.S, Prabowo, T, Kurniani, N. Correlation between Body Mass Index and Disability in Patient with Chronic Lower back pain. Althea Med. J. 2016, 3, 624–628. https://doi.org/10.15850/amj.v3n4.949.

43. Alizadeh, M.H, Jafari, B, Amiri, M.R. The Effect of Prevention and Management Protocols on Lower back pain in Athletes—A systematic review. Phys. Treat. 2022, 12, 233–248. https://doi.org/10.32598/ptj.12.4.537.1.

44. Bishop, F.L, Lewis, G, Harris, S, McKay, N, Prentice, P, Thiel, H, Lewith, G.T. A within-subjects trial to test the equivalence of online and paper outcome measures: The Roland Morris disability questionnaire. BMC Musculoskelet. Disord. 2010, 11, 113. https://doi.org/10.1186/1471-2474-11-113.

Chapter V

Paper 3 - Effects of a 12-week specific training program on lower back pain symptoms in equestrian athletes

Chapter V

Paper 3 - Effects of a 12-week specific training program on lower back pain symptoms in equestrian athletes

Abstract

This intervention study evaluates the effects of a twelve-week specific training program (STP) on lower back pain (LBP) symptoms among equestrian athletes. The study included 52 participants divided into an experimental group (N=28) and a control group (N=24), all of whom experienced non-specific LBP within the past year. The STP aimed to reduce LBP intensity and disability while improving functional movements. Data were collected at baseline and after 12 weeks, utilizing the body composition variables, Roland Morris Disability Questionnaire, functional movement screening tests, and a tailored pain questionnaire for equestrians. Results indicate that the STP resulted in significant reductions in pain intensity, disability scores, pain perceptions in equestrian related activities, and improvements in functional movement scores. These findings suggest that the STP effectively alleviates LBP symptoms and enhances functional performance among equestrian athletes, emphasizing the importance of structured exercise interventions in managing pain. Furthermore, the results highlight the need for further research to explore the long-term benefits and potential adaptations of such programs to optimize outcomes for this population.

Keywords

Back pain; Disability; Exercise; Horse riding; Intervention; Lumbago; Sports.

5.1. Introduction

Many equestrian athletes find themselves enduring persistent discomfort and pain as they ride, compete, and go about their daily lives, with the lower back emerging as the most frequently reported site of pain complaints.[1-5] The prevalence of this pain in the lower back is higher among equestrian athletes [6-8] compared to their counterparts in other sports [9'10] and is significantly higher than in the general population.[11] The high incidence of lower back pain (LBP) in equestrian athletes can be attributed to the unique demands of the sport, which subjects the lumbopelvic-hip complex to repetitive compressive mechanical forces.[6'12'13] This constant strain, inherent to the training regimen, places significant stress on the musculoskeletal system, often resulting in muscle tightness.[13'14] Contributing risk factors for LBP in equestrian athletes include the specific physical demands of the sport, the athlete's level of expertise, the impact of acute trauma and inadequate recovery [15], asymmetric posture [13'14], insufficient postural control [16], as well as issues related to balance, stability, and pelvic alignment.[14'16]

LBP can have profound and multifaceted consequences for equestrian athletes. These athletes experiencing pain, whether general or localized in the lower back, often face limitations in their performance while riding and competing. [2-7] The financial burden of treatment, coupled with a decreased quality of life and functional impairment, further compound this issue.[10'17] Moreover, LBP may affect crucial aspects of riding, including balance, coordination and overall effectiveness. Riders suffering from LBP can be at a heightened risk of falling off the horse due to decreased ability to synchronize with their equine partner.[3'16] Despite these challenges, the pressure from sponsors and the competitive nature of the sport often drive athletes to persist in their training and competitions, potentially exacerbating their injuries.[3]

Although the world anti-doping agency is an organization that strives to promote and achieve clean sport [3], it is known that athletes, including equestrians, commonly tend to self-manage pain by using over-the-counter pain medications [2-5'18] particularly nonsteroidal anti-inflammatory drugs which possess both anti-inflammatory and analgesic properties.[19] The extensive use of these drugs raises practical, ethical and safety concerns [20], particularly, in equestrian sports that are known for being inherently hazardous [3] and require equestrians to be highly alert and prepared. The misuse of some pharmacological drugs that can delay time-response, affect balance among other adverse effects [21] can put equestrians at an eminent risk of serious injury.

Compared with other sports, the career of equestrian athletes can be very long [7], equestrianism is categorized as an “early start-late specialization” sport.[22] It is known that previous episodes of LBP are consistent predictors of future episodes.[10] Therefore, it is important to address prevention and treatment rather than using short-term strategies or pain masking agents. Additionally, managing pain in athletes must consider its protective role in the presence of injury.[18] Guidelines for treatment of acute, subacute and chronic low back pain have suggested that clinicians and patients should select non-pharmacological therapies like exercise.[21] These therapies can be effective for secondary prevention of LBP by reducing both its intensity and the likelihood of recurrence;

additionally, they may help prevent the initial onset of LBP in individuals who have not previously experienced it.[23]

It is known that exercise programs generally reduce pain and improve function in athletes with LBP.[24] Previous research of specific training programs for equestrians has focused on improving rider performance on the horse.[25'26] Other studies evaluated the effectiveness of training programs in low back complaints in equestrians achieving positive results, although, methodologies, sample sizes and assessments different from those in the present study.[27-29]

The primary objective was to evaluate the effectiveness of a twelve-week specific training program (STP) in reducing LBP intensity, disability, as well as in improving functional movements in a broad sample of equestrian athletes.

5.1.1. Study design

Quasi-experimental study.

5.2. Materials and methods

5.2.1. Participants

Ethical approval was obtained for this project from the University of Évora with the approval number GD/29678/2022. All participants signed a written informed consent prior to the beginning of the study.

Fifty-six equestrian athletes participated in the study (26 female and 30 male, age range 18-54). Forty-five participants were recruited from various equestrian institutions: the Alter Real Stud, the Portuguese Dressage Academy, the Polytechnic Institute of Portalegre (Elvas Higher School of Biosciences), and the Mafra School of Arms (Portuguese Army). The remaining participants were recruited through personal contacts and Portuguese riding schools. To be eligible for the study, participants had to be between 18 and 60 years old, have experienced at least one episode of non-specific lower back pain - defined as pain or discomfort in the lower back - within the last 12 months, and have been practicing equestrian sports for at least one hour per week over the past year. The participants were divided into two groups: an experimental group (N=28, 14 female and 14 male) and a control group (N=28, 12 female and 16 male). This division was based on the participants' availability to engage in the training program. Four participants in the control group were lost to follow-up: two due to career changes, one due to failure in assessment data collection, and one due to a traumatic injury sustained during the study period. Participants' anthropometric characteristics and their involvement in equestrian sports are detailed in results - **Table V.2**.

5.2.2. Assessments and procedures

All assessments and testing procedures for each participant were conducted on the same day, ensuring that everyone completed all tests within a single session. However, the overall data collection process was made twice and took place over a period from January to February – first assessment – and April to May - second assessment. All assessments in the present study were conducted by a single examiner, who was specifically trained and certified by experts in the field. This examiner possessed specialized knowledge and skills relevant to the assessments performed, ensuring consistency and reliability in the evaluation process across all participants. By maintaining a single, specialized examiner, the study minimized variability in measurement, enhancing the accuracy of outcome comparisons pre- and post-intervention.

5.2.2.1. Questionnaire

Participants were asked to respond to a questionnaire consisting of 22 questions, divided into four sections and requiring approximately 5 minutes to complete. The first section focused on equestrian sports, including information such as years of experience, weekly training hours, equestrian disciplines, competition level, and the type of saddle used. The second section explored the involvement in other sporting activities. The third section addressed pain experienced during routine equestrian activities, aiming to assess sport-specific limitations. The final section included the Roland Morris Disability Questionnaire.[30'31] This tool contains 24 items that participants either endorse (scoring 1) or leave blank (scoring 0), leading to a total Roland Morris Disability Score (RMDS) ranging from 0 to 24, where higher scores indicate greater levels of pain-related disability in daily activities. A translated version of the questionnaire is provided in the supplementary material.

5.2.2.2. Anthropometric data and body composition

A bioelectrical impedance scale, Tanita SC-0330 [32], was used to assess anthropometric data and body composition for all participants. The bioelectrical impedance scale measurements relevant in the present study include: body mass (BM), body mass index (BMI), body fat percentage (BF%), muscle mass index (MMI), visceral fat index (VFI), and basal metabolic rate (BMR). Additionally, height was measured, and the date of birth was recorded for each participant.

5.2.2.3. Functional movements

The functional movement screening tests - FMS[33-36] evaluates movement patterns to identify limitations and compensatory behaviors. Its primary goal is to assess an individual's capability in performing various movements, particularly those related to flexibility, range of motion, muscle strength, coordination, balance, and proprioception. The assessment comprises seven distinct movements, three of which have clearing tests (CT): deep squat, hurdle step, in-line lunge, shoulder mobility (CT), active straight-leg raise, trunk stability push-up (CT), and rotational stability (CT). Each movement is performed three times and scored, each time, on a scale from 0 to 3, only the lowest score of the attempts is recorded and considered, the total possible score ranges from 0 to 21 points, additionally, if a person has a positive clearing test (indicating the presence of pain during the execution of the test) that test will have a score of 0. Low scores on the FMS can be indicative of a greater relative risk of injury.[33-36] The current protocol included two of the seven FMS tests - the deep squat (DS) and the trunk stability push-up (TPU), **Figure V.1.** Research has demonstrated that patients with LBP score significantly lower on these tests therefore, these assessments are particularly relevant for individuals with this condition.

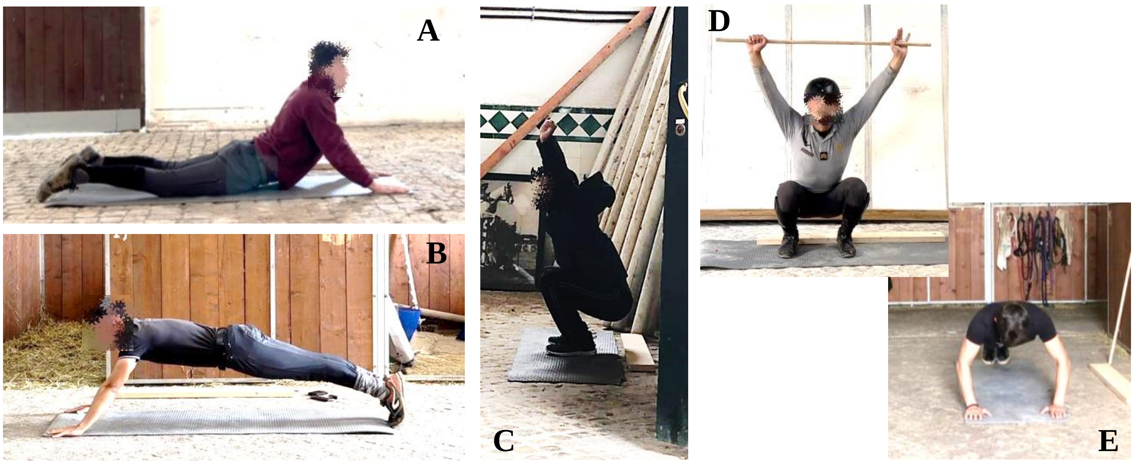


Figure V.1. *Pictures of participants doing FMS tests.*

Note: A. Trunk push-up clearing test; B. Trunk push-up lateral view; C. Deep squat lateral view; D. Deep squat frontal view; E. Trunk push-up frontal view.

5.2.3. Training program

The training program was designed by a team of experts in sports and health – AR and OF, who are co-authors of this paper - focusing on the target population. The fitness features taken into consideration were muscular endurance, symmetry, functional movement, flexibility, mobility and stability. Throughout the development of the STP the support of literature and specialized apps were sought.[37'38]

The specific training program (STP) consisted of a 3 day/week progressive overload strength and stretching program lasting 12 weeks total (**Table V.1.**).

Table V.1. *Progression of specific training program over the 12-week intervention period*

		Week 1	Week 2	Week 3	Week 4	Week 5 *	Week 6	Week 7	Week 8	Week 9 *	Week 10	Week 11	Week 12
N sets/ exercise		3	3	3	3	3	3	3	3	3	3	3	3
N exercises		6	6	6	6	6	6	6	6	6	6	6	6
N warm-up exercises		6	6	6	6	6	6	6	6	6	6	6	6
N stretching exercises		6	6	6	6	6	6	6	6	6	6	6	6
Day 1	Reps/ exercise	10 – 20	15 – 20	10 – 30	15 – 30	10 – 20	10 – 20	15 – 20	15 – 30	10 – 20	10 – 20	15 – 20	15 – 20
	Isometric holds	10 – 15	15 – 20	20 – 25	25 – 30	30	30	30	30	45	45	45	60
Day	Reps/ exercise	6 – 20	6 – 20	10 – 20	10 – 20	6 – 20	6 – 20	10 – 30	10 – 30	6 – 20	6 – 20	10 – 30	10 – 30
	Isometric holds	10 – 15	10 – 15	10 – 15	10 – 15	20	20	20 – 30	20 – 30	20	20	30	30
Day 3	Reps/ exercise	10 – 20	10 – 30	12 – 20	12 – 20	10 – 20	10 – 20	12 – 20	12 – 20	10 – 20	10 – 20	12 – 20	12 – 20
	Isometric holds	15	15	20	20	-	-	-	-	-	-	-	-

*Note: N – number of; Reps/ exercise – number of repetitions per exercise; Isometric holds are in presented in seconds; *Weeks 5 and 9 exercises suffered some variations to increase difficulty.*

The STP had 18 different bodyweight exercises, 6 per day of the week; these exercises suffered some variations to increase difficulty throughout the weeks, with major changes in weeks 5 and 9. The number of repetitions and duration of isometric holds also varied progressively. The STP had three different warm-up and stretching plans, the exercises were chosen to warm up and stretch the primary targeted muscles of the STP.

During the experiment period participants – of the experimental group – were asked to weekly rate the intensity of their LBP at rest and when riding – on a 6 points visual analog scale (VAS), from no pain (0) to worst pain (5). Additionally, they were asked to rate the perceived exertion of each training session with the Borg's perceived exertion scale (PES)[39].

5.2.4. Data analysis

The completed questionnaires, functional movement scores, anthropometric and body composition data were uploaded to LimeSurvey ©[40] for efficient data organization and subsequent transfer to statistical analysis tools. Participants' skill levels were determined using the taxonomy of rider status established by Williams and Tabor.[41] Skill levels were classified as follows: 1 - leisure rider, 2 - novice rider, 3 – experienced rider, 4 – amateur rider, 5 – professional rider and 6 – elite rider. Competition levels were categorized as: 0 – none, 1 – regional, 2 – national and 3 – international.

For the Roland Morris score, a threshold value of 4 was used to classify individuals with LBP as either functional (RMDS $\leq$ 4) or dysfunctional (RMDS > 4), as suggested by Stratford and Riddle.[42]

Pain levels, measured using the visual analog scale, were adapted and categorized based on the findings of Jensen, Chen and Brugger.[43] The stratification was as follows: 0 to 0.2 – No pain; 0.21 to 2.2 – Mild pain; 2.3 to 3.7 – Moderate pain; 3.8 to 5 – Severe pain.

5.2.4.1. Statistical analysis

5.2.4.1.1. Sample size

The sample size for this study was determined using G*Power software[44], focusing on the Roland Morris Disability Score as a standardized measure of disability in Portuguese equestrian athletes with lower back pain, as established in previous research.[7] A cutoff value of 4 for the RMDS, as established by previous authors [42], indicates functionality and was employed as a target for reducing the average RMS score to 4 or below. The mean RMDS of Portuguese equestrian athletes with lower back pain was identified as 5.39, while the desired mean RMDS post-intervention was set at 4. These values were utilized to calculate the effect size, measured using Cohen's d, which resulted in an effect size of 0.31. To ensure sufficient statistical power to detect significant differences resulting from the intervention between the experimental and control groups, repeated measures ANOVA was selected for the analysis. The alpha level was set at 0.05, and the power level was established at 0.95 to enhance the robustness of the findings. G*Power simulations indicated that a minimum sample size of 36 participants was necessary.

However, post-study analysis revealed that the RMDS did not follow a normal distribution, making repeated measures ANOVA inappropriate. To validate the effect size and sample size, a new calculation was conducted. An effect size calculator for non-parametric tests was utilized, specifically for the Mann-Whitney U test. The Mann-Whitney U value for RMDS and the sample sizes were used to calculate Cohen's d, resulting in a higher effect size of 1.796. The statistical test for determining the sample size with G*Power tool was based on the differences between two independent groups, indicating that a minimum sample size of 20 was necessary. Ultimately, data were collected from 52 participants, further enhancing the reliability and generalizability of the study's findings.

5.2.4.1.1. Statistical analysis SPSS

Statistical analysis was performed using SPSS version 27.0 (IBM SPSS Statistics, Armonk, NY, USA)[45]. Baseline characteristics of the sample were evaluated to ensure comparability between the experimental and control groups. Descriptive statistics for variables such as age, years of riding, workload, skill and competition levels were reported as medians with interquartile ranges. Equestrian discipline, stable duties, profession/hobby, and the number of disciplines practiced were presented using counts and categorical descriptive statistics.

The statistical analysis of the variables used to evaluate the effects of the specific training program involved several steps. First, the normality of the distribution for each variable was assessed using the Kolmogorov–Smirnov normality test. For variables that exhibited a normal distribution, repeated measures ANOVA was conducted. In contrast, for non-parametric variables, the differences between post-intervention and pre-intervention values were analyzed for statistical significance using the Mann-Whitney U test.

A table was utilized to stratify data and assess the role of potential effect modifiers on the training intervention's impact on disability scores. The Roland Morris Disability Scores and the number of participants with dysfunctionality were analyzed using the Mann-Whitney U test to identify significant differences within and between groups

The normality of the distribution for the variable associated with the specific training program in the experimental group, Visual Analog Scale (VAS) scores was assessed using the Kolmogorov–Smirnov normality test. VAS scores were reported as medians, and a line chart was created to illustrate trends in this variable over the 12-week intervention period, facilitating the interpretation of the results. To analyze the significance of differences in pain intensity levels—both during riding and at rest—between week one and week twelve of the intervention, the Wilcoxon signed-rank test was employed.

5.3. Results

5.3.1. Baseline characteristics of participants

Baseline anthropometric characteristics and equestrianism characteristics of the sample – experimental and control groups – are presented in **Table V.2**. The Kolmogorov-Smirnov normality test indicated that all variables, including age, years riding, workload, skill level, and competition level, exhibited abnormal distributions. Half of the sample (55.8%, N = 29) participated in only one of the mentioned equestrian disciplines, while the remaining participants engaged in two or three different disciplines. Most participants (88.5%) were involved in equestrian sports professionally, either working with or riding horses, or coaching as their primary form of employment. The remaining participants practiced equestrianism as a hobby, meaning it was not their main activity or main source of income.

Table V.2. *Anthropometric characteristics, involvement in equestrian sports of the sample and statistical significance*

		Experimental group (N – 28)	Control group (N – 24)	*P*
LBP in last 12-months		28	24	-
Sex (female/ male)		14/14	10/14	-
Age (years)		20 (5)	24,5 (15)	**0,007**
Years riding		10 (9,25)	15,5 (14,75)	**0,042**
Workload (h/week)		7,5 (8,5)	12,5 (19,50)	0,376
Skill level		2 (1)	5 (3)	**0,018**
Competition level		1 (1,75)	2 (1)	**0,017**
Stable duties (yes/no)		19/9	18/6	0,571
Equestrian discipline (n)	General riding	8	3	-
	Dressage	17	14	-
	Show jumping	14	15	-
	Eventing	1	6	-
	Endurance	3	0	-
Profession/ Hobby		26/2	20/4	0,283
1 discipline/ 2 or 3 disciplines		15/13	14/10	0,730

n – Number of participants; Age, years riding, workload, skill level, and competition level are presented as median and interquartile range; p-values for the Mann-Whitney U test indicate differences between the experimental and control groups for continuous variables. For stable duties, profession/hobby, and number of disciplines.

In the present sample, both groups comprised participants from all skill levels; however, the control group included significantly more skilled riders than the experimental group, a trend also observed in competition level. Additionally, the control group showed significantly higher values for both age and years of riding experience ($p < 0.04$). For the variable stable duties, the Pearson Chi-squared test revealed no significant differences between groups.

5.3.2. Pre and post intervention outcomes

Table V.3. presents the baseline characteristics and post-intervention outcomes for both the experimental group (N = 28) and the control group (N = 24) regarding body composition variables that exhibited a normal distribution. When comparing the effects of the specific training program (STP) on these body composition variables between the two groups, no significant differences were found.

Table V.3. *Baseline Characteristics and Post-Intervention Outcomes for Body Composition Variables in Experimental and Control Groups (Parametric Data)*

	Experimental group (N – 28)		Control group (N – 24)		*P*
	Baseline	**Post-intervention**	**Baseline**	**After 12-weeks**	
BM	69,9 ± 13	70,1 ± 12,4	68,3 ± 12,5	68,3 ± 12,2	0,626
BMI	24 ± 3,1	24,1 ± 2,8	24,1 ± 3,6	24 ±3,4	0,968
BF%	22,9 ± 8,6	22,1 ±7,7	20,2 ± 7,4	22,4 ± 11,8	0,587
BMR	1,6 ± 0,3	1,7 ± 0,3	1,6 ± 0,3	1,6 ± 0,3	0,688

BM – Body mass; BMI – body mass index; BF% - body fat percentage; BMR – basal metabolic rate; Results are presented as means with standard deviations; p-values for ANOVA repeated measures comparing the difference between baseline and post-intervention outcomes of the experimental vs. control groups.

Table V.4 presents the baseline characteristics and post-intervention outcomes for the experimental group and control group regarding body composition, disability scores, and functional movement scores. The Kolmogorov-Smirnov normality test indicated abnormal distributions for all variables included in this table. The results are expressed as medians with interquartile ranges, and significance was assessed using Mann-Whitney U tests.

MMI and VFI showed no significant differences between the experimental and control groups, indicating that the specific training program did not result in changes in these measures. In contrast, the RMDS revealed a significant reduction in disability in the experimental group compared to the control group. The FMS also demonstrated a significant difference, suggesting a positive impact of the intervention on functional movement. The DS did not show significant changes, indicating that this aspect of functional performance remained unaffected by the training program. However, the TPU presented with significant improvement in the experimental group.

Table V.4. *Baseline Characteristics and Post-Intervention Outcomes of Experimental and Control Groups for Body Composition, Disability Scores, and Functional Movement Scores (Non-Parametric Analysis)*

	Experimental group (N – 28)		Control group (N – 24)		Mann-Whitney U	*P*
	Baseline	Post-intervention	Baseline	After 12-weeks		
MMI	12 (1,5)	12 (3)	12 (2,25)	12 (5)	411,5	0,122
VFI	2 (3)	2 (2,75)	2 (4)	2 (4,75)	290	0,308
RMDS	5 (6,5)	2 (3,75)	2,5 (6,75)	3 (7,5)	73,5	0,000
FMS	2 (1)	3 (2)	3 (2,75)	3,5 (2,75)	448	0,024
DS	2 (1)	2 (1)	2 (1)	2 (1)	311	0,464
TPU	0 (0)	1 (2,75)	2 (3)	2 (3)	458,5	0,011

MMI – Muscle Mass Index; VFI – Visceral Fat Index; RMDS – Roland Morris Disability Score; FMS – Functional Movement Scores; DS – Deep Squat Test; TPU – Trunk Push-Up Test; Results are presented as median and interquartile range; p-values for Mann-Whitney U test, comparing the difference between baseline and post-intervention outcomes of the experimental vs. control groups.

Considering the significant age differences between the experimental and control groups (p=0,007, **Table V.2**), and recognizing that age can act as an effect modifier for lower back pain disability outcomes, an additional analysis was performed to assess the impact of age on changes in disability scores. **Table V.5** presents the variables of the Roland Morris Disability and the number of participants with dysfunctionality (RMDS-D/F) stratified by age groups. The significance of the differences was evaluated using Mann-Whitney U tests.

Table V.5. *Changes in Disability Scores by Age Group in Experimental and Control Groups*

Age group	Variable	Experimental group		Control group		Mann-Whitney U	*P*
		Baseline	Post-intervention	Baseline	After 12-weeks		
18 - 20	N	15		7		-	
	RMDS	6 (7)	3 (5)	7 (8)	5 (9)	20	0,019
	RMDS-D/F	10/5	5/10	4/3	4/3	35	0,090
21 - 25	N	9		6		-	
	RMDS	3 (4,5)	1 (2)	2 (6,25)	4 (9,5)	2	0,003
	RMDS-D/F	4/5	0/9	2/4	3/3	12,5	0,039
26 - 34	N	4		5		-	
	RMDS	6 (8,75)	4 (9,5)	0 (5)	0 (6)	1,5	0,028
	RMDS-D/F	2/2	2/2	1/4	2/3	8	0,371
+ 35	N	-		6		-	
	RMDS	-	-	2,5 (6,5)	3 (7,25)	-	
	RMDS-D/F	-	-	2/4	2/4	-	

RMDS – Median and interquartile ranges; RMDS-D/F – number of participants with dysfunctionality/ functionality.

Notably, there were no participants in the experimental group aged over 35. The RMDS indicates a significant reduction in disability in the experimental group compared to the control group across all age groups ($p<0{,}028$). In terms of functionality, the only age group that demonstrated significant improvement was participants aged 21 to 25. This finding suggests that the observed differences in disability outcomes are attributable to the effects of the training program rather than age-related factors.

With the exception of the FMS clearing test, all variables presented in **Table V.6** are subjective and rely on participants' personal assessments of lower back pain experienced during equestrian-related daily activities, as well as functionality measured by the cutoff value for the Roland Morris Disability Score.

Table V.6. *Impact of Specific Training Program on RMDS Functionality, FMS Outcomes and pain in Equestrian Activities Among Experimental and Control Groups*

		Experimental group (N – 28)			**Control group (N – 24)**			**U-Test**	**P-value**
		I	**NC**	**W**	**I**	**NC**	**W**		
RMDS - Functionality		9	19	0	0	22	2	209	0,001
Clearing test - FMS		13	15	0	2	09	3	185,5	0,001
Pain affecting performance		11	15	2	1	21	2	224	0,011
*Pain mucking out		4	13	2	0	18	0	153	0,599
Pain lunging horses		6	19	3	3	19	2	315,5	0,628
Pain when riding	Overall	4	23	1	2	20	2	303	0,570
	At walk	0	28	0	0	23	1	322	0,280
	At rising trot	4	24	0	1	22	1	290	0,128
	At sitting trot	6	17	5	2	19	3	314	0,619
	At canter	4	22	2	2	15	7	254	0,059
	At canter in jumping position	3	24	1	0	22	2	313	0,446
	Jumping	5	23	0	0	22	2	253	0,010
Riding increases pain		8	18	2	0	21	3	234	0,013
Grooming increases pain		5	21	2	1	20	3	278,5	0,138
Pain when riding	Worsens during the riding session	3	23	2	0	22	2	299	0,252
	The same during the riding session	7	18	3	2	21	1	302,5	0,416
	Increases in the beginning, reducing throughout work	7	15	6	1	23	0	335	0,981
	Reduces during the riding session	0	25	3	2	20	2	369	0,307

I, NC and W represent the number of participants. I = Improved after intervention; NC = No Change after intervention; W = Worsened after intervention. For the variable 'pain mucking out,' the total n for both groups differs, as not all participants performed this activity: experimental group n = 19 and control group *n = 18. p-values for Mann-Whitney U test, comparing the difference between baseline and post-intervention outcomes of the experimental vs. control groups.*

The Mann-Whitney U tests revealed significant differences in several variables, including functionality – RMDS, FMS clearing test, pain affecting performance, and the impact of jumping and riding on LBP felt, between the experimental and control groups following the intervention, as detailed in **Table V.6**

5.3.3. Experimental group weekly pain intensity levels

Table V.7 illustrates that the intensity of lower back pain experienced at rest and during riding in the experimental group significantly decreased by the 12th week of the intervention, with p-values of 0.001 and 0.003, respectively, compared to the pain levels reported at the beginning of the intervention (Week 1). These differences were determined using the Wilcoxon signed-rank test.

Table V.7. *Changes in Weekly Levels of Lower Back Pain at Rest and During Riding in the Experimental Group*

	Week 1	**Week 12**	***P***
Rest	3 (5)	1 (1)	0,001
Riding	2 (4,75)	1 (2,75)	0,003

P-value for Wilcoxon signed-rank test; Results are presented as median (interquartile range)

Figure V.2 shows a line chart illustrating the median trends in LBP intensity levels of the experimental group – rest and riding - over the 12-week intervention period.

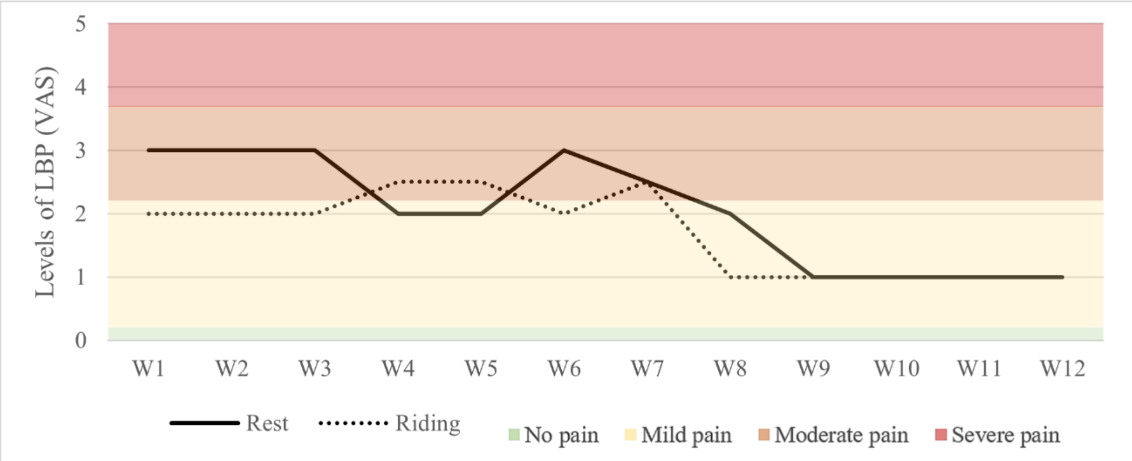


Figure V.2. *Levels of LBP at rest and while riding over the 12-week intervention period*

The graph displays weekly median pain intensity levels for the experimental group, comparing pain at rest and during riding over the 12-week intervention period. Color-coded zones indicate pain intensity: green for 'No Pain,' light yellow for 'Mild Pain,' yellow for 'Moderate Pain,' and red for 'Severe Pain.' W represents the week.

5.4. Discussion

5.4.1. Baseline characteristics of participants

All participants in the present study reported experiencing lower back pain within the last 12 months. Participant characteristics align with findings from previous literature regarding risk factors for LBP. A workload exceeding 7 hours per week, engaging in stable duties, and practicing equestrian sports professionally are significant risk factors for LBP.[7] Additionally, Ferrante et al.[6] identified younger age as a risk factor for LBP among adult equestrian athletes. Although differences in characteristics between the two groups of the present study may exist, due to the convenience sampling method used in this study, these differences are not expected to impact the results.

5.4.2. Pre and post intervention outcomes

5.4.2.1. Body composition

There are specific body composition variables that represent risk factors for lower back pain [9’10’23’46’47]. Ferrante et al.[6] identified higher weight as a risk factor for low back pain in equestrian athletes. Additionally, Duarte et al.[7] reported that an elevated body mass index is linked to an increased risk of disability due to lower back pain in this population. Although these authors did not provide cutoff values for comparison. Cejudo et al.[13] found that higher body fat percentage is a validated predictive factor for low back pain in child equestrian athletes. However, since this study pertains to a pediatric population, these values are not directly comparable to adults.

There is limited research analyzing body composition in equestrian athletes,[48] equestrians concerns regarding body composition and weigh are usually due to two different factors: aesthetical concerns [49] and equine welfare and performance,[50] although, equestrian athletes may demonstrate higher fat mass than other athletic populations.[51] The present sample presented with normal weight,[6] body mass index [1] and body fat percentage [52], previously seen in equestrian athletes. It is important to note that the research team did not attempt to control participants' dietary habits. Participants were instructed to maintain their existing exercise routines and participation in other sports throughout the 12-week period. Overall, all participants were advised to uphold their regular lifestyles, and no changes were reported to the research team.

No significant changes in body composition variables were observed, a finding that is consistent with existing literature indicating similar outcomes in athletic populations.[53] One possible explanation for the absence of positive changes in body weight or fat reduction is that individuals with healthy weight, like those in this equestrian athlete population, often experience slower weight loss compared to overweight or obese populations.[54] Furthermore, it is important to note that the primary objective of the specific training program was not to alter body composition variables. The intensity and nature of the exercises in the STP were designed to enhance performance and functional capacity rather than to change body composition in an already athletic and active population.

5.4.2.2. Disability scores

Several studies have validated the positive effects of exercise interventions and specialized programs in the reduction of disability felt by populations with chronic non-specific lower back pain,[55'56] chronic lower back pain,[57] non-specific lower back pain [58] and lower back pain [59].

In this study, the Roland Morris disability questionnaire was used to measure perceived disability and dysfunctionality caused by lower back pain in equestrian athletes daily activities. Considering subjects had stated suffering from non-specific lower back pain, dysfunctionality results were lower than expected, since only 48 % of the study participants presented with dysfunctional Roland Morris scores (RMDS >4) at baseline. This could be due to the lack of sensitivity of the tool in the assessment of disability in the athletic population, since athletes could have limitations to their athletic performance and yet have little or no disability in their daily activities.[60]

In the present study, the specific training program intervention demonstrated significant effects on disability scores and dysfunctionality. This highlights the effectiveness of the STP in reducing the perceived impact of lower back pain on daily activities among equestrian athletes. The positive changes in disability scores suggest that the STP not only alleviated symptoms but also improved functional capacity, allowing participants to engage more fully in both their athletic pursuits and everyday life. These results emphasize the importance of targeted training programs in managing lower back pain and enhancing overall functionality in athletic populations.

Conversely, a decline in both disability and functionality was observed in the control group after the 12-week period, which does not appear to be influenced by age. This finding suggests that neglecting lower back pain while continuing regular sports activities, rather than addressing the underlying issues, may exacerbate long-term low back pain symptoms and perceptions of disability. Furthermore, when analyzing functionality with age as an effect modifier, the effects of the STP were found to be significant only in the group aged 21 to 25 years.

5.4.2.3. Functional movement scores

Previous research has demonstrated that populations with lower back pain tend to have lower scores in the deep squat, hurdle step, inline lunge, active straight leg raise, trunk push up and rotational stability screens tests of the functional movement screening test battery, when compared to healthy individuals.[61] In the present study protocol the included FMS tests were the deep squat (DS) and trunk push up (TPU). Deckers et al.[15] concluded that equestrian athletes with higher levels of back pain tended to have lower scores in the FMS test. Additionally, Lewis, Douglas, Edwards and Dumbell [22] found that healthy equestrian athletes have higher FMS scores than non-rider populations, yet lower than scores seen in other athletic populations.

In the present study the STP significantly improved the overall FMS and TPU scores, with a notable reduction in the number of participants reporting pain during the TPU clearing test. These results indicate that the STP effectively enhanced functional movement and muscular stability among participants. However, no changes were observed in the DS test scores, suggesting that while trunk stability improved, the STP may need to incorporate specific exercises to target deep squat performance effectively. Research has demonstrated that exercise interventions and tailored programs can significantly enhance both functional movements, as assessed through physical tests, and overall functionality, evaluated via subjective assessments, in populations with chronic non-specific lower back pain [55’56], chronic lower back pain,[57] non-specific lower back pain [58].

5.4.2.4. Pain in equestrian daily chores

In this study, the research team developed a pain questionnaire specifically tailored to the equestrian population and the demands of equestrian activities. This questionnaire was initially validated by a panel of experts in sports health research and equine sciences, ensuring its relevance to the target population. However, it has not yet undergone the full validation process required to be recognized as a standardized tool for broader use in clinical or research settings. The questionnaire assessed the effects of pain on sports performance, daily activities, and riding performance.

In the control group, the 12-week study period resulted in minimal changes regarding the impact of pain on daily equestrian activities. Participants continued to face the challenges associated with lower back pain, which likely hindered their ability to fully engage in equestrian pursuits. This ongoing pain emphasizes the necessity of addressing non-specific lower back pain through targeted training and rehabilitation strategies, as merely maintaining regular activity without a structured program may not effectively alleviate symptoms or enhance functionality.

In contrast, the STP demonstrated significant effects on pain perception among equestrian athletes, particularly regarding performance, canter work (nearly statistically significant), jumping, and the perception that riding exacerbates pain. These findings indicate that the STP positively influenced pain perceptions and mitigated the adverse effects of pain on performance in equestrian athletes. This suggests that tailored training interventions not only enhance physical capabilities but also play a crucial role in improving athletes' mental resilience and confidence in their abilities, thereby fostering a more favorable overall riding experience.

5.4.3. Experimental group weekly pain intensity levels

Several studies have reported LBP intensity levels experienced by equestrian athletes.[6’8’62] The pain intensity felt at baseline by the experimental group coincides with the results reported by Ferrante et al.[6] but is slightly higher than the ones reported by Kraft et al. in equestrian athletes [62] and elite equestrians [8]. Literature has validated the positive effects exercise interventions and specialized programs have in the reduction of pain intensity levels felt by populations with non-specific LBP [58] and chronic non-specific LBP [55’56].

Throughout the 12-week period, pain intensity levels remained relatively stable for both riding and at rest, indicating a consistent experience of pain across these different activities. The variations in pain levels observed are expected during an exercise intervention, as muscle soreness - a natural result of physical activity [63] - can sometimes be mistaken for a worsening of existing pain. In this study, participants maintained regular communication with the research team and were advised not to push through exercises or stretches that significantly exacerbated their low back pain. Fortunately, no cases of such exacerbation were reported.

The experimental group experienced a significant reduction in pain intensity, both during riding and at rest, following the 12-week intervention. In contrast, no significant changes were observed at the 6-week mark, suggesting that longer-duration exercise intervention programs may be more effective in alleviating pain intensity. Two studies evaluating the effects of exercise programs on back pain in equestrians concluded that these interventions helped reduce both pain intensity and disability. Biau et al.[28] developed a 10-week training program that greatly lowered pain intensity levels (baseline score of 4, post-intervention score 1, on a scale of 1 to 10); however, they did not provide statistical analysis to support the significance of these results. In another study, Sedlecka et al.[29] reported a moderate reduction in disability due to low back pain after a 6-week intervention program for equestrians.

5.5. Limitations and suggestions for future research

The present study has some limitations that warrant consideration. Firstly, the nonrandomized design may introduce selection bias, as participants were assigned to groups based on their availability rather than random selection. While this approach may affect the applicability of the findings, it nonetheless provides valuable insights into the effects of the specific training program within the selected population. Notably, there were no participants in the experimental group aged over 35, which may limit the generalizability of the findings. Further research is warranted to explore the effects of training on older populations, given the lack of data in this age group within the current study.

Furthermore, the reliance on self-reported measures for pain and disability introduces an element of subjectivity; participants may have different interpretations of their symptoms, which could influence the results. Finally, the study did not control for participants' dietary habits or other physical activities outside the training program, factors that might also contribute to the outcomes.

Overall, while these limitations are acknowledged, the study still offers meaningful insights into the effectiveness of structured exercise interventions for managing lower back pain among equestrian athletes.

The observed improvements in lower back pain symptoms and functionality are promising; however, future research could further explore the sustainability of these benefits over the long term. Studies with larger, randomized samples and extended follow-up periods would be valuable for assessing the longevity of intervention effects. These steps would provide greater insight into the durability of the intervention's impact and its potential for long-term benefit. Future research could benefit from using the current questionnaire as a foundation for developing a validated, population-specific pain assessment tool, enhancing its applicability and precision for future studies and assessments.

5.6. Conclusions

The present study demonstrates that a twelve-week specific training program effectively reduces lower back pain symptoms and enhances functional movements among equestrian athletes. Significant improvements in the experimental group's Roland Morris Disability scores and functional movement assessments indicate that structured exercise interventions can mitigate the impact of lower back pain, thereby enhancing athletes' overall performance and well-being. Participants reported a notable reduction in pain intensity both during riding and at rest, suggesting that regular physical activity tailored to address lower back pain can yield meaningful benefits.

Furthermore, the study found that the specific training program positively influenced pain perception, particularly in relation to performance in equestrian activities such as canter work and jumping. These findings reinforce the idea that targeted training interventions not only improve physical capabilities but also contribute to mental resilience and confidence among athletes.

The results align with previous studies advocating exercise as a viable non-pharmacological treatment for lower back pain. Overall, the evidence supports the implementation of targeted exercise programs for equestrian athletes, emphasizing the importance of addressing physical conditioning and pain management within this population to promote long-term health and performance.

5.7. References

1. Hobbs S.J, Baxter J, Louise B, Laura-An R, Jonathan, S, Hilary CM. Posture, Flexibility and Grip Strength in Horse Riders. *J Hum Kinet*. 2014; 42(1): 113-125. doi:10.2478/hukin-2014-0066

2. Lewis V, Baldwin K. A preliminary study to investigate the prevalence of pain in international event riders during competition, in the United Kingdom. *Comp Exerc Physiol*. 2018; 14(3): 173-181. https://doi.org/10.3920/CEP180006

3. Lewis V, Kennerley R. A preliminary study to investigate the prevalence of pain in elite dressage riders during competition in the United Kingdom. *Comp Exerc Physiol*. 2017; 13(4): 259-263. doi:10.3920/CEP170016

4. Lewis V, Dumbell L, Magnoni F. A Preliminary Study to Investigate the Prevalence of Pain in Competitive Showjumping Equestrian Athletes. *J Phys Fitness Med Treat Sports*. 2018; 4(3). doi:10.19080/JPFMTS.2018.04.555637

5. Lewis V, Nicol Z, Dumbell L, Cameron L. A Study Investigating Prevalence of Pain in UK Horse Riders over Thirty-Five Years Old. *Int J Equine Sci*. 2023; 2(2): 9-18.

6. Ferrante M, Bonetti F, Quattrini M, Mezzetti, M, Demarie S. Low Back Pain and Associated Factors among Italian Equestrian Athletes: a Cross-Sectional Study. *MLTJ*. 2021; 11(2): 344. doi:10.32098/mltj.02.2021.19

7. Duarte C, Santos R, Fernandes O, Raimundo A. Prevalence of Lower Back Pain in Portuguese Equestrian Riders. *Sports*. 2024; 12(8): 207. doi:10.3390/sports12080207

8. Kraft CN, Peter PH, Ute B, Mei Y, Oliver D, Christian L, Makus FV. Magnetic Resonance Imaging Findings of the Lumbar Spine in Elite Horseback Riders: Correlations With Back Pain, Body Mass Index, Trunk/Leg-Length Coefficient, and Riding Discipline. *Am J Sports Med*. 2009; 37(11): 2205-2213. doi:10.1177/0363546509336927

9. Trompeter K, Fett D, Platen P. Prevalence of Back Pain in Sports: A Systematic Review of the Literature. *Sports Med*. 2017; 47: 1183-1207. https://doi.org/10.1007/s40279-016-0645-3

10. Wilson F, Ardern CL, Hartvigsen J, Dane K, Trompeter K, Trease L, et al. Prevalence and risk factors for back pain in sports: a systematic review with meta-analysis. *Br J Sports Med*. 2021; 55(11): 601-607. https://doi.org/10.1136/bjsports-2020-102537

11. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, Woolf A, Vos T, Buchbinder R. A systematic review of the global prevalence of low back pain. *Arthritis rheum*. 2021; 64(6): 2028-2037. https://doi.org/10.1002/art.34347

12. Pugh TJ, Bolin D. Overuse Injuries in Equestrian Athletes. *Curr Sports Med Rep*. 2004; 3(6): 297-303. https://doi.org/10.1007/s11932-996-0003-6

13. Cejudo A, Ginés-Díaz A, Rodrígues-Ferrán O, Santonja-Medina F, Sainz De Baranda P. Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes. *Children*. 2020; 7(10): 172. doi:10.3390/children7100172

14. Cejudo A, Ginés-Días A, Sainz De Baranda P. Asymmetry and Tightness of Lower Limb Muscles in Equestrian Athletes: Are They Predictors for Back Pain? *Symmetry*. 2020; 12(10): 1679. doi:10.3390/sym12101679

15. Deckers I, De Bruyne C, Roussel NA, Truijen S, Minguet P, Lewis V, et al. Assessing the sport-specific and functional characteristics of back pain in horse riders. *Comp Exerc Physiol*. 2021; 17(1): 7-15. doi:10.3920/CEP190075

16. González, M.E, Sarabon, N. Shock Attenuation and Electromyographic Activity of Advanced and Novice Equestrian Riders' Trunk. *Appl. Sci*. 2021, 11, 2304. https://doi.org/10.3390/app11052304.

17. Nadler S, Moley P, Malanga G, Rubbani M, Prybicien M, Feinberg JH. Functional deficits in athletes with a history of low back pain: a pilot study. *Arch Phys Med Rehabil*. 2002; 83(12): 1753-1758. https://doi.org/10.1053/apmr.2002.35659

18. Hainline B, Derman W, Vernec A, Budget R, Deie M, Dvořák J, et al. International Olympic Committee consensus statement on pain management in elite athletes. *Br J Sports Med*. 2017; 51(17): 1245-1258. http:// dx. doi. org/ 10. 1136/bjsports- 2017- 097884

19. Ghlichloo I, Gerriets V. Nonsteroidal anti-inflammatory drugs (NSAIDs). [Internet]. 2019. [accessed on: 01 Sep 2024] Available from: https://www.ncbi.nlm.nih.gov/books/NBK547742/.

20. Lundberg TR, Howatson G. Analgesic and anti-inflammatory drugs in sports: Implications for exercise performance and training adaptations. *Scand J Med Sci Sports*. 2018; 28(11): 2252-2262. https://doi.org/10.1111/sms.13275

21. Qaseem A, Wilt TJ, McLean RM, Forciea MA, Clinical Guidelines Committee of the American College of Physicians. Noninvasive treatments for acute, subacute, and chronic low back pain: a clinical practice guideline from the American College of Physicians. *Ann Intern Med. 2017*; 166(7), 514-530. 10.7326/M16-2367

22. Lewis V, Douglas JL, Edwards T, Dumbell L. A preliminary study investigating functional movement screen test scores in female collegiate age horse-riders. *Comp Exerc Physiol*. 2019; 15(2): 105-112. doi:10.3920/CEP180036

23. Shiri R, Falah-Hassani K, Heliövaara M, Solovieva S, Amiro S, Lallukka T, et al. Risk factors for low back pain: a population-based longitudinal study. *Arthritis Care Res*. 2019; 71(2): 290-299. https://doi.org/10.1002/acr.23710

24. Thornton JS, Caneiro JP, Hartvigsen J, Ardern CL, Vinther A, Wilkie K, et al. Treating low back pain in athletes: a systematic review with meta-analysis. *Br J Sports Med*. 2021; 55(12):656-662.

25. Hampson A, Randle H. The influence of an 8-week rider core fitness program on the equine back at sitting trot. *Int J Perf Anal Spor*. 2015; 15(3):1145-1159.

26. Lee JT, Soboleswki EJ, Story CE, Shields EW, Battaglini CL. The feasibility of an 8-week, home-based isometric strength-training program for improving dressage test performance in equestrian athletes. *Comp Exerc Physiol*. 2015; 11(4):223-230.

27. Weeks RA, McLaughlin PA, Vaughan BR. The efficacy of an eight-week exercise program for the management of chronic low back pain in the equestrian population. *The Journal of sports medicine and physical fitness*. 2024.

28. Biau S, Le Navenec C, Pycik E, Noury B. Un cycle de dix semaines d'étirement et de renforcement des muscles du tronc impacte l'activité équestre et diminue les

douleurs lombaires des futurs cavaliers professionnels. *Sci Sports*. 2024; 39(1):36-42.

29. Siedlecka M, Aniśko B, Placek K, Wójcik M. Low back pain occurrences and gynecological disorders in female equestrians and strengthening of core stability muscles lumbar spine. *Fizjoterapia Polska*. 2023; 23(4).

30. Roland, M, Morris, R. A Study of the Natural History of Back Pain: Part I. *Spine* 1983, 2, 141–144. https://doi.org/10.1097/00007632-198303000-00004.

31. Monteiro, J, Faísca, L, Nunes, O, Hipólito, J. Roland Morris disability questionnaire-adaptation and validation for the Portuguese speaking patients with back pain. *Acta Med*. Port 2010, 23, 761–766. Available online: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/728 (accessed on 26 August 2023).

32. Corporation, TANITA. TANITA health equipment H.K.LTD. SC3307601; Japan. 2008.

33. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function–part 1. *N Am J Sports Phys Ther*. 2006; 1(2), 62.

34. Cook G, Burton L, Hoogenboom B. Pre-participation screening: The use of fundamental movements as an assessment of function–Part 2. *N Am J Sports Phys Ther*. 2006; 1(3), 132.

35. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 1. *Int J Sports Phys Ther*. 2014; 9(3), 396.

36. Cook G, Burton L, Hoogenboom BJ, Voight M. (2014). Functional movement screening: the use of fundamental movements as an assessment of function-part 2. *Int J Sports Phys Ther*. 2014; 9(4), 549.

37. Walker BE. The big book of stretch routines. s.l.: The Stretching Institute; 1971. ISBN 978-0-9943733-2-8.

38. Muscle & Motion. Strength training by Muscle & Motion [Internet]. Muscle and Motion Ltd; 2024 [cited 2024 Sep 1]. Available from: https://app.strength.muscleandmotion.com/exercises/all

39. Borg G. Borg's perceived exertion and pain scales. *Hum kin*. 1998.

40. LimeSurvey [Internet]. 2024 [cited 2024 Sep 1]. Available from: https://www.limesurvey.org/pt

41. Williams J, Tabor G. Rider impacts on equitation. *Appl Anim Behav Sci*. 2017; 190: 28-42.

42. Stratford PW, Riddle DL. A Roland Morris Disability Questionnaire Target Value to Distinguish between Functional and Dysfunctional States in People with Lower back pain. *Physiother Can*. 2016; 68, 29–35. https://doi.org/10.3138/ptc.2014-85.

43. Jensen M, Chen C, Brugger A. Interpretation of visual analog scale ratings and change scores: a reanalysis of two clinical trials of postoperative pain. *J Pain*. 2003; 4(7): 407-414. doi:10.1016/s1526-5900(03)00716-8

44. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-91. doi: 10.3758/BF03193146.

45. IBM Corp. IBM SPSS Statistics for Windows (Version 27.0) [Computer software]; IBM Corp: Armonk, NY, USA, 2020.

46. Moradi, V, Memari, A.-H, ShayestehFar, M, Kordi, R. Lower back pain in Athletes Is Associated with General and Sport Specific Risk Factors: A Comprehensive Review of Longitudinal Studies. Rehabil. Res. Pract. 2015, 2015, 850184. https://doi.org/10.1155/2015/850184.

47. Walsh TP, Arnold JB, Evans AM, Yaxley A, Damarell RA, Shanahan EM. The association between body fat and musculoskeletal pain: a systematic review and meta-analysis. *BMC musculoskeletal disorders*. 2018; 19, 1-13. https://doi.org/10.1186/s12891-018-2137-0

48. Best R, Williams JM, Pearce J. The physiological requirements of and nutritional recommendations for equestrian riders. *Nutrients*. 2023; 15(23), 4977. https://doi.org/10.3390/nu15234977

49. Forino S, Cameron L, Stones N, Freeman M. Potential impacts of body image perception in female equestrians. *J Equine Vet Sci*. 2021; 107, 103776. https://doi.org/10.1016/j.jevs.2021.103776

50. Challinor CL, Randle H, Williams JM. Understanding rider: horse bodyweight ratio trends, weight management practices and rider weight perceptions within leisure and amateur riders in the UK. *Comp Exerc Physiol*. 2021; 17(5), 403-418. https://doi.org/10.3920/CEP200082

51. Meyers MC, Sterling JC. Physical, hematological, and exercise response of collegiate female equestrian athletes. *J Sports Med Phys Fit*. 2000; 40(2), 131.

52. Douglas JL, Price M, Peters DM. A systematic review of physical fitness, physiological demands and biomechanical performance in equestrian athletes. *Comp exerc physiol*. 2012; 8(1): 53-62.

53. Xiao W, Soh KG, Wazir MRWN, Talib O, Bai X, Bu T, et al. Effect of functional training on physical fitness among athletes: a systematic review. *Front Physiol*. 2021; 12: 738878. https://doi.org/10.3389/fphys.2021.738878

54. Jakicic JM, Clark K, Coleman E, Donnelly JE, Foreyt J, Melanson E, et al. American College of Sports Medicine position stand. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc*. 2001; 33(12), 2145-2156. https://doi.org/10.1097/00005768-200112000-00026

55. Van Middelkoop M, Rubinstein SM, Kuijpers T, Verhagen AP, Ostelo R, Koes BW, van Tulder MW. A systematic review on the effectiveness of physical and rehabilitation interventions for chronic non-specific low back pain. *Eur Spine J*. 2011; 20, 19-39. https://doi.org/10.1007/s00586-010-1518-3

56. Gordon R, Bloxham S. A systematic review of the effects of exercise and physical activity on non-specific chronic low back pain. In: *Healthcare*. 2016; 4(2):22. MDPI. https://doi.org/10.3390/healthcare4020022

57. Searle A, Spink M, Ho A, Chuter V. Exercise interventions for the treatment of chronic low back pain: a systematic review and meta-analysis of randomised controlled trials. *Clin Rehabil*. 2015; 29(12):1155-67. https://doi.org/10.1177/0269215515570379

58. Luomajoki H, Kool J, De Bruin ED, Airaksinen O. Improvement in low back movement control, decreased pain and disability, resulting from specific exercise intervention. *BMC Sports Sci Med Rehabil*. 2010; 2:1-7. https://doi.org/10.1186/1758-2555-2-11

59. Moffett JK, Torgerson D, Bell-Syer S, Jackson D, Llewlyn-Phillips H, Farrin A, et al. Randomised controlled trial of exercise for low back pain: clinical outcomes, costs, and preferences. *BMJ*. 1999; 319(7205): 279-83. https://doi.org/10.1136/bmj.319.7205.279

60. Noormohammadpour P, Khezri AH, Farahbakhsh F, Mansournia MA, Smuck M, Kordi R. Reliability and Validity of Athletes Disability Index Questionnaire. *Clin J Sport Med*. 2018; 28(2): 159-167. doi:10.1097/JSM.0000000000000414

61. Alkhathami KM, Alqahtani B. Comparing the Scores of The Functional Movement Screen™ in Individuals with Low Back Pain versus Healthy Individuals: A Systematic Review and Meta-Analysis. *Int J Sports Phys Ther*. 2024; 19(7), 834. 10.26603/001c.120199

62. Kraft C, Urban N, Ilg A, Wallny T, Scharfstädt A, Jäger M, Pennekamp P. *Einfluss der Reitdisziplin und -intensität auf die Inzidenz von Rückenschmerzen bei Reitsportlern*. Influence of the riding discipline and riding intensity on the incidence of back pain in competitive horseback riders. *Sportverletz Sportschaden*. 2007; 21(1): 29-33. doi:10.1055/s-2007-963038

63. Pate D. Exercising with lower back pain: should you work through pain? [Internet]. Spine-Health; 2024 [cited 2024 Oct 10]. Available from: https://www.spine-health.com/blog/exercising-lower-back-pain-should-you-work-through-pain

Chapter VI

Paper 4 - The effect of an intervention on activation levels across four lower back muscles and lower back pain symptoms of equestrian athletes

Chapter VI

Paper 4 - The effect of an intervention on activation levels across four lower back muscles and lower back pain symptoms of equestrian athletes

Abstract

Introduction: Lower back pain (LBP) is a common issue among equestrian athletes, often impacting their performance and daily activities. Specific training programs (STP) targeting core stability may offer a potential solution to alleviate LBP symptoms and improve functionality.

Aims: This study aimed to evaluate the effects of a twelve-week STP on lower back muscle activation, disability, and functional movement in equestrian athletes with non-specific LBP.

Materials and Methods: A quasi-experimental design was used, with 52 equestrian athletes (28 experimental, 24 control). The intervention group underwent a 12-week progressive STP targeting core stability, while the control group maintained regular activity. Measures included the Roland Morris Disability Scale, Functional Movement Scores (Trunk push-up and deep squat), and electromyographic analysis of key lower back muscles (*multifidus* and *erector spinae iliocostalis*) accelerometry and kinematic of the rider on horseback.

Main Results: The STP significantly reduced muscle activation levels in all four muscles, improved functional movement scores, and decreased RMDS scores in the experimental group. Large effect sizes were observed for muscle activation reductions, indicating improved muscle efficiency and reduced compensatory strain.

Conclusions: A structured twelve-week STP effectively reduced LBP, disability, muscle activation, and improved functional movement in equestrian athletes. These findings support the use of targeted core stability interventions to enhance performance and prevent injury in this population.

6.1. Introduction

Equestrian sports involve a unique partnership between two athletes, the horse and the rider, each with their own physical abilities, mental characteristics, and objectives, working together toward shared success, making effective coordination between them essential. The horse's gaits - walk, trot, and canter - each have distinct dynamics, and research has shown that the kinematics of the horse's trunk varies significantly depending on the gait. [1,2] In walk and canter, the horse's trunk rotates around the medial-lateral axis, which requires the rider to align with this rotational motion to maintain stability, during the trot, however, the horse's trunk exhibits vertical movements in both the front and back due to diagonal limb pairing, demanding adjustment from the rider to these concurrent vertical shifts to sustain harmonious movement. [2]

Achieving harmony between horse and rider, along with a balanced seat, requires the rider to skillfully coordinate with the horse's movement patterns,[3,4] as a stable seat ultimately allows for more effective communication and connection with the horse. [5] The rider's pelvis serves as a key channel for this interaction, physically conveying aids - cues used by the rider to communicate with the horse and that influence the horse's behavior. [2] This coordination, often described as harmony, [5] is closely tied to the rider's postural control, [6] which relies heavily on core muscle coordination and neuromuscular awareness.[7]

Musculoskeletal pain and lower back pain (LBP) can profoundly impact equestrian athletes' performance by disrupting postural symmetry, muscle balance, trunk proprioception, and stability. [8,9] It also affects range of motion and contributes to other physical and psychological issues, including fatigue, concentration difficulties, and anxiety. [10-12] Pain avoidance during riding can exacerbate postural defects and muscle imbalances, impairing the rider's ability to absorb the horse's movements and leading to increased pain and muscle stiffness. [8]

Research has shown that in individuals with LBP, muscle activation patterns suffer notable adaptations. [13,14] Studies indicate that erector spinae muscles activity is heightened in those with chronic LBP, likely as a compensatory response to pain. This increased activation is thought to contribute to spinal stability, helping to prevent further strain on sensitive structures. [13] In contrast, reduced activation of the multifidus (MF) muscle - a deep stabilizer of the spine - is a strong predictor of successful outcomes in targeted training programs. [14] Furthermore, research indicates that core stability exercises offer significant therapeutic benefits for patients with non-specific low back pain, helping to decrease pain intensity and functional disability while enhancing quality of life, core muscle activation, and muscle thickness. Combining core stability exercises with other exercise modalities has been shown to further improve outcomes in pain and disability. [15]

This study aimed to assess the effectiveness of a twelve-week specific training program (STP) in reducing lower back pain-related disability, enhancing functional movement, and examining changes in muscle activation in four lower back muscles among a broad sample of equestrian athletes with non-specific LBP.

Study design: Quasi-experimental study

6.2. Materials and methods

6.2.1. Participants

Approval for the study was granted by the University of Évora's ethics committee, under the reference number GD/29678/2022. Before the study began, all participants gave their written informed consent. A total of fifty-six equestrian athletes, aged 18 to 54, participated in the study. Participants were required to be between 18 and 60 years of age, have had at least one episode of non-specific lower back pain (pain or discomfort in the lower back) within the last 12 months, and must have been engaging in equestrian activities for at least one hour per week during the previous year. Forty-five participants were recruited from various institutions such as the Mafra School of Arms, the Polytechnic Institute of Portalegre, the Portuguese Dressage Academy, and the Alter Real Stud, while the remaining were recruited via personal contacts and riding schools across Portugal. The athletes were divided into two groups: the experimental group (N=28) and the control group (N=28), based on their availability to participate in the training program. In the control group, four participants (2 female and 2 male) did not complete the study due to personal reasons unrelated to the study itself.

6.2.2. Assessments and procedures

In the current study, all assessments were performed by a single examiner, who received specialized training and certification from experts in the field. Data collection occurred twice, with the first assessment conducted between January and February and the second between April and May of 2024. All assessments and testing procedures for each participant were completed within a single session on the same day.

6.2.2.1. Questionnaire

Participants completed a questionnaire that gathered information on their equestrian experience, pain experienced during equestrian activities, and pain-related disability, which was assessed using the Roland Morris Disability Questionnaire[16'17], where participants scored items to generate a total disability score, with higher scores indicating greater levels of disability.

6.2.2.2. Functional movements screening tests (FMS)

The functional movement screening tests [18-21] focus on evaluating essential movement patterns to pinpoint potential movement restrictions and compensatory habits. This assessment primarily aims to gauge an individual's performance across multiple movement aspects, including flexibility, joint mobility, muscular strength, coordination, balance, and proprioceptive control. Lower FMS scores have been associated with an elevated risk of injury. [18-21] The full FMS assessment comprises seven specific movements, three of which include clearing tests; further instructions for FMS application are available in other sources. [18-21] For the present protocol, only two of the seven FMS tests were administered: the deep squat (DS) and the trunk stability push-up (TPU).

6.2.2.3. Experimental protocol

The experimental protocol consisted of simultaneous electromyography (EMG), accelerometry (ACC) and kinematic data collection. The 8-channel biosignalsplux© [22] kit was used for EMG, after electrodes were placed each athlete performed two exercises for EMG normalization purposes on the biosignalsplux© force platform: sitting with eyes open focusing on a point and sitting with eyes closed, for 1 minute each. Once these exercises were completed, the athlete (with electrodes still attached) moved to the riding arena, where a 10-meter straight corridor on flat ground – with four vertical markers set 2 meters apart - had been prepared, **Figure VI.1**. A Movesense © [23] accelerometer was placed on the riders' lower backs (over the lumbar vertebrae L4/L5) to collect data on lumbar movement during riding. Electrodes and accelerometer were secured using Kinesio tape. The biosignalsplux © wireless hub and mobile devices – with the Movesense © and the OpenSignals © [24] apps – were carried by the rider in a waist pack. The rider was instructed to warm up the horse freely for 5 minutes before beginning the data collection protocol on horseback. The rider was asked to perform four distinct exercises on both right and left reins (direction of travel) – walk, rising trot, sitting trot and canter - always passing through the corridor. As a concern to horse welfare and to prevent any potential injury, the three gait conditions were performed sequentially, yet the rein was randomly chosen. Riders were instructed to perform a medium walk, working trot, and working canter to the best of their abilities (further information on horse gait can be found elsewhere [25)]. If the horse became disunited, cantered on the wrong lead, or if the exercise was not executed as intended, the exercise was repeated. For kinematic analysis, all of the horseback part of the protocol was video recorded using the camera of an iPhone 14 Pro Max © [26], the device was positioned 10 meters away from the corridor and centered with the markers, **Figure VI.1**.

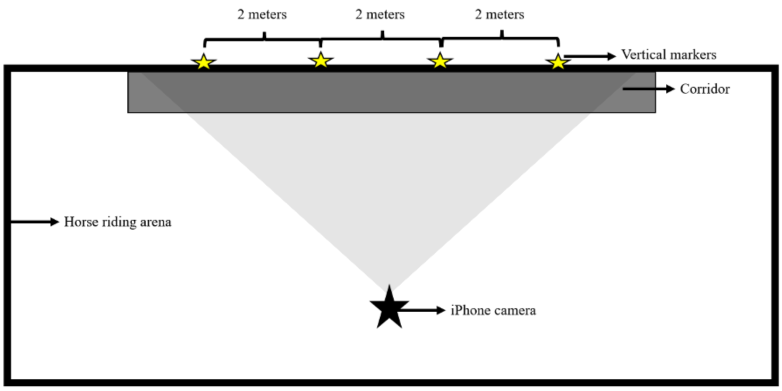


Figure VI.1. *Set up of the riding arena*

6.2.2.4. Horse set-up

Due to the assessments and testing procedures being conducted at various locations, different horses were used for nearly every rider. However, riders were instructed to use the same horse and tack for both assessment sessions to ensure consistency. The selection of the saddle and other tack was made by the rider, based on personal preference, their specific riding discipline and the horse being used.

6.2.2.5. Electromyography

Surface electromyography (sEMG) was used to record the electrical activity of muscles, specifically the *lumbar multifidus* (MF) (located 2 cm lateral to the lumbosacral junction, with reference to the L5 spinous tuberosity) and the *erector spinae iliocostalis* (ESI) (immediately above and below the L1 level) on both the left and right sides, across four channels. The reference electrode was placed on the spinous process of one of the thoracic or lumbar vertebrae. To optimize data quality, the skin was prepared and cleaned with alcohol prior to electrode placement, and a conductive gel was used on the electrodes. Bipolar Ag/AgCl electrodes with a conductive area of 10 mm² (Ambu – White Sensor) were attached to the subjects, oriented parallel to the muscle fibers and placed on the muscle belly. The electrodes, with a diameter of 18 mm, were positioned 20 mm apart. EMG signals were collected at a sampling frequency of 1,000 Hz.

6.2.3. Training program

The authors, a team of sports and health experts developed the training program, focusing on the specific needs of equestrian athletes with lower back pain. The program aimed to improve key fitness elements such as muscular endurance, symmetry, functional movement, flexibility, mobility, and stability. The design of the program was guided by relevant literature and supported by specialized applications. [27'28]

The specific training program (STP) was structured as a 12-week regimen, involving strength and stretching exercises three days per week. Each day featured six bodyweight exercises, making a total of 18 different exercises that progressively increased in challenge, with significant adjustments made during weeks 5 and 9. The number of repetitions and the duration of isometric holds also increased over time. Additionally, the program incorporated three distinct warm-up and stretching routines targeting the primary muscles used in the STP. The STP is available on Appendix Materials 7 and 8. During the experiment period participants were asked to weekly rate the perceived exertion of each training session using Borg's perceived exertion scale (PES).[29]

6.2.4. Data analysis

The questionnaires were uploaded to LimeSurvey ©[30] to streamline data collection and facilitate seamless integration with statistical analysis software. Borg's PES was categorized according to the author's recommendations [29], with the following classifications: 1 and 2 as very light; 2 and 3 as light; 5 and 6 as moderate activity; 7 and 8 as vigorous activity; 9 as very hard; and 10 as maximal effort.

The kinematic data was analyzed with the KINOVEA © [31] annotation tool, used for sport analysis, this tool allows for capture, observation, annotation and measurement. The tool was used to create annotations and facilitate the synchrony of EMG and ACC data, **Figure VI.2**.

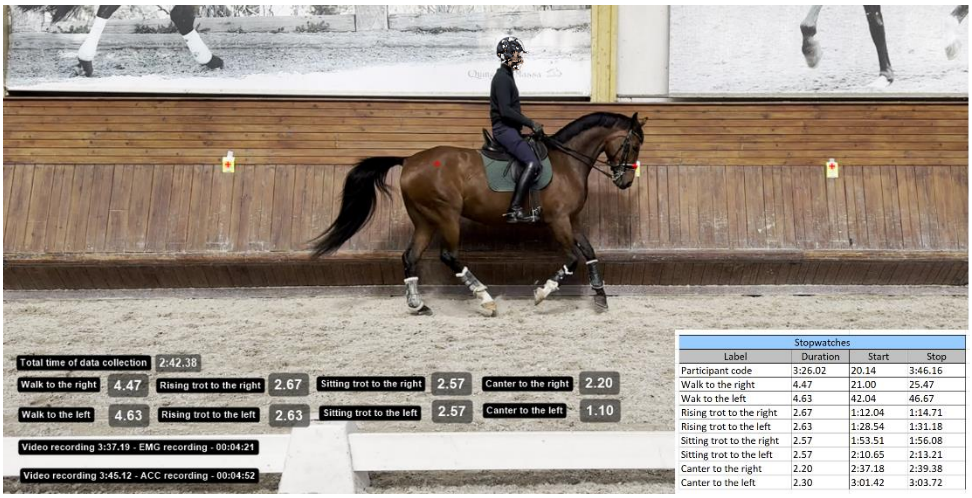


Figure VI.2. *Example of how the KINOVEA app was used for data analysis.*

6.2.4.1. Data analysis – EMG and ACC

EMG collection was carried out in the MF and ESI on both the left and right sides, across four channels. This analysis provides a structured approach to processing and analyzing EMG and ACC data to assess muscle activation and movement dynamics. The key steps include data import, filtering, normalization, downsampling, root mean square (RM-Square) calculation, and saving and visualizing results. Each step is carefully designed to enhance the quality and interpretability of the data, allowing for a comprehensive assessment of muscle activity and movement.

Each step — data import, filtering, normalization, downsampling, RM-Square calculation, and visualization — is carefully structured to provide a meaningful interpretation of muscle activity. By adjusting for individual variability through normalization and aligning sampling rates between EMG and ACC data, the script ensures that the data reflects true physiological patterns rather than noise or artifact.

The choice of window size for RM-Square calculation is critical, as it determines how well the script captures muscle activity changes while minimizing noise. The use of a 2000-sample window aligns with the study's goals by providing a stable measure of muscle activation levels. By visualizing and saving the data, the script enables researchers to monitor and document muscle activation over time, facilitating comparisons across sessions and participants.

This structured approach allows researchers to extract valuable information from complex EMG and ACC data, forming a solid foundation for further biomechanical analysis or clinical research. The saved figures and Excel summary provide a well-organized overview of results, making it easy to interpret and communicate findings. This script is ideal for studies requiring repeated analysis of muscle activation patterns, enabling efficient processing and clear documentation of outcomes across multiple sessions or experimental phases.

6.2.4.1.1. Initial Setup and File Preparation

The first and essential step was to set up a clean environment, ensuring that no residual data from previous runs could interfere with the current analysis. Sampling rates are defined at 1000 Hz for EMG and 200 Hz for ACC data, which determine the resolution and precision of the analysis. These rates affect how much detail can be observed in the data and ensure that both signals are aligned for analysis. Additionally, parameters for filtering the EMG signal are set, allowing for fine-tuning of the signal to remove noise and isolate relevant muscle activity frequencies. For each file, a unique identifier is extracted from the filename, which is used to label outputs. This consistent labeling simplifies tracking and interpretation of results for each dataset, making it easier to organize and compare outputs across multiple files.

6.2.4.1.2. EMG Data Import and Filtering

The script processes EMG data files with an *_OF* suffix, which contain raw EMG data potentially contaminated by noise from equipment or the environment. Only the relevant columns (representing EMG channels) are selected, while the first few rows are skipped to exclude metadata. A custom function created for this purpose is applied, which likely includes bandpass and smoothing filtering. The bandpass filter retains frequencies associated with muscle activity, while the smooth filter removes noise and other low-frequency interference, focusing the signal on frequencies that reflect muscle contractions.

After filtering, the script isolates a subset of the filtered EMG data (1000 samples around the midpoint) as a baseline for normalization. The baseline was obtained from the rider's activation of the muscles in an almost still position before the tests in a quiet place, sitting on a bench with his eyes closed. This baseline ensures consistency across different sessions or participants, allowing for reliable comparison by adjusting for individual variability in muscle activity. By using this baseline as a reference, the script ensures that variations in EMG intensity represent true physiological changes rather than random fluctuations. Next, a second EMG file obtained from the rider's tasks, which represent a different experimental phase. This file undergoes the same filtering steps. Once processed, the EMG data is normalized by dividing each sample by the baseline mean of the previously isolated segment. This normalization is essential as it adjusts the data for individual variability, providing a relative measure of muscle activity that can be compared across sessions and participants.

6.2.4.1.3. ACC Data Processing

The ACC data is then imported from files labeled with an *_ACL1* suffix. The relevant columns containing acceleration values are extracted and filtered. Initially, a bandpass filter is applied to capture frequencies associated with human movement, followed by a lowpass filter to smooth the signal and reduce high-frequency noise. These filtering steps enhance the movement data by minimizing random fluctuations, helping to reveal relevant patterns in the acceleration signal without interference.

6.2.4.1.4. Downsampling and Visualization

To align with the accelerometer's lower sampling rate (200 Hz), the EMG data is downsampled. This involves selecting every nth sample, reducing data size and computational load without losing significant information. Downsampling facilitates efficient analysis by ensuring both EMG and ACC data are processed at the same rate, simplifying comparisons.

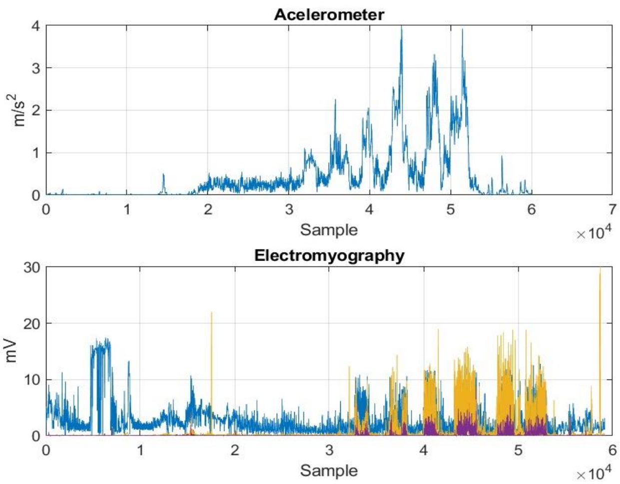


Figure VI.3. *Time-series plots of accelerometer (top) and electromyography (bottom) signals*

Figure VI.3 with two subplots was generated, displaying the filtered ACC data and the downsampled EMG data side by side. This visualization provides a quick overview of muscle activation and acceleration patterns over time, helping assess signal quality and characteristics. The user is prompted to select a specific time segment for further analysis. This flexibility allows focused examination of intervals that may correspond to specific events, such as muscle contractions or specific movements.

6.2.4.1.5. Saving Processed Data and RM-Square Calculation

After defining the time segment, the script saves the plot as a JPEG file and exports the filtered ACC and EMG data as text files. By combining visual and numerical outputs, the script ensures comprehensive documentation of the results, supporting further analysis or inclusion in reports. After defining the interval, the RM-Square for each EMG channel using a sliding window of 2000 samples was calculated. RM-Square is a measure of signal amplitude that reflects muscle activation intensity, commonly used in EMG analysis to quantify muscle engagement. The sliding window approach smooths the data, capturing average activation levels over time. This RM-Square calculation provides insights into the muscle's engagement level and highlights the impact of interventions or movement patterns on muscle activity.

6.2.4.1.6. Final Visualization and Data Export

Each EMG channel's RM-Square values are plotted, with different colors representing each channel, creating a clear visualization of muscle activation levels over time (**Figure VI.4**).

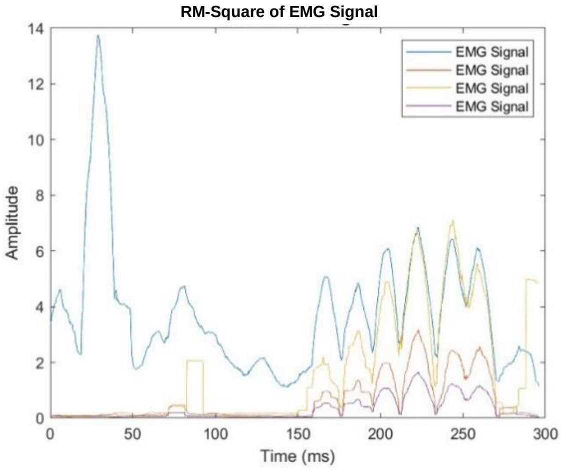


Figure VI.4. *Root Mean Square (RM-Square) calculation for each EMG channel, performed using a sliding window of 2000 samples*

This plot is saved as a new JPEG file, labeled with the unique identifier for easy tracking. The average RM-Square values for each file are then written to a new Excel file (CRD2.xlsx), where each file's results are saved in a separate row. This Excel file provides a consolidated summary of RM-Square values across all files, allowing for easy comparison of muscle activation across sessions, participants, or experimental phases.

6.2.4.1.7. Choosing the Window Size for RM-Square Calculation

An essential consideration for RM-Square calculation is choosing the correct window size (NUMPOINTS). With a sampling rate of 200 Hz, each sample represents 5 milliseconds. The window size typically ranges between 100 ms (20 samples) and 500 ms (100 samples), balancing responsiveness and noise reduction. Shorter windows capture rapid changes in muscle contractions but may retain noise, while longer windows provide smoother trends at the cost of temporal precision. For this study, a window size of 2000 samples, corresponding to 10 seconds, was chosen. This large window is suitable for capturing an overall trend in muscle activation, offering a robust measure of average intensity.

6.2.5. Statistical analysis

Statistical treatment of data was performed using Jamovi, version 2.3 [32]. Descriptive statistics of baseline characteristics, age and workload were summarized as medians with interquartile ranges. Counts and categorical statistics were used to present data on equestrian discipline and stable duties.

The statistical analysis for evaluating the specific training program's effects involved multiple steps. Initially, the Kolmogorov–Smirnov test was used to assess the normality of each variable's distribution. For variables that met normality assumptions, repeated measures ANOVA was applied. For non-parametric variables, statistical significance between post- and pre-intervention values was determined using the Mann-Whitney U test. Variables associated with the training program were presented as medians, and a line chart was generated to depict trends in these variables across the 12-week intervention period.

For the analysis of post-intervention muscle activation levels, independent samples t-tests were conducted to compare the Experimental and Control groups. Confidence intervals for the mean differences were calculated at the 95% level to assess statistical significance. The Mann-Whitney U test was conducted for comparisons of post-intervention muscle activation levels between the Control and Experimental groups. Effect sizes were calculated using the rank biserial correlation to provide a measure of the intervention's impact on muscle activation.

Visual representation of the data was achieved through raincloud plots, which combined dot plots, box plots, and density plots for EMG data. These plots illustrate individual data points, summary statistics (medians and interquartile ranges), and data distributions, enabling the comparison of activation levels between the Experimental and Control groups.

6.2.5.1. Sample size

The study's sample size was calculated using G*Power software[33], with the Roland Morris Disability Score (RMDS) chosen as the standardized measure of disability for Portuguese equestrian athletes experiencing lower back pain, as identified in prior research. [34] A cutoff value of 4 for the RMDS, as determined by previous authors, [35] was set as a functional target, aiming to reduce the average RMDS score to 4 or below. To calculate effect size, the baseline mean RMDS for this population was 5.39, with the intervention's objective to reduce it to 4, resulting in an effect size of 0.31. To achieve sufficient statistical power to detect meaningful differences between experimental and control groups, repeated measures ANOVA was initially chosen for analysis, with an alpha of 0.05 and a power level of 0.95 to strengthen the study's robustness. G*Power simulations determined a minimum sample of 36 participants was needed.

Post hoc analysis indicated a non-normal distribution for the RMDS, rendering repeated measures ANOVA unsuitable. As a result, effect size and sample size were recalculated with a non-parametric approach using the Mann-Whitney U test. This recalculated effect size, based on the Mann-Whitney U statistic and sample sizes, yielded a Cohen's d effect size of 1.796. G*Power software, now applied for independent group comparisons, confirmed a revised minimum sample size requirement of 20 participants.

6.3. Results

6.3.1. Baseline characteristics of participants

Of the participants, 55.8% (N = 29) were active in a single equestrian discipline, while the remainder engaged in two or three different disciplines. A large majority (88.5%) participated professionally in equestrian sports, either through direct work with horses, riding, or as coaches, with equestrianism serving as their primary occupation. The remaining participants pursued equestrian activities recreationally, indicating it was neither their main activity nor source of income. The Mann-Whitney U tests revealed no significant differences between groups for number of disciplines (p = 0.73) or professional involvement in equestrianism (p = 0.283).

Table VI.1. *Anthropometric Profile and Equestrian Engagement Characteristics of the Sample*

		Experimental group	Control group
Age (years)		20 (5)	24,5 (15)
Workload (h/week)		7,5 (8,5)	12,5 (19,50)
Stable duties (yes/no)		19/9	18/6
Equestrian discipline (n)	General riding	8	3
	Dressage	17	14
	Show jumping	14	15
	Eventing	1	6
	Endurance	3	0

n – Number of participants; Age and workload are presented as median and interquartile range.

Some baseline anthropometric and equestrian characteristics of the sample can be found in more detail in **Table VI.1**. When comparing intergroup characteristics (Mann-Whitney U tests), the control group showed a notably higher mean age (p = 0.007), though this difference was not reflected in workload (p = 0.376). For stable duties, the Pearson Chi-squared test indicated no significant differences between groups (p = 0.571

6.3.2. Pre and post intervention outcomes

Table VI.2 provides the baseline characteristics and post-intervention outcomes for the experimental and control groups regarding RMDS and FMS. The Kolmogorov-Smirnov test indicated non-normal distributions for both variables. Results are presented as medians with interquartile ranges, and significance was evaluated using Mann-Whitney U tests.

The RMDS revealed a significant reduction in disability for the experimental group compared to the control group. FMS also showed a significant difference, indicating a positive effect of the intervention on functional movement.

Table VI.2. *Baseline and Post-Intervention Functional Movement and Disability Scores for Experimental and Control Groups (Non-Parametric Analysis)*

	Experimental group		Control group		Mann-Whitney U	*P*
	Baseline	Post-intervention	Baseline	After 12-weeks		
RMDS	5 (6,5)	2 (3,75)	2,5 (6,75)	3 (7,5)	73,5	0,000
FMS	2 (1)	3 (2)	3 (2,75)	3,5 (2,75)	448	0,024

RMDS – Roland Morris Disability Score; FMS – Functional Movement Scores.

The Mann-Whitney U tests revealed significant differences between the experimental and control groups in several variables post-intervention, including functionality (RMDS), pain affecting performance, and the effect of riding on perceived LBP, as shown in **Table VI.3.**

Table VI.3. *Outcomes of Specific Training Program on RMDS Functionality, and pain in Equestrian Activities for Experimental and Control Groups*

	Experimental group			Control group			U-Test	P-value
	I	NC	W	I	NC	W		
RMDS - Functionality	9	19	0	0	22	2	209	0,001
Pain affecting performance	11	15	2	1	21	2	224	0,011
Pain when riding	4	23	1	2	20	2	303	0,570
Riding increases pain	8	18	2	0	21	3	234	0,013

I, NC and W represent the number of participants. I = Improved after intervention; NC = No Change after intervention; W = Worsened after intervention.

6.3.3. Perceived exertion during the training program

Weekly levels of perceived exertion (PE), measured by Borg's PES, felt by the experimental group during the training program, are shown in **Figure VI.5**, a line chart illustrating the median trends in PE levels over the 12-week intervention period.

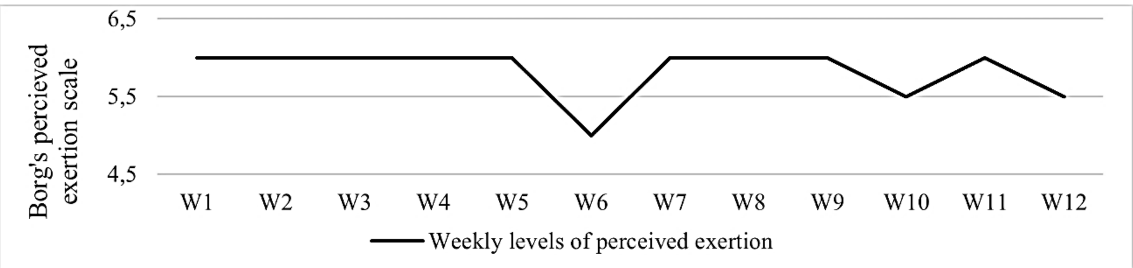


Figure VI.5. *Borg's Perceived Exertion Scale depicting weekly levels of perceived exertion for the STP The graph illustrates the median perceived exertion levels (minimum 0, maximum 10) over the 12-week intervention period. W represents the week.*

6.3.4. EMG results

This analysis examines the effect of an intervention on activation levels across four muscles (ESI-Left, ESI-Right, MF-Left, and MF-Right) by comparing the Experimental and Control groups through independent samples t-tests. For each muscle, the results consistently show lower activation levels in the Experimental group after the intervention, suggesting that the intervention led to significant reductions in muscle activation relative to the Control group, as seen in **Table VI.4**.

Table VI.4. *The average of the Root Mean Square (RM-Square) values calculated for each EMG channel across defined intervals.*

		ESI-Left		ESI-Right	
		Before	**After**	**Before**	**After**
Group	Control	3,67 ± 3,85	4,18 ± 4,06	8,58 ± 8,28	7,27 ± 11,31
	Experimental	2,60 ± 2,97	1,02 ± 1,61	3,68 ± 5,19	1,99 ± 5,39
		MF-Left		**MF-Right**	
		Before	**After**	**Before**	**After**
Group	Control	11,08 ± 13,2	11,22 ± 11,7	15,58 ± 25,97	5,64 ± 5,89
	Experimental	8,44 ± 18,31	2,16 ± 2,23	8,89 ± 15,94	2,13 ± 5,62

Values presented as means with standard deviation, before intervention and after intervention.

For ESI-Left, the Experimental group showed significantly reduced activation levels compared to the Control group. The Control group had a higher mean activation and greater spread in values, whereas the Experimental group displayed lower mean levels and a tighter distribution, **Figure VI.6**. The mean difference for ESI-Left was -3.165, with a 95% confidence interval of [-4.932, -1.398], indicating a statistically significant difference in ESI-Left activation levels between groups. This suggests that the intervention effectively reduced ESI-Left activation in the Experimental group, as reflected by the significant mean difference and confidence interval that does not include zero.

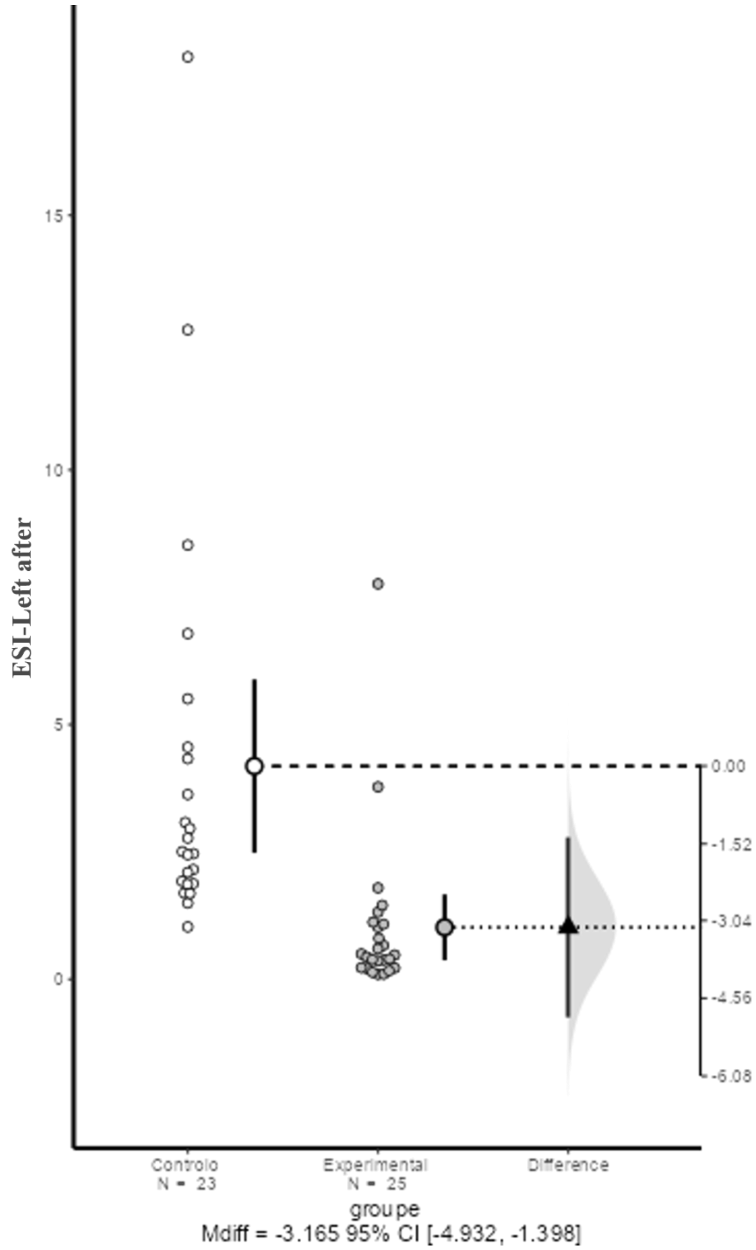


Figure VI.6. *Comparison of ESI-Left activation levels after intervention between the Control and Experimental groups. The larger dot in each group represents the mean activation level, with vertical lines indicating the 95% confidence intervals.*

The results for ESI-Right show a consistent trend, with the Control group demonstrating higher activation levels than the Experimental group. The Experimental group's ESI-Right values were generally lower and displayed less variability, suggesting a more pronounced reduction in muscle activation due to the intervention, **Figure VI.7**. The mean difference for ESI-Right was -5.283, and the 95% confidence interval was [-10.364,

-0.201], again not including zero, which confirms the statistical significance of the reduction. This suggests that the intervention led to a meaningful decrease in ESI-Right activation in the Experimental group, making it significantly lower than in the Control group.

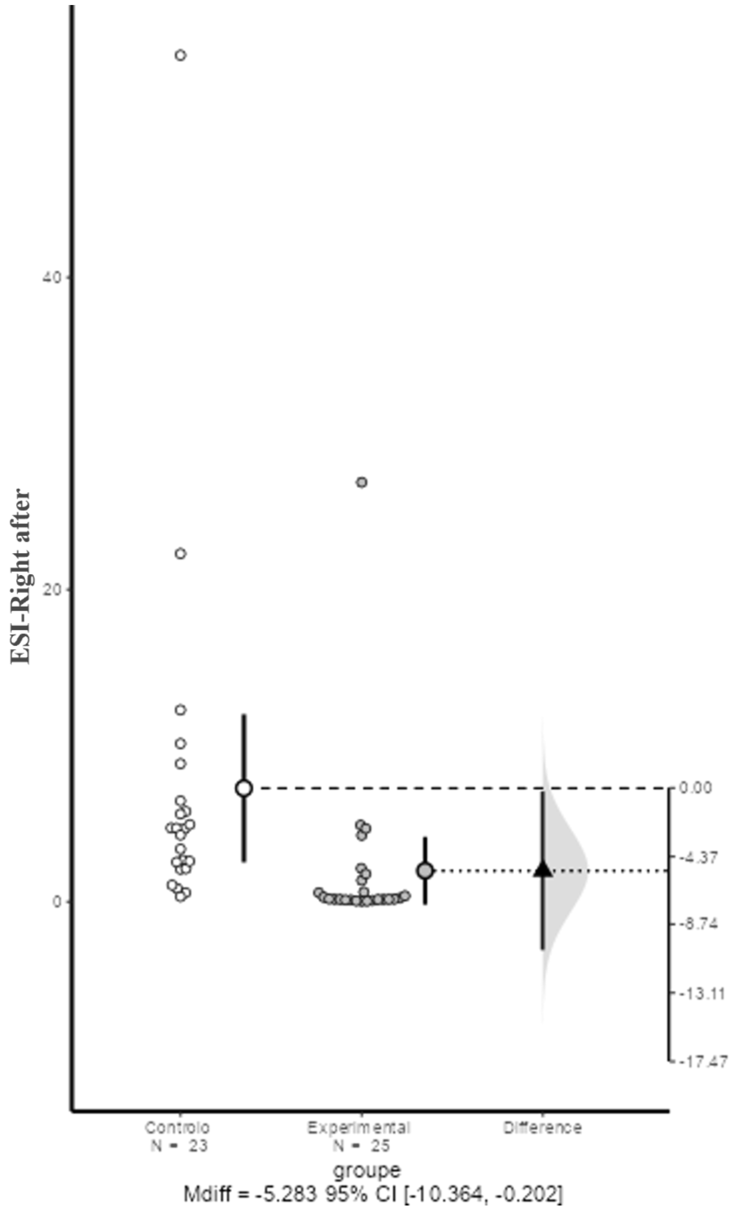


Figure VI.7. *Comparison of ESI-Right activation levels after intervention between the Control and Experimental groups. The larger dot in each group represents the mean activation level, with vertical lines indicating the 95% confidence intervals.*

The Control group had higher and more variable MF-Left activation levels, while the Experimental group showed significantly lower and more consistent values, **Figure VI.8**. The estimated mean difference was -9.065, with a 95% confidence interval of [-13.859, -4.270]. The fact that this confidence interval does not cross zero further confirms a statistically significant reduction in MF-Left activation in the Experimental group post-intervention. This marked reduction indicates that the intervention had a substantial effect on MF-Left, as evidenced by the large mean difference and narrow confidence interval, which imply a meaningful effect of the intervention in lowering muscle activation.

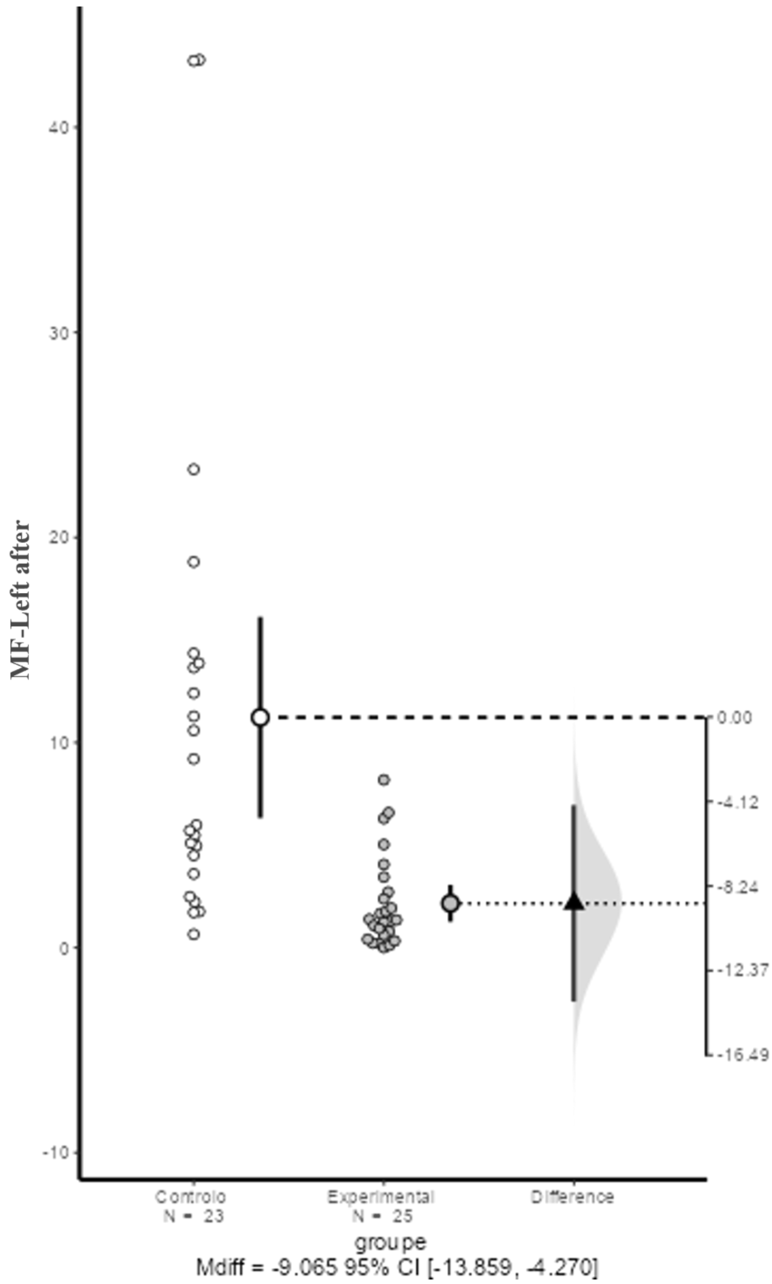


Figure VI.8. *Comparison of MF-Left activation levels after intervention between the Control and Experimental groups. The larger dot in each group represents the mean activation level, with vertical lines indicating the 95% confidence intervals.*

The t-test results for MF-Right reveal that the Experimental group exhibited a significantly lower mean activation level compared to the Control group after the intervention. Lastly, the distribution of MF-Right values shows that the Control group had higher activation with a broader range, while the Experimental group displayed lower values that were tightly clustered around the mean, **Figure VI.9**. The mean difference between the groups was estimated at -3.51, with a 95% confidence interval of [-6.853, -0.167]. Since this interval does not include zero, it indicates a statistically significant difference in MF-Right activation between the groups, supporting the conclusion that the intervention had a measurable impact on reducing MF-Right activation in the Experimental group.

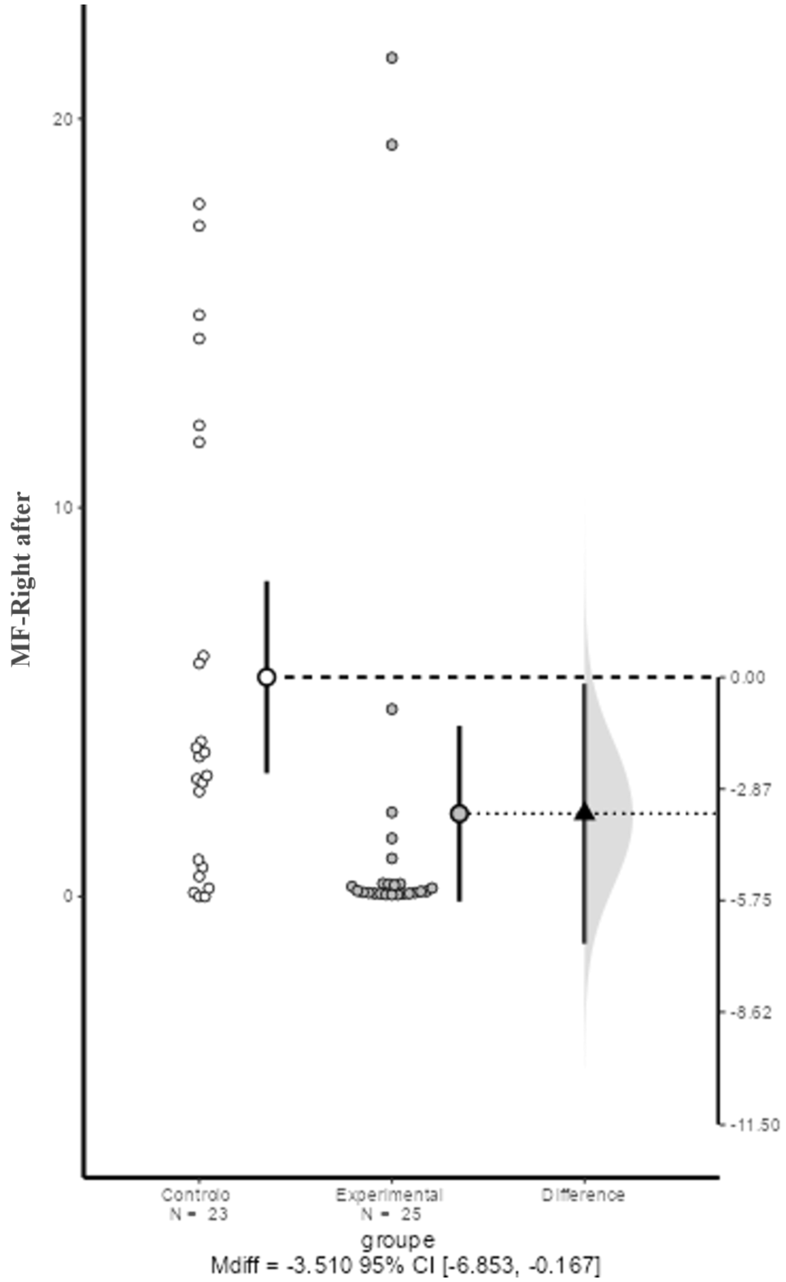


Figure VI.9. *Comparison of MF-Right activation levels after intervention between the Control and Experimental groups. The larger dot in each group represents the mean activation level, with vertical lines indicating the 95% confidence intervals.*

Across all four muscles, the intervention led to significant reductions in activation levels in the Experimental group relative to the Control group. Each t-test confirmed a statistically significant difference between groups, with all confidence intervals for the mean differences excluding zero. These findings consistently indicate that the intervention had a meaningful impact on reducing muscle activation, as demonstrated by the negative mean differences and narrow confidence intervals. The Experimental group showed consistently lower activation levels across ESI-Left, ESI-Right, MF-Left, and MF-Right post-intervention, supporting the effectiveness of the intervention in reducing muscle activity across multiple muscles. The results provide robust evidence that the intervention was successful in lowering muscle activation, as seen in the significant reductions for each muscle group.

Table VI.5. *Results of the Mann-Whitney U test comparing post-intervention activation levels across four muscles (ESI-Left, ESI-Right, MF-Left, and MF-Right) between the Control and Experimental groups.*

	Statistic	p	Effect Size *	
ESI-Left	44	< ,001	0,847	large
ESI-Right	77	< ,001	0,732	large
MF-Left	77	< ,001	0,732	large
MF-Right	136	0,002	0,527	large

** - Rank Biserial Correlation - Mann-Whitney U teste*

Table VI.5 includes the test statistic, p-values, and effect sizes, with effect sizes calculated using the rank biserial correlation. All muscles show statistically significant differences ($p < 0.05$), with large effect sizes for each muscle: ESI-Left (0.847), ESI-Right (0.732), MF-Left (0.732), and MF-Right (0.527). The large effect sizes suggest that the intervention had a strong impact on reducing activation levels in the Experimental group for all muscles.

6.4. Discussion

This study evaluated the effects of a structured twelve-week STP on lower back muscle activation, disability, and functional movement in equestrian athletes with non-specific LBP. Notably, the study utilized a range of variables, including subjective measures dependent on participant perceptions, objective variables that rely on human observation, and purely objective data that are independent of individual perception. The consistency of the findings across these varied types of variables further supports the efficacy of the STP. Our results demonstrate significant reductions in muscle activation levels in the ESI and MF muscles, as well as improvements in functional movement scores and reductions in pain-related disability. These findings highlight the potential of targeted core stability and strengthening exercises to alleviate LBP and enhance muscular efficiency in equestrian athletes.

Prior studies have investigated exercise interventions targeting low back pain in equestrian athletes. Weeks et al.[36] conducted an eight-week exercise program focused on strengthening muscles relevant to equestrian demands, aiming to improve pain management in riders with chronic LBP. Their sample comprised nine participants (aged 23-65), who completed the Brief Pain Inventory and Patient Specific Functional Scale before and after the intervention. Results showed significant improvements in pain severity, pain interference, and riding functionality, with statistical significance (P<0.01) supporting the reported improvements. Similarly, Biau et al.[37] implemented a ten-week program emphasizing stretching and core muscle strengthening, specifically targeting future professional riders. In their study, 20 participants were divided into two groups, with one group receiving the intervention. The researchers evaluated rider movement quality and LBP perception both before and after the program, with movement outcomes showing significant improvement. Siedlecka et al.[38] examined the effects of a six-week core stability training regimen, designed to strengthen the lumbar spine in female amateur equestrians. The study involved 23 participants, divided into a control and an intervention group. Researchers collected self-reported data using the Oswestry LBP Disability Scale and an additional questionnaire on gynecological complaints, though no statistical tests or p-values were provided to support the results. Findings were presented through tables and graphs, detailing reductions in both lumbar pain and minor gynecological complaints after the training period. Overall, these studies vary in their methodologies, sample sizes, duration, and measurements, impacting the strength and generalizability of their findings. In contrast, the present study offers a more extended intervention period (12 weeks) with a larger sample size and includes both subjective and objective measurements, providing a more comprehensive assessment of the program's impact on equestrian athletes with non-specific LBP. The following sections will explore these findings in greater detail, considering their implications for training interventions and injury prevention in equestrian sports.

6.4.1. Disability and functionality

Numerous studies have demonstrated the positive impact of exercise interventions and specialized programs in reducing disability among individuals with various forms of lower back pain, including chronic non-specific LBP, chronic LBP, and general LBP. [39-43] In the present study, the STP intervention was effective in reducing RMDS scores and improving functionality. These outcomes highlight the STP's dual role in alleviating LBP symptoms and enhancing functional capacity, allowing participants to engage more effectively in both equestrian activities and daily tasks. This emphasizes the importance of tailored training programs in managing LBP and promoting functional improvements in athletic populations.

6.4.2. Functional movements

In the present study, the STP led to significant improvements in functional movement scores, indicating enhanced functional movement and increased muscular stability among participants. These findings are consistent with previous research [39-42], supporting the efficacy of tailored exercise interventions in improving functional movement through objective physical tests and enhancing overall functionality in athletes with chronic non-specific or general LBP.

Previous studies have demonstrated that individuals with LBP typically perform poorly on specific functional movement tests, such as the deep squat, hurdle step, inline lunge, active straight leg raise, trunk push-up, and rotational stability screens, when compared to individuals without LBP.[44] To date, no exercise intervention studies have incorporated the Functional Movement Screen Tests as a variable within the equestrian athlete population. However, the FMS has been utilized in earlier research to assess functional movement in equestrians. For example, Deckers et al.[45] reported that equestrian athletes with higher levels of back pain tend to score lower on the FMS, while Lewis, Douglas, Edwards, and Dumbell [46] found that, although equestrian athletes scored higher than non-riders, they still performed worse than athletes from other sports. These studies highlight the relevance of the FMS in evaluating functional movement in equestrian athletes, even though it has not yet been integrated into exercise interventions specifically designed for this population.

6.4.3. Pain in Equestrian Sports

The STP had a marked effect on pain perception, particularly regarding performance and the perception that riding exacerbated pain in the experimental group. These results suggest that the STP effectively modified pain perceptions and reduced the negative impact of pain on performance. This highlights that targeted training programs not only enhance physical strength and stability but also bolster athletes' mental resilience and confidence, contributing to a more positive and effective riding experience. In contrast, minimal changes were observed in the control group over the 12-week study period. Participants continued to experience persistent challenges related to lower back pain, likely limiting their full engagement in equestrian activities. These ongoing symptoms underscore the importance of addressing non-specific lower back pain through targeted rehabilitation and structured training. Simply maintaining general physical activity without a specialized program appears insufficient to provide meaningful relief or improve overall functionality.

6.4.4. Perceived exertion during the training program

In designing the specific training program, a primary concern was to develop an effective program for an athletic population that reduces lower back pain without exacerbating symptoms. Additionally, the program aimed to avoid inducing excessive workload and muscle soreness, ensuring that equestrians could continue to perform their daily professional activities with ease. Consequently, the objective of the STP was to effectively address lower back pain while safeguarding the well-being of participants and their professional performance.

A progressive overload training program was implemented, incorporating variations in the number of repetitions, duration of isometric holds, and types of exercises to increase intensity over the course of the program while maintaining moderate intensity, as suggested by previous authors [47]. This objective was achieved, as demonstrated in **Figure VI.5**, which shows that an average level of moderate intensity/activity was consistently maintained throughout the intervention period.

This result, along with the notable reduction in pain intensity, perceived disability levels, and pain experienced during equestrian activities, as well as the improvement in functional movement scores, supports the effectiveness of the current specific training program.

6.4.5. Muscle activation

The present study analyzed muscle activation by examining the effects of the intervention on four key muscles: ESI-Left, ESI-Right, MF-Left, and MF-Right. Results indicated that the intervention significantly reduced muscle activation across all four muscles in the Experimental group compared to the Control group. These reductions were reflected in lower mean activation levels and decreased variability, suggesting a more efficient use of muscle activation following the intervention. Statistically significant differences between groups, coupled with large effect sizes, highlight the substantial impact of the intervention.

Research as shown that individuals with LBP often exhibit altered patterns of muscle activation.[13'14] In particular, the erector spinae muscles frequently display increased activity in these individuals, which is thought to serve as a compensatory mechanism to stabilize the spine and prevent further injury. [13] Although this response may temporarily enhance stability, it can also increase discomfort and place additional strain on already vulnerable structures. Existing literature suggests that this heightened muscle activity may contribute to the persistence of chronic pain.[13] Additionally, a reduction in MF muscle activation is recognized as a strong predictor of positive outcomes in specialized exercise interventions.[14] The findings of the present study align with this view, as the intervention led to significant reductions in MF muscle activation in the Experimental group, suggesting that the program effectively addressed this critical factor.

Supporting the design of the present STP, studies indicate that core stability exercises offer considerable benefits for individuals with non-specific LBP, contributing to reductions in pain intensity and functional disability, as well as improvements in quality of life, core muscle activation, and muscle thickness.[15] Moreover, combining core stability exercises with other forms of exercise has been shown to further enhance outcomes in pain relief and disability reduction.[15] Furthermore, comparisons between core stability and general exercises in treating LBP indicate that both types of exercise are effective in reducing pain and disability, with both producing similar outcomes in muscle activation patterns, and neither demonstrating a clear advantage over the other. [48] Overall, our findings underscore the potential of targeted interventions to modulate muscle activation patterns in equestrian athletes, which may contribute to improved performance and reduced strain on muscles engaged in equestrian activities.

In the present study, the reduction in muscle activation levels could suggest that the STP helped equestrian athletes develop more efficient neuromuscular control over their lower back muscles. Improved neuromuscular control can allow muscles to activate only as much as needed for stability and movement, rather than over-activating as a compensatory response to pain or instability, which is often observed in individuals with LBP.[49'50'51]

When lower back muscles, such as the ESI and MF, are consistently overactive, they can become fatigued and strained, contributing to discomfort or pain.[50'51'52] Overactivation might also signal that these muscles are compensating for weak or imbalanced muscles elsewhere, particularly the core or hip stabilizers, leading to a cycle where pain persists or worsens due to muscular inefficiency.[51'53] By training the muscles through a targeted program like the STP, participants can learn to stabilize the lower back with less muscle activation, suggesting that their body has become better at coordinating movement and maintaining posture.[14]

This enhanced efficiency in muscle use could mean that the STP helped retrain participants' neuromuscular system, allowing it to respond to the horses' movement demands in a more balanced way. This would not only reduce strain on the back but could also contribute to pain relief and improved functional capacity by restoring a more natural, efficient muscle activation pattern.[54] For example, rather than relying heavily on the lumbar muscles for stability, athletes may start to engage their core and lower body more effectively, distributing the physical demands across multiple muscle groups. This redistribution of effort reduces reliance on any single muscle group, minimizing fatigue and discomfort and potentially decreasing the likelihood of reinjury.

6.4.6. Practical Applications

The findings of this study underscore the value of incorporating structured, progressive core stability and strengthening exercises into the training regimens of equestrian athletes with LBP. Given the demands placed on the lower back during equestrian activities, these exercises can be strategically implemented to build muscular efficiency, reduce compensatory muscle activation, and alleviate pain, thereby supporting athletes' physical performance and resilience.

The structured twelve-week STP used in this study offers a practical framework that coaches, trainers, and sports therapists could readily adapt to the specific needs of equestrians. By gradually increasing intensity through variations in repetitions, isometric holds, and exercise types, athletes can safely improve core stability without exacerbating symptoms. This progressive approach also allows for flexibility in training volume, ensuring equestrians can integrate the STP alongside their riding routines without excessive fatigue or soreness, which is essential for maintaining consistent performance.

Moreover, the program's focus on reducing muscle activation presents a tailored method for minimizing overactivation in these critical areas, which could otherwise lead to chronic strain. Incorporating similar core stabilization techniques may help equestrian athletes not only manage pain but also enhance postural control and balance, which are crucial for maintaining an effective riding posture. By implementing such targeted programs, equestrian professionals and therapists can offer athletes a practical, evidence-based approach to managing LBP and enhancing long-term performance.

6.5. Conclusions

This study demonstrated that a structured twelve-week STP significantly reduces lower back pain, disability, and enhances functional movement and muscle activation efficiency in equestrian athletes with non-specific LBP. The STP's impact on ESI and MF muscles was reflected in decreased activation levels and variability, suggesting improved muscular efficiency and reduced compensatory strain. Improvements in RMDS scores and functional movement support the STP's role in not only alleviating LBP symptoms but also in bolstering functional capacity, thereby enabling athletes to engage more effectively in both equestrian activities and daily tasks. The structured, progressive approach of the STP allowed participants to benefit from moderate-intensity training without exacerbating symptoms, promoting both physical and mental resilience.

Ultimately, this study supports the efficacy of the STP as a practical intervention for managing non-specific LBP in equestrian athletes. By enhancing muscle efficiency, reducing pain, and improving functional movement, the STP represents a valuable strategy for equestrian athletes to address the unique physical demands of their sport, thereby promoting injury prevention and long-term functional enhancement.

6.6. Limitations and suggestions for future research

This study has several limitations that should be considered. First, the quasi-experimental design limits the ability to draw definitive causal conclusions, as participants were not randomly assigned to groups. The lack of randomization introduces the potential for selection bias, which may affect the generalizability of the results. Further research using a randomized controlled trial design is recommended to strengthen the evidence regarding the efficacy of the STP for equestrian athletes with non-specific LBP.

Secondly, while muscle activation was measured using surface electromyography, factors such as electrode placement and skin impedance could introduce variability in the data. However, the research team believes that these factors did not significantly affect the reliability of the measurements in the present study.

Thirdly, this study is limited by the nature of equestrian sports, which involve the participation of an animal over which we have limited control. As such, repeatability of measurements can be influenced by factors related to the horse's behavior and performance. To minimize this variability, participants used the same horse for both data collection sessions. Additionally, participants were asked to choose a consistent and well-trained horse whenever possible. All trials were conducted in quiet indoor arenas with minimal distractions, ensuring consistent conditions for the horses and reducing potential sources of variation.

Additionally, the study relied on self-reported pain and disability measures, which introduce potential subjectivity. Variations in how participants interpret their symptoms could have influenced the results.

Some variables, such as asymmetry in muscle activation and baseline differences participant characteristics between groups, were not analyzed in this study but could be relevant for future research. Although these differences were present, they are not expected to impact the study's validity, as the analysis focused on within-group changes rather than between-group comparisons.

Overall, while these limitations are acknowledged, the study still offers meaningful insights into the effectiveness of structured exercise interventions for managing lower back pain among equestrian athletes.

6.7. References

1. Faber M, Johnston C, Van Weeren PR, Barneveld A. Repeatability of back kinematics in horses during treadmill locomotion. *Equine Vet J*. 2002;34(3):235-241. https://doi.org/10.2746/042516402776186010

2. Münz A, Eckardt F, Witte K. Horse–rider interaction in dressage riding. *Hum Mov Sci*. 2014; 33:227-237. https://doi.org/10.1016/j.humov.2013.09.003

3. Peham C, Kotschwar AB, Borkenhagen B, Kuhnke S, Molsner J, Baltacis A. A comparison of forces acting on the horse's back and the stability of the rider's seat in different positions at the trot. *Vet J*. 2010;184(1):56-59. https://doi.org/10.1016/j.tvjl.2009.04.007

4. Lagarde J, Peham C, Licka T, Kelso JS. Coordination dynamics of the horse-rider system. *J Mot Behav*. 2005 ;37(6) :418-424. https://doi.org/10.3200/JMBR.37.6.418-424

5. Eckardt F, Witte K. Horse–rider interaction: A new method based on inertial measurement units. *J Equine Vet Sci*. 2017;55:1-8. https://doi.org/10.1016/j.jevs.2017.02.016

6. Hobbs SJ, St George L, Reed J, Stockley R, Thetford C, Sinclair J, et al. A scoping review of determinants of performance in dressage. *PeerJ*. 2020;8. https://doi.org/10.7717/peerj.9022

7. Elmeua González M, Šarabon N. Muscle modes of the equestrian rider at walk, rising trot and canter. *PLoS One*. 2020;15(8). https://doi.org/10.1371/journal.pone.0237727

8. Hobbs S.J, Baxter J, Louise B, Laura-An R, Jonathan, S, Hilary CM. Posture, Flexibility and Grip Strength in Horse Riders. *J Hum Kinet*. 2014; 42(1): 113-125. doi:10.2478/hukin-2014-0066

9. Cejudo A, Ginés-Díaz A, Rodrígues-Ferrán O, Santonja-Medina F, Sainz De Baranda P. Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes. *Children*. 2020; 7(10): 172. doi:10.3390/children7100172

10. Lewis V, Baldwin K. A preliminary study to investigate the prevalence of pain in international event riders during competition, in the United Kingdom. *Comp Exerc Physiol*. 2018; 14(3): 173-181. https://doi.org/10.3920/CEP180006

11. Lewis V, Kennerley R. A preliminary study to investigate the prevalence of pain in elite dressage riders during competition in the United Kingdom. *Comp Exerc Physiol*. 2017; 13(4): 259-263. doi:10.3920/CEP170016

12. Lewis V, Nicol Z, Dumbell L, Cameron L. A Study Investigating Prevalence of Pain in UK Horse Riders over Thirty-Five Years Old. *Int J Equine Sci*. 2023; 2(2): 9-18.

13. Koch C, Hänsel F. Chronic non-specific low back pain and motor control during gait. *Front Psychol*. 2018;9:2236. https://doi.org/10.3389/fpsyg.2018.02236

14. Hebert JJ, Koppenhaver SL, Magel JS, Fritz JM. The relationship of transversus abdominis and lumbar multifidus activation and prognostic factors for clinical

success with a stabilization exercise program: a cross-sectional study. *Arch Phys Med Rehabil*. 2010;91:78–85.

15. Frizziero A, Pellizzon G, Vittadini F, Bigliardi D, Costantino C. Efficacy of core stability in non-specific chronic low back pain. *J Funct Morphol Kinesiol*. 2021;6(2):37. https://doi.org/10.3390/jfmk6020037

16. Roland, M, Morris, R. A Study of the Natural History of Back Pain: Part I. *Spine* 1983, 2, 141–144. https://doi.org/10.1097/00007632-198303000-00004.

17. Monteiro, J, Faísca, L, Nunes, O, Hipólito, J. Roland Morris disability questionnaire-adaptation and validation for the Portuguese speaking patients with back pain. *Acta Med*. Port 2010, 23, 761–766. Available online: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/728 (accessed on 26 August 2023).

18. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function–part 1. *N Am J Sports Phys Ther*. 2006; 1(2), 62.

19. Cook G, Burton L, Hoogenboom B. Pre-participation screening: The use of fundamental movements as an assessment of function–Part 2. *N Am J Sports Phys Ther*. 2006; 1(3), 132.

20. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 1. *Int J Sports Phys Ther*. 2014; 9(3), 396.

21. Cook G, Burton L, Hoogenboom BJ, Voight M. (2014). Functional movement screening: the use of fundamental movements as an assessment of function-part 2. *Int J Sports Phys Ther*. 2014; 9(4), 549.

22. BIOSIGNALSPLUX. PLUX Wireless Biosignals System. Lisbon, Portugal: PLUX Wireless Biosignals S.A.; n.d. Available from: https://www.plux.info

23. Movesense Ltd. Movesense Sensor (192730003571). Vantaa, Finland: Movesense Ltd.; n.d. Available from: https://www.movesense.com

24. PLUX Wireless Biosignals S.A. OpenSignals (r)evolution [software]. Version 2.2.5. Lisbon, Portugal: PLUX Wireless Biosignals S.A.; 20231023. Available from: https://www.pluxbiosignals.com/collections/opensignals

25. Fédération Équestre Internationale. FEI Dressage Judging Manual: To be considered in connection with the FEI Dressage Rules and the FEI Dressage Handbook Guidelines for Judging. Lausanne, Switzerland: Fédération Équestre Internationale; 2024.

26. Apple Inc. iPhone 14 Pro Max [device]. Cupertino, CA: Apple Inc.; 2022. Available from: https://www.apple.com

27. Walker BE. The big book of stretch routines. s.l.: The Stretching Institute; 1971. ISBN 978-0-9943733-2-8.

28. Muscle & Motion. Strength training by Muscle & Motion [Internet]. Muscle and Motion Ltd; 2024 [cited 2024 Sep 1]. Available from: https://app.strength.mus-cleandmotion.com/exercises/all

29. Borg G. Borg's perceived exertion and pain scales. *Hum kin*. 1998.

30. LimeSurvey [Internet]. 2024 [cited 2024 Oct 1]. Available from: https://www.limesurvey.org/pt

31. Charmant J. Kinovea [computer program]. Version 0.9.5. 2021. Available from: https://www.kinovea.org

32. The jamovi project. jamovi (Version 2.3) [Computer software]. Sydney, Australia: The jamovi project; 2023. Available from: https://www.jamovi.org

33. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-91. doi: 10.3758/BF03193146.

34. Duarte C, Santos R, Fernandes O, Raimundo A. Prevalence of Lower Back Pain in Portuguese Equestrian Riders. *Sports*. 2024; 12(8): 207. doi:10.3390/sports12080207

35. Stratford PW, Riddle DL. A Roland Morris Disability Questionnaire Target Value to Distinguish between Functional and Dysfunctional States in People with Lower back pain. *Physiother Can*. 2016; 68, 29–35. https://doi.org/10.3138/ptc.2014-85.

36. Weeks RA, McLaughlin PA, Vaughan BR. The efficacy of an eight-week exercise program for the management of chronic low back pain in the equestrian population. *The Journal of sports medicine and physical fitness*. 2024. 10.23736/S0022-4707.24.15830-6

37. Biau S, Le Navenec C, Pycik E, Noury B. *Un cycle de dix semaines d'étirement et de renforcement des muscles du tronc impacte l'activité équestre et diminue les douleurs lombaires des futurs cavaliers professionnels*. A ten weeks program of stretching and strengthening core muscles improves performance and reduces lower back pain of future professional riders. *Sci Sports*. 2024; 39(1):36-42. https://doi.org/10.1016/j.scispo.2023.02.002

38. Siedlecka M, Aniśko B, Placek K, Wójcik M. Low back pain occurrences and gynecological disorders in female equestrians and strengthening of core stability muscles lumbar spine. *Fizjoterapia Polska*. 2023; 23(4). DOI:10.56984/8zg20a371

39. Van Middelkoop M, Rubinstein SM, Kuijpers T, Verhagen AP, Ostelo R, Koes BW, van Tulder MW. A systematic review on the effectiveness of physical and rehabilitation interventions for chronic non-specific low back pain. *Eur Spine J*. 2011; 20, 19-39. https://doi.org/10.1007/s00586-010-1518-3

40. Gordon R, Bloxham S. A systematic review of the effects of exercise and physical activity on non-specific chronic low back pain. In: *Healthcare*. 2016; 4(2):22. MDPI. https://doi.org/10.3390/healthcare4020022

41. Searle A, Spink M, Ho A, Chuter V. Exercise interventions for the treatment of chronic low back pain: a systematic review and meta-analysis of randomised controlled trials. *Clin Rehabil*. 2015; 29(12):1155-67. https://doi.org/10.1177/0269215515570379

42. Luomajoki H, Kool J, De Bruin ED, Airaksinen O. Improvement in low back movement control, decreased pain and disability, resulting from specific exercise

intervention. *BMC Sports Sci Med Rehabil*. 2010; 2:1-7. https://doi.org/10.1186/1758-2555-2-11

43. Moffett JK, Torgerson D, Bell-Syer S, Jackson D, Llewlyn-Phillips H, Farrin A, et al. Randomised controlled trial of exercise for low back pain: clinical outcomes, costs, and preferences. *BMJ*. 1999; 319(7205): 279-83. https://doi.org/10.1136/bmj.319.7205.279

44. Alkhathami KM, Alqahtani B. Comparing the Scores of The Functional Movement Screen™ in Individuals with Low Back Pain versus Healthy Individuals: A Systematic Review and Meta-Analysis. *Int J Sports Phys Ther*. 2024; 19(7), 834. 10.26603/001c.120199

45. Deckers I, De Bruyne C, Roussel NA, Truijen S, Minguet P, Lewis V, et al. Assessing the sport-specific and functional characteristics of back pain in horse riders. *Comp Exerc Physiol*. 2021; 17(1): 7-15. doi:10.3920/CEP190075

46. Lewis V, Douglas JL, Edwards T, Dumbell L. A preliminary study investigating functional movement screen test scores in female collegiate age horse-riders. *Comp Exerc Physiol*. 2019; 15(2): 105-112. doi:10.3920/CEP180036

47. Grummt M, Hafermann L, Claussen L, Herrmann C, Wolfarth B. Rating of Perceived Exertion: A large cross-sectional study defining intensity levels for individual physical activity recommendations. *Sports Med Open*. 2024; 10(1):71. https://doi.org/10.1186/s40798-024-00729-1

48. Shamsi M, Mirzaei M, HamediRad M. Comparison of muscle activation imbalance following core stability or general exercises in nonspecific low back pain: a quasi-randomized controlled trial. *BMC Sports Sci Med Rehabil*. 2020;12:1-9. https://doi.org/10.1186/s13102-020-00173-0

49. Russo M, Deckers K, Eldabe S, Kiesel K, Gilligan C, Vieceli J, et al. Muscle control and non-specific chronic low back pain. Neuromodulation. 2018;21(1):1-9. doi:10.1111/ner.12738

50. Mercè BB, Tine W, Lieven D, Mira M, Dorien G. Differences in myoelectric activity of the lumbar muscles between recurrent and chronic low back pain: a cross-sectional study. BMC Musculoskelet Disord. 2021;22:1-9. doi:10.1186/s12891-021-04623-9

51. Frizziero A, Pellizzon G, Vittadini F, Bigliardi D, Costantino C. Efficacy of core stability in non-specific chronic low back pain. J Funct Morphol Kinesiol. 2021;6(2):37. doi:10.3390/jfmk6020037.

52. Demoulin C, Crielaard JM, Vanderthommen M. Spinal muscle evaluation in healthy individuals and low-back-pain patients: a literature review. Joint Bone Spine. 2007;74(1):9-13. doi:10.1016/j.jbspin.2006.02.013.

53. Knarr BA, Reisman DS, Binder-Macleod SA, Higginson JS. Understanding compensatory strategies for muscle weakness during gait by simulating activation deficits seen post-stroke. Gait Posture. 2013;38(2):270-5. doi:10.1016/j.gaitpost.2012.11.027.

54. Smrcina Z, Woelfel S, Burcal C. A systematic review of the effectiveness of core stability exercises in patients with non-specific low back pain. Int J Sports Phys Ther. 2022;17(5):766. doi:10.26603/001c.37251.

Chapter VII

Discussion

Conclusions

Chapter VII – Discussion and Conclusion

7.1. Discussion

In this thesis, we sought to address key knowledge gaps surrounding lower back pain (LBP) in equestrian athletes (EA), focusing on the prevalence, risk factors (RF), and effective management of LBP through a targeted intervention. The primary objectives of the thesis were threefold. First, we aimed to identify the real prevalence of LBP among EA, with a specific focus on Portuguese riders, to better understand the extent to which this population is impacted compared to general and other athletic populations. Second, we investigated the RF associated with LBP in EA overall and explored additional, unique factors within the Portuguese equestrian community. Third, we designed and implemented a specific 12-week training program (STP) tailored to equestrian demands, evaluating its effects on several variables: perceived disability in daily life and equestrian activities, body composition, functional movement, LBP intensity, muscle activation, and athlete movement patterns while riding. We also compared outcomes for the intervention and control groups to assess the program's effectiveness.

Our hypotheses anticipated that LBP prevalence in EA would be higher than that observed in the general population and other athletic groups, with a significant proportion of Portuguese riders affected. We expected that the STP would lead to substantial reductions in LBP intensity and perceived disability, along with improvements across multiple outcomes, including functional movement patterns and body composition. Lastly, we hypothesized that changes in muscle activation and improved functional movement following the intervention would correlate positively with reduced LBP symptoms, suggesting the STP's potential to improve both physical and performance-related outcomes in EA.

Building on these objectives and hypotheses, the following discussion delves into key areas of investigation, starting with the prevalence of lower back pain in EA and its unique mechanisms of injury, then exploring RF identified across studies and in our specific population. Finally, we examine the role and outcomes of exercise interventions, particularly the effectiveness of our structured training program in addressing LBP symptoms in EA.

7.1.1. Lower back pain prevalence in equestrian athletes

Equestrian sports (ES) are considered high-risk[1] due to the elevated potential for traumatic injuries (TI) associated with handling and riding horses. In addition to these injuries, EA are also significantly affected by overuse injuries[2] (OI), which can increase their susceptibility to falls and further TI [3]. Furthermore, inadequate recovery from a TI can lead to persistent pain and musculoskeletal symptoms [4]. Several studies have reported on injuries in equestrian sports, including traumatic, acute and overuse injuries [2'5'6'7'8'9'10'11] and musculoskeletal pain [12'13'14'15'16]. Among TI, the head [2'7'11], back [2'7'11], and extremities [11] are the most commonly affected areas. For OI, the back [2'5'7'11], neck [11] and lower extremities [5'7'11] are frequently reported. Additionally, EA often report musculoskeletal pain, with the lower back [8'10'12'13'15'16], shoulder [10'12'15], lower extremities [10'15'16], and neck[10'13'14] being the most affected regions. Notably, the lower back consistently appears as the area with the highest musculoskeletal pain complaints. [8'10'13'14'15'16] Kraft et al.[17] designed a study to investigate potential associations between LBP and lumbar spine disk degeneration or MRI changes in EA. However, they found no significant associations, concluding that while LBP is prevalent among riders, it is not directly linked to MRI evidence of spinal degeneration. Conversely, Tsirikos et al.[18] found that jockeys exhibited more pronounced spinal degeneration compared to age-matched non-riding controls. Although some riders in this study reported LBP, the authors did not correlate these complaints with either clinical or radiographic findings.

One of the main findings of **Paper 1**, the systematic review**,** of the present thesis is that the prevalence of LBP in EA is indeed higher than in general population[19] across all recall periods—lifetime, one-year, and point prevalence. The lifetime, one year and point prevalence of LBP in EA is consistently higher than the prevalence seen in other athletic populations.[20'21] Furthermore, chronic low back pain (CLBP) prevalence is also higher in EA than in the general population, regardless of physical activity levels [19'22].

7.1.2. Risk factors for Lower back pain in equestrian athletes

Several RF have been reported in relation to back injuries [2'6'7'11'14'18], back pain (BP) [4'24'25], and LBP [10'17'23'26] in equestrian athletes (EA), including younger age [6], older age [25], fewer years of riding experience [2'6], lower skill level [7], participation in higher levels of competition [2'4'11'24], saddle type [4'8'23], longer exposure to equestrian sports [11'18'23], sex (female)[23], history of acute injury [11], lack of protective gear use [2], posture and asymmetries while riding [14'24], lower functional movement and movement control capacity [4], equestrian discipline practiced [17], performing stable duties [26], and practicing equestrian sports/ horse-riding [10'18'25'26]. Unfortunately, many of these RF are not adequately supported by statistical tests, proper methodologies, or robust study designs. **Paper 2** of the present thesis found that the probability of suffering from LBP was higher in individuals with higher weekly riding workloads, those who reported equestrianism as their primary occupation, and those who performed daily stable duties. Additionally, LBP-related disability was associated with older age, higher BMI, and daily performance of stable duties. In our **Paper 1** - systematic review, the RF for LBP supported by strong evidence included younger age [27], weight [27], body fat percentage [28], low trunk muscle endurance [28], altered range of motion [28'29], sex (female)[30], older age [26], higher BMI [26], equestrian discipline [27], high hours of workload [26'27], practicing ES as a profession [26], and performing stable duties [26]. However, these findings were often inconsistent and difficult to reconcile with existing literature. While some evidence points to sport-specific factors - such as the physical demands of riding and related tasks - as possible contributors to the increased prevalence of LBP, definitive risk factors remain unclear due to methodological inconsistencies and the absence of standardized assessment tools..

7.1.3. Role of exercise interventions in LBP symptoms in EA

Exercise interventions and specific training programs have shown promising outcomes for managing LBP symptoms across various populations. Research highlights the effectiveness of such interventions in reducing disability [31'32'33'34'35], pain intensity levels [31'32'34], functionality – subjective and objective [31'32'33'34], in individuals with chronic non-specific LBP [31'32], CLBP [33], non-specific LBP [34], as well as general LBP [35]. Moreover, studies suggest that a reduction in multifidus muscle activation predict favorable outcomes following exercise-based interventions [36]. Core stability exercises, particularly when combined with other exercise types, have been shown to positively influence muscle activation patterns and muscle thickness, offering significant benefits for individuals with non-specific LBP [37'38].

Prior studies have investigated exercise interventions targeting low back pain in equestrian athletes. Weeks et al.'s [39] eight-week exercise program, focused on equestrian-specific muscle strengthening, significantly improved pain severity, pain interference, and riding functionality. Biau et al.'s [40] ten-week stretching and core strengthening program, improved movement quality and LBP perception. Siedlecka et al.[41] examined a six-week core stability regimen targeting lumbar strength in female amateur riders, with reported reductions in lumbar pain, disability and minor gynecological complaints.

In this thesis, we developed a specialized, well-structured training program designed to alleviate LBP symptoms in EA, with a large sample size and a comprehensive approach that incorporated both subjective and objective measurements. The findings from **Papers 3** and **4** demonstrated significant improvements across multiple fronts. The STP - "Rider Back, No Pain and Gain Program" led to notable reductions in Roland Morris Disability scores, RMDS functionality, and a decrease in pain intensity both in daily life and particularly during equestrian activities. It also enhanced functional movements, muscular stability, and overall performance, while modulating muscle activation patterns, specifically reducing multifidus and erector spinae activation. The structured, progressive nature of the program allowed participants to engage in moderate-intensity training without exacerbating symptoms, promoting both physical and mental resilience.

These results highlight the effectiveness of the STP "Rider Back, No pain and Gain" in not only improving physical capabilities but also boosting mental confidence in athletes. Ultimately, both studies support the STP as an effective and practical intervention for managing non-specific LBP in equestrian athletes, by improving muscle efficiency, reducing pain, and enhancing functional movement, the STP proves to be a valuable strategy for meeting the physical demands of equestrian sports and fostering injury prevention and long-term functional improvement.

7.2. Conclusions

This thesis addresses critical aspects of lower back pain in equestrian athletes, focusing on its prevalence, risk factors, and effective management strategies. Through a systematic review and three empirical studies, this work highlights the higher prevalence of LBP in EA compared to the general population and other athletic groups. Factors such as increased weekly riding workloads, stable duties, and equestrianism as a primary occupation were found to significantly elevate the likelihood of experiencing LBP among Portuguese equestrian athletes. Despite the identification of various potential risk factors, the inconsistent methodologies and lack of standardized assessment tools in existing literature necessitate further research to refine our understanding of what factors pose a higher risk for LBP in this population.

The thesis further emphasizes the importance of exercise-based interventions in managing LBP symptoms. The 12-week specific training program – Rider Back, No pain and Gain, designed specifically for the unique demands of equestrian sports, proved highly effective in alleviating LBP. Significant improvements were observed in pain intensity, disability scores, and functional movement, as well as in muscle activation efficiency, particularly in the lumbar muscles. These findings support the use of structured, progressive training as a non-pharmacological approach to managing LBP, helping athletes improve both their physical capabilities and psychological resilience. The program not only reduced pain but also enhanced muscular efficiency, allowing athletes to perform more effectively in equestrian activities and daily tasks.

In conclusion, this thesis demonstrates that targeted exercise interventions, such as the STP developed here, are a valuable strategy for managing non-specific LBP in equestrian athletes. By addressing the specific physical demands of equestrian sports, the STP contributes to improved muscle efficiency, reduced pain, and enhanced functional movement, ultimately supporting injury prevention and promoting long-term functional enhancement for EA.

7.3. Limitations

This thesis has several limitations that should be considered. **Paper 1** - the systematic review, while offering valuable insights into the prevalence and risk factors of lower back pain (LBP) in equestrian athletes, had some methodological constraints. The review process was not blinded, which could introduce bias, particularly since some studies included in the review shared authorship with this thesis. The tools used to assess study quality and prevalence, though well-established in general health research, may not have been sensitive enough to the specific needs of athlete populations. Additionally, the interchangeable use of "back pain" and "lower back pain" in some studies created challenges in data interpretation, and the absence of standardized exposure measures for equestrian activities further complicated risk factor assessments. Future research would benefit from more consistent definitions and tailored tools to improve comparability and accuracy in studying LBP in equestrian sports.

Paper 2’s cross-sectional nature and the use of self-reported data also introduced limitations, particularly regarding the potential bias in online questionnaire responses. The Roland Morris Disability Questionnaire (RMDS), though validated, was not specifically adapted for the equestrian population, and the cut-off value used to define functional impairment may not be universally applicable. These factors should be considered when interpreting the study’s findings. Additionally, the associations observed cannot be viewed as causal, highlighting the need for further experimental studies.

Paper 3, while demonstrating the positive effects of a 12-week specific training program (STP) on LBP symptoms, faced limitations related to its non-randomized design, which may have introduced selection bias. The study's generalizability is also limited by the absence of participants aged over 35, and the reliance on self-reported measures for pain and disability adds subjectivity to the findings. Furthermore, the lack of control over dietary habits and other activities outside the training program may have influenced the results. Future research could benefit from randomized designs, larger sample sizes, and longer follow-up periods to better understand the sustainability of the intervention's effects.

Paper 4's quasi-experimental design also posed challenges, particularly in terms of causal inference due to the lack of randomization. Additionally, variability in muscle activation measurements due to factors like electrode placement and skin impedance was a potential limitation, though not expected to significantly affect the results. The study's reliance on self-reported pain and disability further introduces subjectivity. Finally, although some baseline differences between groups were not analyzed, the study focused on within-group changes, mitigating the potential impact of these differences. Despite these limitations, the findings offer valuable insights into the effectiveness of structured exercise interventions for managing LBP in equestrian athletes.

In addition to the limitations identified in the individual studies, time constraints also presented a challenge for this thesis. The need for the student to complete the doctorate promptly due to both personal and professional reasons made time a scarce resource. This limitation impacted various stages of the research process, including the depth of literature review, data collection, and analysis. The tight timeline necessitated prioritizing certain aspects of the thesis, limiting the opportunity for further refinement or additional data collection that could have enriched the findings. Nevertheless, despite these challenges, the research still provides valuable contributions to the field and lays a foundation for future studies to build upon.

In summary, while these limitations should be considered, the research presented in this thesis provides important evidence on the prevalence, risk factors, and effective management strategies for LBP in equestrian athletes, with implications for future research and clinical practice.

7.4. Practical implications/ suggestions for future research

7.4.1. Practical Implications

Tailored Training Programs for Equestrian Athletes: The thesis findings highlight the need for specialized exercise programs designed specifically for equestrian athletes, considering the sport's unique demands. Such programs should address common risk factors, such as high training workloads, repetitive movements, and off-horse activities like stable duties, to prevent and manage lower back pain effectively.

Integration of Physical Rehabilitation in the equestrian athletes' training: The positive effects observed in functional movements and pain reduction suggest that physical rehabilitation strategies, including targeted strength and mobility exercises, should be integrated into regular equestrian training routines off the horse. Emphasizing physical conditioning and muscle balance could help maintain athlete performance and reduce injury risk.

Early Intervention to Prevent Chronic LBP and Sport Abandonment: Given the high prevalence of LBP among equestrian athletes, early detection and intervention are crucial to prevent the progression to chronic pain. The implications of LBP extend beyond health concerns, potentially leading athletes to reduce their training, suspend activities, or give up the sport entirely. Proactive management could minimize these consequences and support long-term participation.

Development of Sport-Specific Assessment Tools: The study findings highlight the need for validated, sport-specific tools to assess pain, functional limitations, and injury risk in equestrian athletes. These tools should be tailored to more effectively detect specific risk factors for injury, such as high training workloads, repetitive movements, and asymmetrical postures. By enhancing the accuracy of injury diagnosis and the evaluation of rehabilitation outcomes, these tools can guide more targeted prevention and treatment strategies. Ultimately, this approach would enable the implementation of tailored training programs and rehabilitation interventions aimed at minimizing injury risks and enhancing overall athletic performance.

Monitoring Workload and Stable Duties: Workload management and the inclusion of stable duties as potential risk factors for LBP should be considered when developing training and rehabilitation plans for equestrian athletes. Reducing harmful postures and incorporating corrective exercises could mitigate the impact of daily equestrian activities on lower back health.

7.4.2. Suggestions for Future Research

Tailoring and Validation of a Sport-Specific Questionnaire: Future research should prioritize the development of a validated, sport-specific questionnaire designed for equestrian athletes. This tool must capture the unique demands of the sport, including workload specifics such as the number of horses ridden, the nature of the riding work, horse characteristics (e.g., young or trained), and off-horse responsibilities like grooming, stable duties, and management. Additionally, it should assess equestrian discipline, competition frequency, skill level, and detailed competition information. Accounting for teaching or training responsibilities and past riding experience for less active or non-active riders is also essential. A holistic and well-structured questionnaire will help better characterize the equestrian athlete’s involvement, and when combined with other validated tools, it can significantly enhance the understanding of injury risks and athletic demands, guiding more effective prevention and treatment strategies.

Validation of the Population-Specific Pain Questionnaire: The development of a validated pain assessment tool tailored to the specific needs of equestrian athletes is crucial for accurately measuring the impact of pain on performance and daily activities. Such a tool should address not only pain during riding but also pain associated with off-horse responsibilities like grooming, stable duties, and horse management, which are integral parts of an equestrian's workload. Future research should focus on refining and validating this questionnaire to ensure its reliability and applicability across diverse equestrian populations, including riders of different skill levels, competition levels, and disciplines. Additionally, the tool should be designed for use in both clinical and research settings, allowing for comprehensive monitoring of pain progression, functional limitations, and treatment outcomes. Incorporating this tool into practice would enhance the understanding of pain patterns in equestrian athletes and guide more targeted rehabilitation and prevention strategies.

Tailoring and Validation of a Population-Specific Disability Questionnaire: Future research should prioritize the development and validation of a comprehensive disability assessment tool specifically designed for equestrian athletes. This questionnaire should be tailored to capture the unique physical demands and challenges faced by equestrians in their daily activities. It would have a broader approach to be sensitive to assess various musculoskeletal issues that impact riding performance and off-horse activities. The tool should cover a wide range of functional limitations that may affect athletes' abilities to compete, train, and teach. By creating a validated, sport-specific disability questionnaire, future research would enhance the ability to accurately measure functional impairments and disabilities in equestrian athletes, ultimately guiding more effective interventions and improving athlete outcomes.

Longitudinal Studies on the Sustainability of Training Program Benefits: While the 12-week intervention demonstrated short-term improvements, future studies should investigate the long-term sustainability of these benefits. Extending follow-up periods could provide valuable insights into the durability of reduced pain, improved functional movement, and the potential for relapse or regression in LBP symptoms.

Randomized Controlled Trials with Larger Sample Sizes: To strengthen the evidence base, future research should involve randomized controlled trials with larger, more diverse samples. This approach would help validate the effectiveness of the training programs, enhance the generalizability of the findings, and account for variability across different equestrian populations.

Exploration of Asymmetry and LBP in Equestrian Athletes: Investigating the relationship between asymmetry, pain, and functional limitations could clarify whether LBP is a consequence of underlying asymmetries or if these asymmetries develop in response to pain. Further research on this topic could help inform targeted interventions aimed at correcting asymmetry and mitigating LBP risk.

Impact and risks of Off-Horse Activities on musculoskeletal pain: Additional studies are needed to explore the role of off-horse activities, such as stable duties and management tasks, in the development and exacerbation of LBP. Understanding the impact of these activities could lead to more comprehensive prevention strategies, including ergonomic adjustments and tailored training programs.

7.5. References

1. Krüger L, Hohberg M, Lehmann W, Dresing K. Assessing the risk for major injuries in equestrian sports. BMJ Open Sport Exerc Med. 2018; 4(1). 10.1136/bmjsem-2018-000408
2. Meyer, H.-L, Scheidgen, P, Polan, C, Beck, P, Mester, B, Kauther, M.D, Dudda, M, Burggraf, M. Injuries and Overuse Injuries in Show Jumping—A Retrospective Epidemiological Cross-Sectional Study of Show Jumpers in Germany. Int. J. Environ. Res. Public Health 2022, 19, 2305. https://doi.org/10.3390/ijerph19042305
3. Lewis, V, Douglas, J.L, Edwards, T, Dumbell, L. A preliminary study investigating functional movement screen test scores in female collegiate age horse-riders. Comp. Exerc. Physiol. 2019, 15, 105–112. https://doi.org/10.3920/CEP180036.
4. Deckers I, De Bruyne C, Roussel NA, Truijen S, Minguet P, Lewis V, et al. Assessing the sport-specific and functional characteristics of back pain in horse riders. Comp Exerc Physiol. 2021; 17(1): 7-15. doi:10.3920/CEP190075
5. Pugh TJ, Bolin D. Overuse injuries in equestrian athletes. Curr Sports Med Rep. 2004;3(6):297-303. doi:10.1007/s11932-996-0003-6
6. Nelson DE, Rivara FP, Condie C, Smith SM. Injuries in equestrian sports. Physician Sportsmed. 1994;22(10):53-60. doi:10.1080/00913847.1994.11710501
7. Ekberg J, Timpka T, Ramel H, Valter L. Injury rates and risk factors associated with eventing: A total cohort study of injury events among adult Swedish eventing athletes. Int J Inj Contr Saf Promot. 2011;18(4):261-7. doi:10.1080/17457300.2010.545129
8. Lewis V, Kennerley R. A preliminary study to investigate the prevalence of pain in elite dressage riders during competition in the United Kingdom. Comp Exerc Physiol. 2017; 13(4): 259-263. doi:10.3920/CEP170016
9. Pilato M, Henry T, Malavase D. Injury History in the Collegiate Equestrian Athlete: Part I: Mechanism of Injury, Demo-graphic Data and Spinal Injury. J Sports Med Allied Health Sci. 2017; 2(3): 3. doi:10.25035/jsmahs.02.03.03
10. Orr R, Canetti E, Pope R, Lockie R, Dawes J, Schram B. Characterization of Injuries Suffered by Mounted and Non-Mounted Police Officers. Int J Environ Res Public Health. 2023; 20(2): 1144. https://doi.org/10.3390/ijerph20021144.

11. Keener MM, Tumlin KI. Self-reported acute injury and chronic pain in American equestrian athletes. Compar Exerc Physiol. 2023;1(aop):1-14. doi:10.1163/17552559-20230021

12. Löfqvist L, Pinzke S, Stål M, Lundqvist P. Riding instructors, their musculoskeletal health and working conditions. J Agric Saf Health. 2009;15(3):241-54. doi:10.13031/2013.27408

13. Lewis V, Baldwin K. A preliminary study to investigate the prevalence of pain in international event riders during competition, in the United Kingdom. Comp Exerc Physiol. 2018; 14(3): 173-181. https://doi.org/10.3920/CEP180006.

14. Wang TJ, Ward T, Nguyen HT, Hurwitz EL. Equestrian-related musculoskeletal injuries presenting to a chiropractic practice: a retrospective chart review of 19 patients. J Chiropr Med. 2023;22(2):103-6. doi:10.1016/j.jcm.2022.07.004.

15. Lewis V, Nicol Z, Dumbell L, Cameron L. A Study Investigating Prevalence of Pain in UK Horse Riders over Thirty-Five Years Old. Int J Equine Sci. 2023; 2(2): 9-18.

16. Lewis V, Dumbell L, Magnoni F. A Preliminary Study to Investigate the Prevalence of Pain in Competitive Showjumping Equestrian Athletes. J Phys Fitness Med Treat Sports. 2018; 4(3). doi:10.19080/JPFMTS.2018.04.555637

17. Kraft CN, Peter PH, Ute B, Mei Y, Oliver D, Christian L, Makus FV. Magnetic Resonance Imaging Findings of the Lumbar Spine in Elite Horseback Riders: Correlations With Back Pain, Body Mass Index, Trunk/Leg-Length Coefficient, and Riding Discipline. *Am J Sports Med*. 2009; 37(11): 2205-2213. doi:10.1177/0363546509336927

18. Tsirikos, A, Papagelopoulos, P.J, Giannakopoulos, P.N, Boscainos, P.J, Zoubos, A.B, Kasseta, M, Nikiforidis, P.A, Korres, D.S. Degenerative Spondyloarthropathy of the Cervical and Lumbar Spine in Jockeys. Orthopedics 2001, 24, 561–564. https://doi.org/10.3928/0147-7447-20010601-12.

19. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F, Woolf A, Vos T, Buchbinder R. A systematic review of the global prevalence of low back pain. *Arthritis rheum*. 2021; 64(6): 2028-2037. https://doi.org/10.1002/art.34347.

20. Trompeter K, Fett D, Platen P. Prevalence of Back Pain in Sports: A Systematic Review of the Literature. *Sports Med*. 2017; 47: 1183-1207. https://doi.org/10.1007/s40279-016-0645-3.

21. Wilson F, Ardern CL, Hartvigsen J, Dane K, Trompeter K, Trease L, et al. Prevalence and risk factors for back pain in sports: a systematic review with meta-analysis. *Br J Sports Med*. 2021; 55(11): 601-607. https://doi.org/10.1136/bjsports-2020-102537.

22. Heneweer H, Vanhees L, Picavet H. Physical activity and low back pain: A U-shaped relation? *Pain*. 2009; 143(1-2): 21-25. doi:10.1016/j.pain.2008.12.033.

23. Quinn, S, Bird, S. Influence of Saddle Type upon the Incidence of Lower Back Pain in Equestrian Riders. Br. J. Sports Med. 1996, 30, 140–144. https://doi.org/10.1136/bjsm.30.2.140.

24. Hobbs S.J, Baxter J, Louise B, Laura-An R, Jonathan, S, Hilary CM. Posture, Flexibility and Grip Strength in Horse Riders. *J Hum Kinet*. 2014; 42(1): 113-125. doi:10.2478/hukin-2014-0066.

25. Kraft C, Urban N, Ilg A, Wallny T, Scharfstädt A, Jäger M, Pennekamp P. *Einfluss der Reitdisziplin und -intensität auf die Inzidenz von Rückenschmerzen bei Reitsportlern*. Influence of the riding discipline and riding intensity on the incidence of back pain in competitive horseback riders. *Sportverletz Sportschaden*. 2007; 21(1): 29-33. doi:10.1055/s-2007-963038

26. Duarte C, Santos R, Fernandes O, Raimundo A. Prevalence of Lower Back Pain in Portuguese Equestrian Riders. Sports. 2024; 12(8): 207. doi:10.3390/sports12080207

27. Ferrante M, Bonetti F, Quattrini M, Mezzetti, M, Demarie S. Low Back Pain and Associated Factors among Italian Equestrian Athletes: a Cross-Sectional Study. MLTJ. 2021; 11(2): 344. doi:10.32098/mltj.02.2021.19

28. Cejudo A, Ginés-Díaz A, Rodrígues-Ferrán O, Santonja-Medina F, Sainz De Baranda P. Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes. Children. 2020; 7(10): 172. doi:10.3390/children7100172

29. Cejudo A, Ginés-Días A, Sainz De Baranda P. Asymmetry and Tightness of Lower Limb Muscles in Equestrian Athletes: Are They Predictors for Back Pain? Symmetry. 2020; 12(10): 1679. doi:10.3390/sym12101679

30. Puszczałowska-Lizis E, Szymański D, Pietrzak P, Wilczyński M. Incidence of back pain in people practicing amateur horse riding. Fizjoterapia polska. 2022; 22. doi.org/10.56984/8ZG1A68mY

31. Van Middelkoop M, Rubinstein SM, Kuijpers T, Verhagen AP, Ostelo R, Koes BW, van Tulder MW. A systematic review on the effectiveness of physical and rehabilitation interventions for chronic non-specific low back pain. Eur Spine J. 2011; 20, 19-39. https://doi.org/10.1007/s00586-010-1518-3

32. Gordon R, Bloxham S. A systematic review of the effects of exercise and physical activity on non-specific chronic low back pain. In: Healthcare. 2016; 4(2):22. MDPI. https://doi.org/10.3390/healthcare4020022

33. Searle A, Spink M, Ho A, Chuter V. Exercise interventions for the treatment of chronic low back pain: a systematic review and meta-analysis of randomised controlled trials. Clin Rehabil. 2015; 29(12):1155-67. https://doi.org/10.1177/0269215515570379

34. Luomajoki H, Kool J, De Bruin ED, Airaksinen O. Improvement in low back movement control, decreased pain and disability, resulting from specific exercise intervention. BMC Sports Sci Med Rehabil. 2010; 2:1-7. https://doi.org/10.1186/1758-2555-2-11

35. Moffett JK, Torgerson D, Bell-Syer S, Jackson D, Llewlyn-Phillips H, Farrin A, et al. Randomised controlled trial of exercise for low back pain: clinical outcomes, costs, and preferences. BMJ. 1999; 319(7205): 279-83. https://doi.org/10.1136/bmj.319.7205.279

36. Hebert JJ, Koppenhaver SL, Magel JS, Fritz JM. The relationship of transversus abdominis and lumbar multifidus activation and prognostic factors for clinical success with a stabilization exercise program: a cross-sectional study. Arch Phys Med Rehabil. 2010;91:78–85.

37. Frizziero A, Pellizzon G, Vittadini F, Bigliardi D, Costantino C. Efficacy of core stability in non-specific chronic low back pain. J Funct Morphol Kinesiol. 2021;6(2):37. https://doi.org/10.3390/jfmk6020037

38. Shamsi M, Mirzaei M, HamediRad M. Comparison of muscle activation imbalance following core stability or general exercises in nonspecific low back pain: a quasi-randomized controlled trial. BMC Sports Sci Med Rehabil. 2020;12:1-9. https://doi.org/10.1186/s13102-020-00173-0

39. Weeks RA, McLaughlin PA, Vaughan BR. The efficacy of an eight-week exercise program for the management of chronic low back pain in the equestrian population. The Journal of sports medicine and physical fitness. 2024. 10.23736/S0022-4707.24.15830-6

40. Biau S, Le Navenec C, Pycik E, Noury B. Un cycle de dix semaines d'étirement et de renforcement des muscles du tronc impacte l'activité équestre et diminue les douleurs lombaires des futurs cavaliers professionnels. A ten weeks program of stretching and strengthening core muscles improves performance and reduces lower back pain of future professional riders. Sci Sports. 2024; 39(1):36-42. https://doi.org/10.1016/j.scispo.2023.02.002

41. Siedlecka M, Aniśko B, Placek K, Wójcik M. Low back pain occurrences and gynecological disorders in female equestrians and strengthening of core stability muscles lumbar spine. Fizjoterapia Polska. 2023; 23(4). DOI:10.56984/8zg20a371

Appendices

Appendix 1 – Ethical approval

Documento	2	2	0	7	4

Comissão de Ética da Universidade de Évora

A Comissão de Ética da Universidade de Évora informa que, com base nas apreciações favoráveis dos seus membros, deliberou dar

Parecer Positivo

para a realização do Projeto: "Caracterização da prevalência de dor lombar em cavaleiros – efeitos de um programa de treino na redução de dor lombar", pela doutoranda **Carlota Beatriz Rico Duarte** sob a supervisão Professor Doutor Armando Manuel Mendonça Raimundo (responsável académico).

Universidade de Évora, 14 de outubro de 2022

O Presidente da Comissão de Ética

(Prof. Doutor Hugo Miguel Cardinho Alexandre Folgado)

Appendix 2 – Systematic review registration

NIHR | National Institute for Health Research

PROSPERO
International prospective register of systematic reviews

Prevalence of Low Back Pain and possible Risk Factors in Equestrian Athletes: a systematic review

To enable PROSPERO to focus on COVID-19 submissions, this registration record has undergone basic automated checks for eligibility and is published exactly as submitted. PROSPERO has never provided peer review, and usual checking by the PROSPERO team does not endorse content. Therefore, automatically published records should be treated as any other PROSPERO registration. Further detail is provided here.

Review methods were amended after registration. Please see the revision notes and previous versions for detail.

Citation

Carlota Beatriz Rico Duarte, Armando Raimundo, Orlando Fernandes, Rute Santos, João Paulo Sousa. Prevalence of Low Back Pain and possible Risk Factors in Equestrian Athletes: a systematic review. PROSPERO 2024 CRD42024568577 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024568577

Review question

Participants: The information that will be sought relating to the participants will be number of participants, age, sex, weight, BMI,

Exposure: The data to be retrieved about exposure will be riding discipline, riding level, competition level, time riding (years), time riding (hours per day or week), equestrian related daily activities

Outcome: The information to be retrieved about outcomes will be location of injury (back or lower back), type of injury (chronic, overuse, pain, others), level of pain.

Methods: The information about methods used to measure low back pain, what standardized questionnaire tools were used, if they were complemented with clinical examination.

Results: Risk factors detected (for example: if the sport is considered a risk factor check if variables like time riding and riding load per week were taken into account)

Discussion: If any prevention tools are suggested. If a study determines that EA that complement ES with other physical activity have less impact of pain, suggesting to complement ES with other sports to prevent pain.

Searches [1 change]

The electronic searches for eligible studies will be conducted within each of the following databases:

- Scopus

- EBSCO

- MEDLINE/ PubMed

To ensure literature saturation, the reference lists of the included studies will be scanned.

Types of studies

Fully published observational studies (cohort, case-control, cross-sectional, case reports, case series) irrespectively of the timeframe window.

Language

English, Portuguese and Spanish.

Date of Publication

20 years time frame (2004-2024)

Types of study to be included [1 change]

Types of studies

Fully published observational studies (cohort, case-control, cross-sectional, case reports, case series)

Condition or domain being studied

The existence of pain is related with the decrease in health, increased prevalence of depression, incapacity and need of health services. The chronic musculoskeletal pain is the most prevalent dire condition between chronic pain disorders. Equestrian sports (ES) demand a very high interaction between horse and rider, where every horse gait (movement) creates different coordination dynamics with the rider's movements. In ES repetitive comprehensive forces of high intensity are exerted on the rider, these are softened and absorbed by the vertical axis of the rider's body, specially by the lumbo-pelvic-hip complex. Low back pain (LBP) is defined as pain and or discomfort located below the costal margin and above the inferior gluteal folds, with or without referred leg pain. LBP in the most frequent musculoskeletal lesion felt by ES athletes (riders) leading to interruptions in training and competition, shifting the dynamic of coordination between horse and rider and contributing to early fatigue, which can enhance the risk of falls with grave consequences.

Participants/population

Types of participants

The review will include people of any age or gender that practice Equestrian Sports. EA that present with LBP due to traumatic injuries will not be included.

Intervention(s), exposure(s)

Types of exposure

Equestrian sports (training and competition): we consider ES all activities were a person rides a horse in all three gaits (walk, trot and canter).

The main equestrian disciplines included are:

- Show-jumping

- Dressage

- Eventing

- Endurance

- Racing

- Western Sports

- Vaulting

Other ES can be considered if the main activity is riding directly on a horse in all three gaits.

We will not include ES like driving, para-equestrian, or rodeo due to their specific characteristics.

The minimal time exposure to the ES considered will be one hour/week and there will be no maximum exposure time.

Comparator(s)/control

Not applicable

Main outcome(s)

The primary outcomes sought are sport related low back pain and/ chronic low back pain, non-specific low back pain and/ chronic low back pain.

Measures of effect

Additional outcome(s)

Secondary outcomes will be sport related back pain and/ chronic back pain, non-specific back pain and/ chronic back pain.

LBP or BP in to be measured standardized questionnaire tools.

Data extraction (selection and coding)

Data Management

The literature search will be done by (CRD and RS) and the raw results will be filtered according to relevance, language and to eliminate duplicate references resulting from the search in different interfaces. It is not predicted to use a systematic review data management software.

Selection process

CRD and RS will independently screen titles and abstracts of the research results against the inclusion criteria. Full reports will be obtained for studies whose titles or abstracts leave uncertainty about meeting the inclusion criteria. After studies selection the lists of studies of both authors conducing the search will be scanned, it is hoped to find a similarity of 90% (or more) to assess the quality of the search strategy and selection process. If such does not happen the team will meet to review the search strategy and selection process.

AR and JPS will then review the selected studies full text reports to decide whether these meet the inclusion criteria and validate the (internal and external) quality of the reports. If needed additional information will be requested to study authors. If any reports are excluded at this time the explanation will be recorded.

Data collection process

A data extraction sheet will be developed. One of the authors will perform the initial data extraction for all included articles and a second author will check all the proceedings. If needed corresponding authors will be contacted to ask about additional information not present in their papers.

Risk of bias (quality) assessment [1 change]

The tool to be used for assessement of quality and risk bias in The Observational Study Quality Evaluation (OSQE), as it is adecuate for the study designs included in the present systematic review. This tool was created in 2021 and has been cited at least 40 times. This tool measures both quality and risk bias.

Strategy for data synthesis

Data will be collected and summarized descriptively with tables and graphs and they will be analyzed through a descriptive narrative synthesis. And will consider all of the above-mentioned data items.

Analysis of subgroups or subsets

Not applicable

Contact details for further information

Carlota Beatriz Rico Duarte

carlota.beatriz.duarte@gmail.com

Organisational affiliation of the review

Universidade de Évora

https://www.uevora.pt/

Review team members and their organisational affiliations

Miss Carlota Beatriz Rico Duarte. Universidade de Évora

Dr Armando Raimundo. Comprehensive Health Research Centre (CHRC)-Universidade de Évora, Portugal

Dr Orlando Fernandes. CHRC - Comprehensive Health Research Centre, Universidade de Évora

Rute Santos. Escola Superior de Biociências de Elvas, Instituto Politecnico de Portalegre

João Paulo Sousa. Universidade de Évora

Type and method of review

Systematic review

Anticipated or actual start date

01 January 2024

Anticipated completion date

31 August 2024

Funding sources/sponsors

CHRC - Comprehensive Health Research Centre, University of Évora

Conflicts of interest

Language

English

Country

Portugal

Stage of review [1 change]

Review Completed not published

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

MeSH headings have not been applied to this record

Date of registration in PROSPERO

23 July 2024

Date of first submission

12 July 2024

Stage of review at time of this submission [1 change]

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Revision note

The systematic review has been completed, not published yet.

The record owner confirms that the information they have supplied for this submission is accurate and complete and they *understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.*

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

23 July 2024
23 July 2024
06 August 2024
20 September 2024

Appendix 3 – Systematic review (Paper 1) supplementary material

3.10. Supplementary material I

3.10.1. Search strategy

Table VIII.1. *Search strategy performed in all databases, number of articles found in each search.*

Database	Filters /restrictions	Nº of articles
Scopus	AT, A, K	134
	AT, A, K (2004-PRESENT)	96
	AT, A, K, English, Portuguese and Spanish (2004-PRESENT)	80
	AT, A, K, German (2004-PRESENT)	13
	Total	**93**
PubMed	All PE words & Lower back pain	33
	All PE words & Lower back pain (2004 – Present)	30
	All PE words & Lower back pain (2004 – Present), E,P&S G	27
	All PE words & Lumbago	22
	All PE words & Lumbago (2004 – Present)	20
	All PE words & Lumbago (2004 – Present), E,P&S G	18
	All PE words & lumbar pain	33
	All PE words & lumbar pain (2004 – Present)	28
	All PE words & lumbar pain (2004 – Present), E,P&S G	25
	All PE words & dorsalgia	72
	All PE words & dorsalgia (2004 – Present)	67
	All PE words & dorsalgia (2004 – Present), E,P&S G	62
	All PE words &lower spine pain	7
	All PE words &lower spine pain (2004 – Present)	6
	All PE words &lower spine pain (2004 – Present), E,P&S G	5
	All PE words & spinal injur*	82
	All PE words & spinal injur*(2004 – Present)	58
	All PE words & spinal injur*(2004 – Present), E,P&S G	49
	All PE words & back pain	72
	All PE words & back pain (2004 – Present)	67
	All PE words & back pain (2004 – Present), E,P&S G	62
	Total	**248**
EBSCO	Txt	246
	Txt, 2004-2024	177
	Txt, English and spanish, 2004-2024	153
	Txt, English and spanish, 2004-2024, academic journals	112
	Txt, German, 2004-2024, academic journals	8
	Total	**120**
Web of science	Txt	97
	Txt, 2004-2024	84
	Txt, English, Portuguese, Spanish and German, 2004-2024	84
	Total	**84**

Note: AT – Article title; A – Abstract; K – keywords; PE – Population and exposure keywords; E, P & S – language restrictions; Txt – Full text; G – German.

Table VIII.2. *Key words selected regarding population & exposure, and outcome of interest*

Population and exposure	Outcomes	Population and exposure (contin.)	Outcomes (contin.)
Horseback rider	Low back pain	Equestrian	Spinal injuries
Horseback riding	Lower back pain	Dressage	Back injuries
Equestrian athlete	Back pain	Eventing	Overuse injuries
Horse riding	Lumbar back pain	Showjumping	
Horse rider	Lumbar pain		
Equitation	Lumbar spine		

Note: These keywords were combined using "OR" and "AND" operators to facilitate search (e.g. ["Equestrian" OR "Horse rider"] AND ["Lower back pain" OR "Overuse Injuries"])

3.10.2. Study details – Tables and content

Table VIII.3. *Summary of data items collected from included studies*

Categories	Items
Study characteristics	(1) Year of publication; (2) Study design; (3) Outcomes; (5) Statistical analysis;
Data collection	(1) Sources; (2) Country; (3) Tools and methods; (4) Injury categorization; (5) Riding discipline;
Sample details	(1) Sex; (2) Age; (3) Height; (4) Weight; (5) BMI; (6) Body fat percentage; (7) Riding level; (8) Competition level; (9) Skill level; (10) Time practicing sport; (11) Workload; (12) Equestrian related activities;
Pain details	(1) Anatomical location; (2) Nature; (3) Prevalence; (4) Incidence; (5) Number of occurrences; (6) Level of pain; (7) Pain management; (8) Time loss; (9) Level of disability.
Risk factors	(1) Risk factors; (2) Not risk factors; (3) Contributing factors; (4) Not contributing factors;

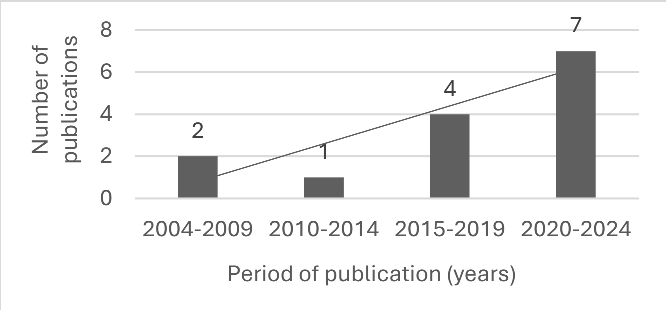


Figure VIII.1. *Number of publications per period*

Table VIII.4. *Study design features (n=14)*

Design	Statistical analysis	References
Cross-sectional	Descriptive	*Lewis et al. [31] *Pilato et al. [30]
	Analytical	Duarte et al. [26] *Puszczałowska-Lizis et al. [32] Ferrante et al. [27] *Lewis, Dumbell & Magnoni. [23] *Lewis & Baldwin. [21] *Lewis & Kennerley. [22] *Hobbs et al. [24] Kraft et al. [25] *Kraft et al. [33]
Cohort	Analytical	Cejudo et al. [28] Cejudo et al. [29]
Case control	Analytical	Deckers et al. [20]

Note: **Papers that did specify study design*

Table VIII.5. *Study outcomes (n=14)*

Outcomes	N	References

Low back pain	5	Duarte et al. [26]; Ferrante et al. [27]; Cejudo et al. [28]; Cejudo et al. [29]; Kraft et al. [25];
Back pain	3	Puszczałowska-lizis et al. [32]; Deckers et al. [20]; Kraft et al. [33];
Equestrian related injury	1	Pilato et al. [30];
Pain	4	Lewis et al. [31]; Lewis & Baldwin. [21]; Lewis, Dumbell & Magnoni. [23]; Lewis & Kennerley [22];
Posture	1	Hobbs et al. [24];

Table VIII.6. *Sample details of included studies*

Reference	Country	Source (n)	Sample	Equestrian discipline	Age group
Duarte et al. [26]	PT	Equestrians of the Portuguese equestrian federation	-	Dressage Show Jumping General riding Eventing Endurance Horseball Working equitation	Adults
Lewis et al. [31]	GB	Equestrian population of UK	Leisure, amateur & professional	Dressage Show jumping Eventing Hunting Showing	Over 35 y.o.
Puszczałowska-lizis et al. [32]	PL	Equestrian centers	Amateur	Dressage Show jumping Hacking	40-45
Ferrante et al.[27]	IT	Members of Italian national equestrian federation	Competitive Non-competitive	Dressage Show jumping Eventing Country horse riding Reining Endurance Vaulting Driving Other	Adults
Deckers et al. [20]	BE	Equestrian population of Belgium	Professional National competition Competitive level	Dressage Show jumping Eventing Icelandic riding	18-60
Cejudo et al. [28]	ES	Murcia regional team	Competitive	Dressage Show jumping	12-17
Cejudo et al. [29]	ES	Equestrian technical camps	Competitive	Dressage Show jumping	9-18
Lewis & Baldwin. [21]	GB	Hartpury international horse trials	International (1* to 3*)	Eventing	18-55
Lewis, Dumbell & Magnoni. [23]	GB	Equestrians of the United Kingdom	Competitive Professional Amateur Recreational	Show Jumping	Adults

Pilato et al. [30]	US	Intercollegiate equestrian team	Intercollegiate competitive level	English Western Eventing Hunt Dressage	Adults
Lewis & Kennerley [22]	GB	Hartpury festival of dressage	International (3*)	Dressage	19-52
Hobbs et al. [24]	GB & US	British dressage camp & Michigan state university	Competitive	Dressage	Adults
Kraft et al. [25]	DE	National training camps	Elite	Dressage Show jumping Vaulting	18-41
Kraft et al. [33]	DE	Rhineland Equestrian sports association	Performance classes	Dressage Show jumping Vaulting	All

Table VIII.7. *Data collection tools, dissemination procedure and sample size with details*

Reference	Tools (timeframe)	Recall period	Procedure	Participants (number, sex)
Duarte et al. [26]	Quest. (retrospective career)	One-year	Indirect (online)	N – 347 (M – 143; F – 204)
Lewis et al. [31]	Quest. (retrospective career)	Point	Indirect (online)	N – 2185 (M – 44; F – 2141)
Puszczałowska-lizis et al. [32]	Quest. (retrospective career)	Point	-	N – 88 (M – 44; F – 44)
Ferrante et al. [27]	Quest. (retrospective career)	Lifetime One-year Six-months Three-months One-month	Indirect (online)	N – 886 (M – 194; F – 692)
Deckers et al. [20]	Quest. (retrospective career) Phys. Exam	Lifetime Last month	Direct (each participant)	N – 32 (M – 10; F – 22)
Cejudo et al. [28]	Quest. (retrospective 12 mo.) Phys. Exam	One-year	Direct (each participant)	N – 19 (M – 8; F – 11)
Cejudo et al. [29]	Quest. (retrospective career) Phys. Exam	One year	Direct (each participant)	N – 43 (M – 15; F – 28)
Lewis & Baldwin. [21]	Quest. (retrospective career)	Point	Direct (each participant)	N – 31 (M – 13; F – 18)
Lewis, Dumbell & Magnoni. [23]	Quest. (retrospective career)	Point	Indirect (online)	N – 80 (M – 9; F – 71)

Pilato et al. [30]	Quest. (retrospective career)	Lifetime	Indirect (email)	N – 73 (M – 2; F – 71)
Lewis & Kennerley [22]	Quest. (retrospective career)	Point	Direct (each participant)	N – 50 (F – 50)
Hobbs et al. [24]	Quest. (retrospective career) Kinematics	Point	Direct (each participant)	N – 127 (M - 1; F - 126)
Kraft et al. [25]	Quest. (retrospective career) Phys. Exams Clinical exams (retrospective)	Point	Direct (each participant)	N – 58 (M – 18; F – 40)
Kraft et al. [33]	Quest. (retrospective career)	Point	Indirect (online) Direct	N – 508 (M – 187; F – 321)

Note: (*) number of samples included for each variable was not consistent throughout the study.

Table VIII.8. *Detailed data collection tools of included studies.*

Reference	Questionnaire tools	Clinical examination tools	Others
Duarte et al. [26]	- Self designed questionnaire - Roland Morris Disability questionnaire	-	
Lewis et al. [31]	- Self designed questionnaire - McGill Pain Questionnaire - Oswestry Low Back Pain Disability Questionnaire	-	
Puszczałowska-lizis et al. [32]	- Self designed questionnaire - Neck Disability Index - Oswestry Low Back Pain Disability Questionnaire	-	
Ferrante et al. [27]	- Self designed questionnaire - Standardized Nordic Questionnaires for the analysis of musculoskeletal symptoms - Numeric rating scale - Pain self-efficacy questionnaire	-	
Deckers et al. [20]	- Self designed questionnaire - Visual Analog Scale - Oswestry Low Back Pain Disability Questionnaire	- Functional Movement screening tests - Luomajoki's Motor Control screening tool	
Cejudo et al. [28]	- Self designed questionnaire	- Tanita-305 body fat analyser - Sagittal spinal curvatures - ROM-SPORT battery - Trunk muscle endurance	
Cejudo et al. [29]	- Self designed questionnaire	- ROM-SPORT I Battery	

Lewis & Baldwin. [21]	- Self designed questionnaire - McGill Pain Questionnaire	-	
Lewis, Dumbell & Magnoni. [23]	- Self designed questionnaire - McGill Pain Questionnaire - Oswestry Low Back Pain Disability Questionnaire	-	
Pilato et al. [30]	- Self designed questionnaire	-	
Lewis & Kennerley [22]	- Self designed questionnaire	-	
Hobbs et al. [24]	- Self designed questionnaire	- Grip strength - Trunk flexibility	- Images of standing posture - Infra-red motion capture system
Kraft et al. [25]	- Self designed questionnaire - Visual Analog Scale - Oswestry Low Back Pain Disability Questionnaire	- Physical examinations - Magnetic Resonance Imaging	
Kraft et al. [33]	- Self designed questionnaire - Visual Analog Scale	-	

3.11. Supplementary material II

3.11.1. Risk of bias and quality assessment OSQE tool

Table VIII.9. *Detailed information of OSQE tool – cross-sectional studies, with comments and explanation.*

Study	Duarte et al. [26]		Lewis et al. [31]	
	Stars	Comments	Stars	Comments
Representative				
Validity	*		*	
Internal validity	1	The study includes a sample of Portuguese equestrian riders, which is relevant to the research question. The sample appears to be diverse and representative of the equestrian population in Portugal	1	The article provides a clear description of the study population, including the selection criteria for participants, which indicates that the sample is representative of the target population of horse riders over thirty-five years old in the UK.
External validity	1		1	
Selection process	1		1	
Reasons refusing	1	No data on refusal.	1	No data on refusal.
Independent variable				
Assessment valid	*	The exposure variables related to lower back pain are well-defined and measured using validated questionnaires, ensuring the reliability of the data collected	*	The exposure variables related to riding habits and frequency are well-defined and measured using appropriate and validated tools, ensuring the reliability of the data collected.
Presence optimal	*	Presence of years of sport and workload optimal.	*	Presence of years of sport and workload optimal.
Dependent variable				
Assessment	*	The outcome measures for lower back pain prevalence are clearly described and validated, demonstrating that the study effectively captures the intended outcomes	*	The outcome measures concerning pain prevalence are clearly described and validated, demonstrating that the study effectively captures the intended outcomes related to pain experienced by the participants.
Other				
Conflict of interest	*	The authors declare no conflicts of interest.	*	The authors declare no conflicts of interest.
Comparability				

Confounders control	*	The study identifies potential confounders related to lower back pain and describes the methods used to control for them in the analysis, enhancing the validity of the findings. (logistic, regression)		The statistical analysis of the study is basic and does not control for confounders of interest.
Following a protocol		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional				
Missing data	*	No missing data	*	No missing data
Effect modifiers	*	Yes	*	Yes
Systematic review	*	Article mentions sample size and justifies sample size and power analysis.		The article mentions the sample size but does not provide a detailed justification or power analysis to support the adequacy of the sample size.
Reporting				
Stating objectives	1	Investigate the prevalence of LBP in Portuguese equestrian athletes and to gain insight into the primary factors or possible causes leading to LBP in this population	1	Investigate the prevalence, location, and severity of pain in riders over the age of 35 years. It also aims to discover factors that affect the pain that riders experience and the pain management techniques used by riders over the age of 35 years
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars - 10	9	No veto |Max. sum of stars - 10	7	No veto |Max. sum of stars - 10

Table III.11. (continuation).

Study	Puszczałowska-lizis et al. [32]		Ferrante et al. [27]	
	Stars	Comments	Stars	Comments
Representative				
Validity			*	
Internal validity	1	In- and external validity not optimal (Participants do not represent [age] targeted population in title and objectives). Selection process not transparent. Sample not representative.	1	The study includes a large sample of competitive equestrian athletes from the Italian Equestrian Sport Federation, which enhances the representativeness of the findings for this population.
External validity			1	
Selection process			1	
Reasons refusing	1	No data on refusal.	1	No data on refusal.
Independent variable				
Assessment valid	*	The exposure variables related to horse riding practices are well-defined and measured using appropriate methods, ensuring the reliability of the data collected.	*	The exposure variables related to equestrian activities and riding practices are well-defined and measured using appropriate survey methods, ensuring the reliability of the data collected.
Presence optimal	*	Yes	*	Yes
Dependent variable				
Assessment	*	The outcome measures for back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes	*	The outcome measures for low back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.
Other				
Conflict of interest		Authors did not disclose.	*	The authors declare no conflicts of interest.
Comparability				

Confounders control		The statistical analysis of the study does not control for confounders of interest.	*	The study identifies potential confounders related to low back pain and describes the methods used to control for them in the analysis, enhancing the validity of the findings.
Following a protocol		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional				
Missing data	*	No missing data	*	No missing data
Effect modifiers	*	Yes	*	Yes
Systematic review		The article mentions the sample size but does not provide a detailed justification or power analysis to support the adequacy of the sample size.	*	The article mentions the sample size and provides a detailed justification or power analysis to support the adequacy of the sample size.
Reporting				
Stating objectives	1	Analyze the incidence of back pain in people who practice amateur horse riding	1	Investigate, through a self-reported questionnaire, the prevalence of LBP among Italian equestrian athletes; which disciplines in equestrian sports are associated with a higher prevalence of LBP; how the training and competition levels affect the prevalence.
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars - 10	5	No veto |Max. sum of stars - 10	9	No veto |Max. sum of stars - 10

Table III.11. (continuation).

Study	Cejudo et al. [28]		Cejudo et al. [29]	
	Stars	Comments	Stars	Comments
Representative				
Validity	*		*	
Internal validity	1	The study includes a sample of child equestrian athletes, which is relevant to the research question. The sample appears to be diverse and representative	1	The study includes a sample of child equestrian athletes, which is relevant to the research question. The sample appears to be diverse and representative
External validity	1		1	
Selection process	1		1	
Reasons refusing	1	No data on refusal.	1	No data on refusal.
Independent variable				
Assessment valid	*	The exposure variables related to trunk lateral flexor endurance and body fat are well-defined and measured using appropriate methods, ensuring the reliability of the data collected	*	The exposure variables related to asymmetry and range of motion of lower limb muscles are well-defined and measured using appropriate methods, ensuring the reliability of the data collected
Presence optimal	*	Yes	*	Yes
Dependent variable				
Assessment	*	The outcome measures for back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.	*	The outcome measures for back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.
Other				
Conflict of interest	*	The authors declare no conflicts of interest.	*	The authors declare no conflicts of interest.
Comparability				

Confounders control	*	The study identifies potential confounders related to back pain and describes the methods used to control for them in the analysis, enhancing the validity of the findings. (logistic, linear regression).	*	The study identifies potential confounders related to back pain and describes the methods used to control for them in the analysis, enhancing the validity of the findings. (logistic, linear regression).
Following a protocol		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional				
Missing data	*	No missing data	*	No missing data
Effect modifiers	*	Yes	*	Yes
Systematic review		While the article mentions the sample size, it does not provide a detailed justification to support the adequacy of this sample size. It reports on power analysis using Gpower.		While the article mentions the sample size, it does not provide a detailed justification to support the adequacy of this sample size. It reports on power analysis using Gpower.
Reporting				
Stating objectives	1	Were (I) to analyze the relationship between lower limb ROM (tightness and asymmetry) and LBP and (II) to determine the reference values for lower limb ROM indicating high risk of LBP	1	Determine whether anthropometric, range of motion (ROM), core endurance and sagittal spinal morphotype measures are risk factors for LBP and to establish a diagnostic cutoff value for those factors associated with LBP
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars - 10	8	No veto |Max. sum of stars - 10	8	No veto |Max. sum of stars - 10

Table III.11. (continuation).

Study	Deckers et al. [20]		Lewis & Baldwin [21]	
	Stars	Comments	Stars	Comments
Representative				
Validity			*	
Internal validity	1	The study includes a sample of horse riders, which is relevant to the research question.	1	The study includes a substantial sample of international event riders competing at a recognized event (Hartpury International Horse Trials), which enhances the representativeness of the findings for this population.
External validity		Sample not representative of sample described in title or aims of the study.	1	
Selection process	1	Selection process transparent.	1	
Reasons refusing	1	No data on refusal.	1	No data on refusal.
Independent variable				
Assessment valid	*	The exposure variables related to sport-specific and functional characteristics of back pain are well-defined and measured using appropriate methods, ensuring the reliability of the data collected		Merely descriptive
Presence optimal	*	Yes		Merely descriptive
Dependent variable				
Assessment	*	The outcome measures for back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes	*	The outcome measures for pain prevalence and its perceived impact on performance are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.
Other				

Conflict of interest	*	The authors declare no conflicts of interest.		Authors did not disclose.
Comparability				
Confounders control		The statistical analysis of the study does not control for confounders of interest.		The statistical analysis of the study does not control for confounders of interest.
Following a protocol		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional				
Missing data	*	No missing data.	*	No missing data.
Effect modifiers	*	Yes	*	Yes
Systematic review		While the article mentions the sample size, it does not provide a detailed justification or power analysis to support the adequacy of this sample size.		The article mentions the sample size (31 questionnaires completed) but does not provide a detailed justification or power analysis to support the adequacy of this sample size.
Reporting				
Stating objectives	1	Explore sport-specific and functional characteristics of BP in horse riders.	1	Was to investigate the prevalence of riders at the International CCI*, CCI** and CIC*** levels in eventing competing with pain, the location of their pain, factors affecting their pain and whether they perceived this pain to have an effect on their performance.
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars - 10	6	No veto |Max. sum of stars - 10	4	No veto |Max. sum of stars - 10

Table III.11. (continuation).

Study	Lewis, Dumbell & Magnoni [23]		Lewis & Kennerley [22]	
	Stars	Comments	Stars	Comments
Representative				
Validity	*			
Internal validity	1	The study includes a sample of competitive showjumping equestrian athletes, which is relevant to the research question and enhances the representativeness of the findings for this specific population.		In- and external validity not optimal (Participants [sex] do not represent targeted population in title and objectives). Sample not representative of population of interest. Selection process not transparent enough.
External validity	1			
Selection process	1			
Reasons refusing	1	No data on refusal.	1	No data on refusal.
Independent variable				
Assessment valid	*	The exposure variables related to pain experienced by the athletes are well-defined, and the study employs a structured questionnaire to gather data, ensuring the reliability of the information collected.		The exposure variables related to pain experienced by the riders are well-defined, and the study employs a structured questionnaire to gather data, ensuring the reliability of the information collected.
Presence optimal		Not controlled		Not possible to assess
Dependent variable				
Assessment	*	The outcome measures for pain prevalence and its perceived impact on performance are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.	*	The outcome measures for pain prevalence and its perceived impact on performance are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.
Other				

Conflict of interest		Authors did not disclose.		Authors did not disclose.
Comparability				
Confounders control		The statistical analysis of the study does not control for confounders of interest.		The statistical analysis of the study does not control for confounders of interest.
Following a protocol		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional				
Missing data	*	No missing data.	*	No missing data.
Effect modifiers	*	Yes	*	Yes
Systematic review		The article mentions the sample size but does not provide a detailed justification or power analysis to support the adequacy of this sample size.		The article mentions the sample size but does not provide a detailed justification or power analysis to support the adequacy of this sample size.
Reporting				
Stating objectives	1	Investigate the prevalence of competitive showjumping athletes who experience pain, the location of their pain, factors affecting their pain and whether they perceive this pain to effect on their riding performance.	1	Investigate the prevalence of riders at the elite level competing with pain and whether they perceived this pain to have a negative effect on their performance
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars - 10	5	No veto |Max. sum of stars - 10	3	No veto |Max. sum of stars - 10

Table III.11. (continuation).

Study	Pilato et al. [30]		Hobbs et al. [24]	
	Stars	Comments	Stars	Comments
Representative				
Validity	*			
Internal validity	1	The study includes a sample of collegiate equestrian athletes, which is relevant to the research question and enhances the representativeness of the findings for this specific population.		In- and external validity not optimal (Participants do not represent targeted population in title and objectives). Sample not representative of population of interest. Selection process not transparent enough.
External validity	1			
Selection process	1			
Reasons refusing	1	No data on refusal.		Sample size varies throughout the study, no explanation provided for this fact, impossible to know if reason for refusal have effects on data representativeness.
Independent variable				
Assessment valid	*	The exposure variables related to pain experienced by the athletes are well-defined, and the study employs a structured questionnaire to gather data, ensuring the reliability of the information collected.	*	The exposure variables related to posture, flexibility, and grip strength are well-defined and measured using appropriate methods, ensuring the reliability of the information collected.
Presence optimal	*	Yes	*	Yes
Dependent variable				
Assessment	*	The outcome measures for injury history, including spinal injuries, are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.	*	The outcome measures for injury history, including spinal injuries, are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.

Other				
Conflict of interest		Authors did not disclose.		Authors did not disclose.
Comparability				
Confounders control		The statistical analysis of the study does not control for confounders of interest.	*	The study identifies potential confounders related to posture and strength and describes the methods used to control for them in the analysis, enhancing the validity of the findings (ANOVA).
Following a protocol		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional				
Missing data	*	No missing data.		The n of samples included for each variable was not consistent throughout the study.
Effect modifiers*	-	Not applicable (descriptive).	-	Not applicable (differences not association).
Systematic review		The article mentions the sample size but does not provide a detailed justification or power analysis to support the adequacy of this sample size.		The article mentions the sample size but does not provide a detailed justification or power analysis to support the adequacy of this sample size.
Reporting				
Stating objectives	1	Analysis is to describe the demographics of collegiate equestrian athletes, their conditioning patterns, their history of pain medication usage and their incidence of injury. Part I includes the demographic data, conditioning patterns, history of pain medication and incidence of injury to the spine. Part II details the incidence of injury for the upper and lower extremity and the head.	1	Determine whether anatomical asymmetry (leg length, pelvis and shoulder height), functional asymmetry (trunk lateral bending and axial rotation range of motion (ROM) during sitting) and dynamical asymmetry (grip strength) were prevalent in a larger population of riders and to determine whether typical traits exist due to riding.
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars – 9*	5	No veto |Max. sum of stars - 9	4	No veto |Max. sum of stars - 9

Table III.11. (continuation).

Study	Kraft et al. [25]		Kraft et al. [33]	
	Stars	Comments	Stars	Comments
Representative				
Validity	*		*	
Internal validity	1	The study includes a sample of elite horseback riders, which is relevant to the research question and enhances the representativeness of the findings for this specific population.	1	The study includes a sample of competitive horseback riders from various disciplines, which enhances the representativeness of the findings for this specific population.
External validity	1		1	
Selection process	1		1	
Reasons refusing	1	No data on refusal.	1	No data on refusal.
Independent variable				
Assessment valid	*	The exposure variables related to riding discipline, body mass index, and trunk/leg-length coefficient are well-defined and measured using appropriate methods, ensuring the reliability of the information collected.	*	The exposure variables related to riding discipline and intensity are well-defined and measured using appropriate methods, ensuring the reliability of the information collected.
Presence optimal	*	Yes	*	Yes

Dependent variable Assessment	*	The outcome measures for MRI findings and back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes	*	The outcome measures for the incidence of back pain are clearly described and validated, demonstrating that the study effectively captures the intended outcomes.
Other Conflict of interest	*	The authors declare no conflicts of interest.		Authors did not disclose.
Comparability Confounders control Following a protocol		The statistical analysis of the study does not control for confounders of interest. While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection		The statistical analysis of the study does not control for confounders of interest. While the article outlines the statistical methods used for analysis, it does not clearly indicate whether these analyses were pre-registered or determined prior to data collection
Optional Missing data Effect modifiers* Systematic review	* - 	No missing data Not applicable (mostly descriptive) While the article mentions the sample size, it does not provide a detailed justification to support the adequacy of this sample size. It reports on power analysis using Gpower.	* * 	No missing data Yes While the article mentions the sample size, it does not provide a detailed justification to support the adequacy of this sample size. It reports on power analysis using Gpower.
Reporting Stating objectives	1	Determine whether excessive riding activity accelerates lumbar DD and so leads to lumbar overuse syndromes. Furthermore, we wanted to analyse whether the development of LBP and DDD in the lumbar spine of competitive horseback riders is associated with the riding discipline, body mass index (BMI [kg/m2]), and the trunk/ leg-length coefficient.	1	Assess whether an equestrian discipline leads to increased back pain and to what extent the intensity of equestrian sport is a predisposing factor for the development of this pain. In addition to determining the incidence of back pain in riders, we also wanted to assess whether riding leads to a change in the intensity of pain and whether there is an equestrian discipline that has a positive effect on the symptoms.
Background provided	1	Yes	1	Yes
Background stratified	1	Yes	1	Yes
Description statistics	1	Yes	1	Yes
Sum of stars	7	No veto |Max. sum of stars - 9	6	No veto |Max. sum of stars - 10

Table VIII.10. *Quality score of all included studies and quality taxonomy*

Cross-sectional studies	Total number of stars	Max. sum of stars	% Score	Quality assessment
Duarte et al. [26]	9	10	90	High-quality
Lewis et al. [31]	7	10	70	High-quality
Puszczałowska-lizis et al. [32]	5	10	50	Low-quality
Ferrante et al. [27]	9	10	90	High-quality
Cejudo et al. [28]	8	10	80	High-quality
Cejudo et al. [29]	8	10	80	High-quality
Deckers et al. [20]	6	10	60	Low-quality
Lewis & Baldwin [21]	4	10	40	Low-quality
Lewis, Dumbell & Magnoni [23]	5	10	50	Low-quality
Pilato et al. [30]	5	9	55.6	Low-quality
Lewis &1 Kennerley [22]	3	10	30	Low-quality
Hobbs et al. [24]	4	9	44.4	Low-quality
Kraft et al. [25]	7	9	77.8	High-quality
Kraft et al. [33]	6	10	60	Low-quality

Note: Cut-off value 65%.

3.11.2. JBI check list for prevalence studies

Table VIII.11. *JBI critical appraisal checklist for included studies reporting prevalence data.*

	Duarte et al. [26]	Lewis et al. [31]	Ferrante et al. [27]	Lewis & Baldwin [21]	Lewis, Dumbell & Magnoni [23]	Lewis &1 Kennerley [22]	Hobbs et al. [24]	Kraft et al. [25]	Kraft et al. [33]
1- Was the sample frame appropriate to address the target population?	Y	Y	Y	Y	Y	**N**	Y	Y	Y
2 - Were study participants sampled in an appropriate way?	Y	Y	Y	**U**	Y	**N**	Y	Y	Y
3 - Was the sample size adequate?	Y	**U**	Y	**U**	**U**	**U**	**U**	**U**	Y
4 - Were the study subjects and the setting described in detail?	Y	**U**	Y	**U**	**U**	**U**	**U**	**U**	**U**
5 - Was the data analysis conducted with sufficient coverage of the identified sample?	Y	Y	Y	**N**	Y	**N**	Y	Y	Y
6 - Were valid methods used for the identification of the condition?	Y	Y	Y	Y	Y	Y	**U**	Y	Y
7 - Was the condition measured in a standard, reliable way for all participants?	NA	NA	NA	NA	NA	NA	NA	NA	NA
8 - Was there appropriate statistical analysis?	Y	**U***	**U***	**U***	**U***	**U***	**U***	**U***	**U***
9 - Was the response rate adequate, and if not, was the low response rate managed appropriately?	Y	Y	Y	**N**	Y	Y	Y	Y	Y
Overall appraisal	I	I	I	**E**	I	**E**	I	I	I
Real sample size -precision of the results (%) **	-	2,5	-	**>15**	**13**	**12**	8	9	5
Percentage score (Max. "yes" points - 8) ***	100	62,5	87,5	-	62,5	-	50	62,5	75
Prevalence study quality assessment	HQ	LQ	HQ	-	LQ	-	LQ	LQ	HQ

Note: Y – yes; N – No; U – Unclear; NA – Not Applicable; I – Include; E – Exclude; HQ – High-quality; LQ - Low-quality

** For studies that did not present confidence intervals in LBP prevalence, these were calculated by the review team and are presented in table 18. ** For studies that did not justify sample size the SCALEX SP calculator [16] was used, to calculate the precision of the results. A level of confidence of 95% was used for all studies, and loss was considered when authors provided N of non-response or non-completion. Expected prevalence was filled out with the prevalence results of each particular study.*

**** Percentage score of all prevalence studies quality to determine quality taxonomy, cut-off value 65%.*

Table VIII.12. *Confidence intervals of LBP prevalence*

	Prevalence	**N total/ N LBP**	**Lower 95% CL**	**Prevalence %**	**Upper 95% CL**
Duarte et al. [26]	One-year	347/214	56,5	61,7	66,6
Lewis et al. [31]	Point	2185/969	42,3	44,3	46,4
Ferrante et al. [27]	Lifetime One-year CLBP	886/812 886/658 886/212	89,6 71,3 21,2	91,6 74,3 23,9	93,3 77 26,8
Lewis & Baldwin [21]	Point	31/16	34,8	51,6	68
Lewis, Dumbell & Magnoni [23]	Point	80/29	26,6	36,2	47,2
Lewis & Kennerley [22]	Point	50/28	42,3	56	68,8
Hobbs et al. [24]	Point	122/34	20,7	27,9	36,4

Kraft et al. [25]	Point	58/51	77,1	87,9	94
Kraft et al. [33]	Point	508/298	54,3	58,7	62,9

Note: Calculated with Epitools – Confidence limits for a sample proportion [19], Confidence level 0.95, Wilson method. Calculated by the review team for all studies that did not provide confidence intervals.

3.12. Supplementary material III

3.12.1. Risk factors and contributing factors for pain in EA

Table VIII.13. *Population characteristics (demographic and anthropometric) that do not pose a risk or do not contribute to pain.*

Anatomic location of pain	Variable	Timeframe/ Details	Not risk factors (no correlation)	Not contributing factors
All body	Prevalence	Point	Age (p=0.114) [21]	
	Intensity		Age (p=0.885) [21]	
			Previous injury (perceived pain) (p=0.781) [21]	
Back	Prevalence	Lifetime		Sex [20]
				Age [20]
	Frequency		Sex (p>0.46) [33]	
	Intensity			Sex [20]
				Age [20]
	Disability			Sex [20]
				Age [20]
Lower back	Prevalence	Lifetime	Sex (p>0,409) [27]	BMI [27]
			Height (p>0,884) [27]	
			Practicing other sports (p>0,6) [27]	
		Point	Incipient disk degeneration (p=0.73) [25]	
		One year	Sex (p=0.243) [26]	
			Sex (p>0,293) [27]	
			Practicing other sports (p=0.210) [26]	
			Practicing other sports (p>0,052) [27]	
			Age (p=0.061) [26]	
			Age (p=0.702) [28]	
			Age (p=0.840) [29]	
			BMI (p=0.178) [26]	
			BMI (p=0.457) [28]	
			BMI (p=0.615) [29]	
			BF% (p=0.626) [29]	
			Height (p>0,839) [27]	
			Height (p=0.282) [28]	
			Height (p=0.881) [29]	
			Weight (p>0,962) [27]	
			Weight (p=0.934) [28]	
			Weight (p=0.775) [29]	
			Asymmetry of ROM in dominant and non-dominant limb (HE, HAD-HF, HAB, HIR, HF-KF) (p<0.04) [28]	
			Asymmetry of ROM in dominant and non-dominant limb (HE, HAB, HIR HAB-HF) (p<0.017) [29]	
			Asymmetry of trunk muscle endurance in dominant and non-dominant limb (ISBE) (p=0.024) [28]	
		Chronic	Sex (p>0,612) [27]	Weight [27]
			Age (p>0,750) [27]	
	Disability	Scores	Sex (p=0.304) [26]	

			Age class ($p=0.309$) [26]	
			BMI category ($p=0.065$) [26]	
		Dysfunctional/ Functional	Sex ($p=0.171$) [26]	
			Practicing other sports ($p=0.499$) [26]	
			BMI ($p=0.075$) [26]	
	Disk degeneration	DDD	BMI category ($p>0.79$) [25]	
			Trunk/ Leg-length coefficient ($p>0.73$) [25]	

Note: BMI – Body mass index; BF% - Body fat percentage; ROM – Range of motion; HE – hip extension test (iliopsoas); HAD-HF – Hip adduction with hip flexed test (piriformis); HAB – Hip abduction with hip neutral test (adductors); HIR – Hip internal rotation test (external rotators); HF-KF – Hip flexion with knee flexed test (gluteus maximus); ISBE – Isometric side bridge endurance (trunk lateral flexors); HAB-HF – Hip abduction with flexed hip (monoarticular adductors); DDD – Degenerative disk disease;

Table VIII.14. *Exposure characteristics (related with Equestrianism) that do not pose a risk or do not contribute to pain.*

Anatomic location of pain	Variable	Timeframe/ Details	Not risk factors (no correlation)	Not contributing factors
All body	Prevalence	Point		Injuries resulting from falls – 57% [22]
Back	Prevalence	Lifetime	Level of competition (Professionals>amateurs) ($p>0.05$) [20]	Years riding [20]
			Equestrian discipline ($p>0.05$) [20]	Workload (H/day) [20]
		Point		Years riding (riders w/ postural defects) [24]
				Equestrian discipline [33]
				Performance classes [33]
				Workload (h/ week) [33]
				Jumping (86.3 % did not affect BP or improved complaints) [33]
	Frequency			Workload (h/week) [33]
				Equestrian discipline [33]
	Intensity		Level of competition (Professionals>amateurs) ($p>0.05$) [20]	Years riding [20]
				Workload (H/day) [20]
				Equestrian discipline [33]
			Equestrian discipline ($p>0.05$) [20]	Workload (h/week) [33]
	Disability		Level of competition (Professionals>amateurs) ($p>0.05$) [20] Equestrian discipline ($p>0.05$) [20]	Years riding [20] Workload (H/day) [20]
Lower back	Prevalence	Lifetime	Workload ($p>0,567$) [27]	Sport license [27]
				Years riding [27]
		Point		Workload h/week [25]
		One year	Equestrian sports being a profession vs hobby ($p=0.087$) [26]	
			Equestrian discipline ($p=0.59$) [26]	
			Rider warming up before riding ($p=0.151$) [26]	
			Years riding ($p=0.245$) [26]	
			Years riding ($p=0.557$) [28]	
			Years riding ($p=0.604$) [29]	
			Workload H/Week ($p>0,491$) [27]	
			Workload H/Week ($p=0.089$) [28]	
			Workload H/Week ($p=0.148$) [29]	
			Workload H/Year ($p=0.089$) [28]	
			Workload H/Year ($p=0.148$) [29]	

		Chronic	Sport license (p>0,178) [27]	Equestrian discipline [27]
	Intensity			Equestrian discipline [25] Workload h/week [25]
	Disability	Scores		Equestrian discipline [25]
		Dysfunctional/ Functional	Workload (p=0.276) [26] Performing stable duties (p=0.077) [26] Rider warming up before riding (p=0.948) [26] Years riding (p=0.241) [26]	
	Disk degeneration	T2-Weighted signal intensity	Being an Equestrian athlete (p>0.46) [25]	
		DDD	Equestrian discipline (p>0.15) [25]	

Note: H/day – hours per day; H/Week – hours per week; H/ Year – hours per year; BP – back pain;

Table VIII.15. *Population characteristics (demographic and anthropometric) that pose a risk or contribute to pain.*

Anatomic location of pain	Variable	Timeframe/ Details	Risk factors (correlation)	Contributing factors
All body	Prevalence	Point	Age (positive correlation, no p values given) [31] Sex (female) (p=0.006) [21]	Not practicing other sports (O.R. 1,4) [31]
Back	Prevalence	Lifetime	Lower scores in the in-line lunge test (FMS) (p=0.022) [20] Lower scores in the rocking backwards test (MC) (p=0.014) [20]	
		Point	Age (100% incidence in population 40-45 y.o.) [32] Pain location and sex (p<0.001) [32]	Age (average age of riders w/ no BP lower than those with frequent symptoms) [33]
		One month	Lower scores in the rotary stability test (FMS) (p=0.04) [20] Lower scores in the rocking forwards test (MC) (p=0.02) [20]	
	Intensity		Lower scores in movement control (MC) (p=0.001) [20] Lower scores in functional movement (FMS) (p=0.024) [20]	
	Disability		Lower scores in movement control (MC) (p=0.006) [20] Lower scores in functional movement (FMS) (p<0.001) [20]	
Lower back	Prevalence	Lifetime	Younger age (p>0.000) [27] Weight (p>0.003) [27]	
		Point	Pain location and sex (p<0.001) [32]	
		One year	Younger age (p>0.000) [27] BF% (p=0.01) [28] Lower values in trunk muscle endurance (ISBE_ND, ISBE) (p<0.039) [28] Higher values in ROM (HTR) (p=0.043) [28] Lower values in ROM (HAD-HF, KF) (p<0.025) [29]	
	Disability	Scores	BMI (p=0.016) [26]	

		Dysfunctional (as opposed to Functional)	Older age (*p*=0.022) [26]	

Note: O.R. – Odds ratio; BF% - Body fat percentage; FMS – Functional movement screening tests; MC - Luomajoki's Motor Control screening tool; ISBE -Isometric side bridge endurance (trunk lateral flexors); ISBE_ND – Isometric side bridge endurance in non-dominant side (trunk lateral flexors); ROM – Range of motion; HTR – Hip total rotation (hip rotators); HAD-HF – Hip adduction with flexed hip (abductors); KF – Flexion of knee (quadriceps); y.o. – years old.

Table VIII.16. *Exposure characteristics (related with Equestrianism) that pose a risk or contribute to pain.*

Anatomic location of pain	**Variable**	**Timeframe/ Details**	**Risk factors (correlation)**	**Contributing factors**
All body	Prevalence	Point	Years riding (*p*=0.004) [21]	Saddle – 62% [22]
				Nº of horses ridden – 22% [22]
				Horse's movement – 14% [22]
				Cold weather – 2% [22]
				Years riding, riding for <11 y. leads to < O.R. [31]
				Level of competition (O.R. – leisure 5,46 < amateur 6,30 < professional 7,22) [31]
				Equestrian discipline (eventing) – 96% [21]
		Chronic		Equestrian discipline (Competitive SJ only 2.2 O.R.> Competitive SJ and others 1.5 O.R. (Chronic pain: acute pain)) [23]
	Intensity			Weather (no further explanation) – 41,3% [31]
				Riden activities – 72.8% [31]
				Stable duties – 27.2% [31]
Back	Prevalence	Point		Competition level (riders w/ postural defects) [24]
				Riding (91.5% developed BP during riding career regardless of riding discipline) [33]
		One month	Level of competition (Professional> Amateur) (*p*=0.014) [20]	
			Saddle type (Jumping saddle> Dressage saddle> Jumping and Dressage saddle) (*p*=0.027) [20]	
Lower back	Prevalence	Lifetime	Equestrian discipline (Show jumping, Dressage, country riding, reigning, and Eventing) (*p<0.001*) [27]	
		One year	Workload over 7h/ week (*p*=0.045) [26]	
			Equestrian sports being a profession vs hobby (*p*=0.039) [26]	
			Performing stable duties (*p*=0.029) [26]	
		Chronic	Workload (5-6 hours) (*p*>0.017) [27]	
			Workload (13-18 hours) (*p*>0.027) [27]	

			Workload (>19 hours) (p>0.043) [27]	
	Intensity			Riding – 42,5% [26]
				Cleaning/ grooming horses – 27,1% [26]
				Lunging horses – 26,2% [26]
				“Mucking out” – 55,1% [26]
	Disability	Scores	Equestrian sports being a profession vs hobby (p=0.017) [26]	Performing stable duties (higher values of estimated marginal means, age and BMI fixed at mean values) [26]
		Dysfunctional (as opposed to Functional)	Equestrian sports being a profession vs hobby (p=0.041) [26]	
	Disk degeneration	T2-Weighted signal alterations		Equestrian discipline (Dressage) [25]

Note: O.R. – Odds ratio.

Appendix 4 – Supplementary material Paper 2

4.9. Supplementary Material 1 – Questionnaire

Objectives

To characterize equestrian athletes in Portugal, and understand the incidence of low back pain, and associated injuries, in this population.

Inclusion criteria:

- Portuguese nationality
- Age equal or over 18 years old
- Having federated license in the Portuguese equestrian federation in the years of 2023 or 2022.

Informed consent

In the scope of the PhD in Human Motricity, a study is under development, to characterize Portuguese equestrian athletes, and the rates of low back pain and injuries in this population.

Your participation is requested, by filling out a brief form, with a total duration of 10 minutes. There are no right or wrong answers, but it is important for you to read carefully and answer honestly to every question. If you make a mistake filling out the form, it is possible for you to go back and correct your answer, but once submitted it will not be possible for you to reopen or fill out a new form.

There are 51 questions in this form.

1 – Athlete characterization

(in this section there will be questions regarding anthropometric and demographic details about the athlete)

1.1 – Age (years)*

(Please write down your answer)

1.2 – Sex: *

(Please select the one that applies)

	Feminine
	Masculine

1.3 – Height (cm)*

(Please write down your answer)

1.4 – Weight (kg)*

(Please write down your answer)

1.5 – Nationality* (Please select one answer)

	Portuguese
	Other

1.6 – Country of residence and equestrian practice *

(Please select all that apply)

	Portugal
	Spain
	Netherlands
	Germany
	United Kingdom
	United States of America
	Other

1.7 – If the country of residence and equestrian practice selected was Portugal, city of location of the equestrian facility where you practice your equestrian activities. *

(Please write down your answer)

2 - Equestrian practices

(in this section there will be questions related only to your equestrian practices/ activities)

2.1 – For you equestrianism is: *

(Please select the one that applies)

	Hobby
	Profession

(in case you are in an equestrian related study program select the option "profession")

2.2 – Years of equestrian practice*

(Please write down your answer)

2.3 – Hours of equestrian practice per week (hours/week) *

(Please select the one that applies)

	1 to 2
	3 to 4
	5 to 6
	7 to 12

	13 to 18
	More than 19

*(How many hours per week you ride **horses** - in case of doubt, think about the last year 2022-2023 to answer this question)*

2.4 – Equestrian discipline: *

(Please select all that apply)

	General equitation
	Dressage
	Show Jumping
	Eventing
	Endurance
	Other

You indicated that you practiced "other" equestrian discipline, which one(s)?

(Please write down your answer)

2.4.1 – Level of competition in Dressage *

(Please select the appropriate position for each element)

	Throughout life	In the last 12 months	Never
Festival			
National			
International			
Olympic			

2.4.2 – Level of competition in Show Jumping *

(Please select the appropriate position for each element)

	Throughout life	In the last 12 months	Never
Festival			
National			
International			
Olympic			

2.4.3 – Level of competition in Eventing *

(Please select the appropriate position for each element)

	Throughout life	In the last 12 months	Never
National			
International			
Olympic			

2.4.4 – Level of competition in Endurance *

(Please select the appropriate position for each element)

	Throughout life	In the last 12 months	Never

Festival			
National			
International			
Olympic			

2.4.4 – Level of competition in "Other" *

(Please select the appropriate position for each element)

	Throughout life	In the last 12 months	Never
Festival			
National			
International			

2.5 – Discipline in which you were federated in the sportive year of 2022 or 2023. *

(In case you are already federated in the present year, 2023, answer regarding this year)

(Please select all that apply)

	General equitation
	Dressage
	Show Jumping
	Eventing
	Endurance
	Other

2.6 – Sporting license in the year 2022 or 2023: *

(Please select all that apply)

	Practitioner license
	National competition license
	International competition license

2.7 – Beyond equestrian practice, do you also participate in activities inherent to treatment and management of horses? *

(Please select the one that applies)

	Yes, daily
	Yes, sometimes
	No

(in case of doubt, think about the last year 2022-2023 to answer this question)

With treatment and management of horses we mean:

- *Cleaning and mucking out stalls*
- *Grooming, tacking and untacking horses*
- *Feeding of horses*
- *Management and maintenance of equestrian spaces*
- *Others*

3 – Sporting practices

(in this section you should answer about your practice of other sports not related with equestrian sports)

3.1 – Other than equitation, do you practice other sports or physical activities? *

(Please select the one that applies)

	Yes
	No

3.1.1 – Do you practice other sports or physical activities to complement equitation?

(Please select the one that applies)

	Yes
	No

3.1.1.1 – If so, was it prescribed by a specialist?

(Please select the one that applies)

	Yes
	No

3.1.2 – Which sports do you practice?

(Please select all that apply)

	Gym (free training)
	Gym (personalized training)
	Walking
	Running
	Cycling
	Swimming
	Yoga
	Pilates
	Other

3.1.3 – Do you consider equitation to be your main sport?

(Please select the one that applies)

	Yes
	No

Which is your main sport?

(Please write down your answer)

3.1.4 – The other sports you practice are federated?

(Please select the one that applies)

	Yes
	No

3.1.5 – How many hours per week do you practice other sports?

(Please select the one that applies)

	1 to 2
	3 to 4
	5 to 6
	7 to 12
	13 to 18
	More than 19

4 – Musculoskeletal injuries

(In this section you will answer to questions regarding musculoskeletal injuries)

4.1 – Have you ever sustained a bone fracture? *

(Please select the one that applies)

	Yes
	No

(if you ever sustained a bone fracture diagnosed by a specialist physician)

4.1.1 – In which body region?

(Please select all that apply)

	Head
	Upper limbs and scapular waist
	Lower limbs and pelvic waist
	Spine
	Sacrum
	Coccyx
	Other

4.1.2 – Have you sustained any fractures due to the practice of equestrian sports?

(Please select the one that applies)

	Yes
	No

(Consider fractures sustained as a direct consequence of falling of a horse, or being on a horse)

4.1.3 – Have you sustained any fractures due to the direct interaction with horses?

(Please select the one that applies)

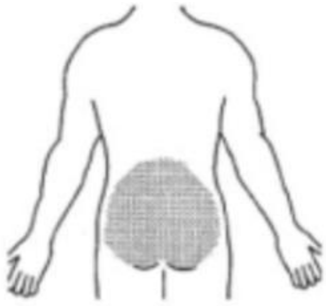
	Yes
	No

(Consider fractures sustained as a direct consequence of any activity or interaction with horses. This question does not apply to falling of a horse)

4.2 – Considering the last 12 months, have you had any problem (such as pain, discomfort or numbness) in the lower back? *

(Please select the one that applies)

Table VIII.17. *The image represents the approximate region of the body mentioned in this question.*



	Yes
	No

5 – Low Back Pain in equestrian practices

(Answer this category thinking about what you feel when you are developing equestrian activities)

(Answer the following questions regarding what you feel/ do when the ***pain in the lower back in present)***

5.1 – Do you feel the pain is worst/ feel more pain when you ride a horse?

(Please select the one that applies)

	Yes
	No
	Never thought about that

(with "ride a horse" we mean the direct practice of equitation, of being on a horse in the three gaits)

5.2 – Do you feel that pain harms your performance while riding?

(Please select the one that applies)

	Yes
	No

5.3 – When you are on a horse when is the pain you feel stronger?

(Please select all that apply)

	Walk
	Rising trot/ posting trot
	Sitting trot
	Canter
	Canter in jumping position
	During jumps
	Does not apply

Answer thinking about the circumstance when you feel more pain, or the pain gets worst, it is possible to choose more than one option, think about your answer.

Explanation:

- *"Canter" – sitting on the saddle*
- *"Canter in jumping position" – cantering with short stirrups in a jumping position, with seat off the saddle.*
- *"During jumps" – in show jumping lessons, when you have to use the jumping position a lot over jumps.*

5.4 – During horse grooming, in which situation do you feel more pain?

(Please select the one that applies)

	Cleaning the horse's body
	Cleaning the horse's hoofs
	During both
	Pain does not enhance

5.5 – When you are lunging a horse, do you feel discomfort or pain?

(Please select the one that applies)

	Yes
	No
	Does not apply to me

5.6 – Do you feel pain cleaning or mucking out stalls?

(Please select the one that applies)

	Yes
	No
	Does not apply to me

5.7 – When you ride a horse, you feel pain:

(Please select the one that applies)

	Gets worst
	Is constant
	Gets worst in the beginning, but with the continuation of exercise it returns back to normal levels
	Decreases

5.8 – When you feel pain do you do any exercise of movement that helps reduce it? If you do, what do you do?

(Please write down your answer)

5.9 – The pain you feel is constant, or accentuates in a specific season?

(Please select all that apply)

	Is constant
	Accentuates with cold

	Accentuates with humidity
	Accentuates with heat
	Other

With cold, humidity or heat we are referring to climatic conditions.

6 – Day to day in equestrianism, practices and pain

(to answer the following questions, think about what you felt/ did during the last year)

6.1 – In your daily activities do you warm up before riding on a horse?

(Please select the one that applies)

	Yes
	No

(warm up of the horse rider before riding on the horse)

6.2 – During the management of equestrian spaces/ infrastructures can you lift weights?

	Yes, without a problem
	No, some are hard to lift

6.2.1 – Which one's can´t you lift? (answer this question only if the following are true)

(Please select all that apply)

	Wheelbarrow (with content inside)
	Poles and jumps
	Shaving bales
	Hard feed bags
	Other (things I consider heavy)
	Other (things I consider light)

"Other (things I consider heavy)" – things that are possible to lift without pain, but due to pain you can't.

6.3 – Do you tend to wear clothes that keep the lower back region warm when you are riding horses?

(Please select the one that applies)

	Yes
	No
	Never thought about that

(example: vests, jackets or long sweaters/shirts that do not expose the lower back)

6.4 – What shoes do you use more frequently in your day to day outside of equitation?

(Please select all that apply)

	High heels
	Flat heels with rigid soles
	Sports shoes
	Orthopaedic shoes

6.5 – How do you mount on the horse? (Please select all that apply)

	With a step
	With the help of someone "leg up"
	Without any help and directly from the floor
	Other

(The act of getting on the horse)

6.6 – What type of saddle do you use?

(Please select the appropriate position for each element)

	Never (0%)	Rarely (till 10%)	Frequently (more than 50%)	Always (99%)
Dressage				
Jumping/ eventing				
Mixed saddle				
Portuguese or Spanish saddle				
Endurance				

(The percentages are according to the amount of times you ride horses. Think about the last year of equestrian practice)

Example of the answer of a instructor, horse trainer and eventer below:

	Never (0%)	*Rarely (till 10%)*	*Frequently (more than 50%)*	*Always (99%)*
Dressage			*X*	
Jumping/ eventing			*X*	
Mixed saddle		*X*		
Portuguese or Spanish saddle	*X*			
Endurance	*X*			

6.7 – The saddles you use personalized and measured for you?

(Please select all that apply)

	Yes (jumping saddle)
	Yes (dressage saddle)
	No

(To answer this question, think about the saddles you use more frequently. Not saddles you do not use often)

7 - The Roland-Morris Disability Questionnaire

When your back hurts, you may find it difficult to do some of the things you normally do. This list contains sentences that people have used to describe themselves when they have back pain. When you read them, you may find that some stand out because they describe you today. As you read the list, think of yourself today. When you read a *sentence that describes you today, put a tick against it. If the sentence does not describe you, then leave the space blank and go on to the next one. Remember, only tick "yes" the sentence if you are sure it describes you today, if not answer "no".*

	Yes	No
I stay at home most of the time because of my back.		
I change position frequently to try and get my back comfortable.		
I walk more slowly than usual because of my back.		
Because of my back I am not doing any of the jobs that I usually do around the house.		
Because of my back, I use a handrail to get upstairs.		
Because of my back, I lie down to rest more often.		
Because of my back, I have to hold on to something to get out of an easy chair.		
Because of my back, I try to get other people to do things for me.		
I get dressed more slowly then usual because of my back.		
I only stand for short periods of time because of my back.		
Because of my back, I try not to bend or kneel down.		
I find it difficult to get out of a chair because of my back.		
My back is painful almost all the time.		
I find it difficult to turn over in bed because of my back.		
My appetite is not very good because of my back pain.		
I have trouble putting on my socks (or stockings) because of the pain in my back.		
I only walk short distances because of my back.		
I sleep less well because of my back.		
Because of my back pain, I get dressed with help from someone else.		
I sit down for most of the day because of my back.		
I avoid heavy jobs around the house because of my back.		
Because of my back pain, I am more irritable and bad tempered with people than usual.		
Because of my back, I go upstairs more slowly than usual.		
I stay in bed most of the time because of my back.		

Author notes regarding the questionnaire

All questions that have an asterisk were mandatory to answer.

Topics 2.4.1, 2.4.2, 2.4.3 and 2.4.4 were only presented if the participant selected named equestrian discipline in topic 2.4.

In topic 3, if the answer to the question 3.1 was “No” the remaining questions 3.* were not presented.

Question 3.1.1.1 was only presented if the answer to the topic 3.1.1 was “Yes”.

In topic 4.1, if the answer was “no” the remaining topics 4.1.* were not presented.

In question 4.2 if the answer was “No” topics 5 and 7 were not presented to the participant.

Question 6.2.1 was only shown if the participant answered “No, some are hard to lift” in question 6.2.

All questions that had the option “other” allowed the respondent to write down a short answer.

4.10. Supplementary Material 2

Table VIII.18. *Demographic and anthropometric data of respondents, according to sex.*

Discipline[1]		**Dressage**	**Jumping**	**Eventing**	**General**	**Endurance**	**Horseball**	**Working Equitation**	**Total**
n (%)		79 (22.8)	139 (40.1)	30 (8.6)	76 (21.9)	14 (4.0)	5 (1.4)	4 (1.2)	347 (100)
Female	*n* (%)	44 (21.6)	86 (42.2)	7 (3.4)	51 (25.0)	9 (4.4)	5 (2.5)	2 (1.0)	204 (100)
Male	*n* (%)	35 (24.5)	53 (37.1)	23 (16.1)	25 (17.5)	5 (3.5)	0 (0)	2 (1.4)	143 (100)
Age (years)	Female	23.7	30.9	24.7	26.7	24.9	22.0	22.5	24.8
	Male	28.4	40.1	36.8	32.9	32.6	---	28.0	33.0
Height (cm)	Female	165	168	165	163	163	167	164	165
	Male	177	178	176	178	173	---	178	177
Weight (kg)	Female	59.7	59.4	61.2	60.5	59.0	60.8	57.5	60.2
	Male	74.1	79.9	77.0	78.0	72.0	---	81.0	76.5
BMI	Female	21.9	21.0	22.6	22.7	22.2	21.7	21.3	22.2
	Male	23.7	25.3	24.7	24.6	23.9	---	25.6	24.4

Note: 1 – According to the last National Federation inscription

Table VIII.19. *Distribution of respondents that reported feeling Lower Back Pain in the last 12 months according to the equestrian discipline Pearson's Chi-square and p-value.*

12-month LBP	**Dressage**	**Endurance**	**Eventing**	**General**	**Horseball**	**Jumping**	**Working Equitation**	**Total**
Yes	53	9	18	51	3	77	3	214
No	26	5	12	25	2	62	1	133
Total	79	14	30	76	5	139	4	347

	Value	**Degrees of freedom**	***p*-Value**

Pearson's Chi-square	4.629	6	0.592

Table VIII.20. *Binary logistic regression model for 12-month Lower Back Pain (variables in the equation)*

	B (SE)	Adj. OR	95% Confidence Interval	*p*-Value
Sex (female/male)	0.399 (0.240)	1.490	0.931 - 2.385	0.096
Main occupation (no/yes)	-0.264 (0.258)	0.768	0.463 - 1.274	0.308
Daily stable duties (yes/no)	0.365 (0.238)	1.441	0.904 - 2.296	0.124
Other sports (no/yes)	0.219 (0.234)	1.245	0.786 - 1.971	0.350
Warm up (no/yes)	-0.556 (0.328)	0.573	0.301 - 1.090	0.090
Weekly workload (up to 6h/7h or more)	0.304 (0.263)	1.355	0.809 - 2.270	0.249
Constant	0.109 (0.583)	1.115		0.852

Note: B: unstandardized regression coefficient. SE: standard error. Adj. OR: adjusted odds ratio. Reference category for each variable is underlined.

Table VIII.21. *Odds ratio for rider status (main occupation vs. hobby), weekly riding workload and daily stable duties.*

	Main occupation	Hobby	Odds Ratio	95% Confidence Interval	*p*-Value
Weekly load: 7h or more/up to 6 h	111/49	44/143	7.3622	4.5710 - 11.8580	< 0.0001
Daily stable duties: yes/no	117/43	96/91	2.5792	1.6411 - 4.0536	< 0.0001

Note: Reference category for each variable is underlined.

Table VIII.22. *Age, BMI and years of equestrian practice – comparison of groups with, and without Lower Back Pain in the last 12 months (p-value for Mann-Whitney U test).*

	12-month LBP – Yes (*n* = 214)	12-month LBP – No (*n* = 133)	*p*-Value
Age (years)	27.16 ± 10.31	29.83 ± 12.24	0.061
BMI (kg/m^2)	22.95 ± 3.23	23.40 ± 3.37	0.178
Years of equestrian practice	16.28 ± 9.92	17.93 ± 11.45	0.245

Table VIII.23. *Binary logistic regression model for Dysfunctional RMDS according to rider status (main occupation vs. hobby) (variables in the equation)*

Group	Variables	B (SE)	Adj. OR	95% Confidence Interval	*p*-Value
Hobby	Sex (female/male)	-0.821 (0.485)	0.440	0.170 - 1.140	0.091
	Daily stable duties (yes/no)	1.467 (0.457)	4.335	1.770 - 10.621	**0.001**
	Other sports (no/yes)	0.216 (0.441)	1.241	0.522 - 2.948	0.625
	Warm up (no/yes)	0.586 (0.572)	1.796	0.586 - 5.511	0.306
	Weekly workload (up to 6h/7h or more)	-0.553 (0.510)	0.575	0.212 - 1.564	0.279
	Constant	-0.394)0.874)	0.674		0.652
Main occupation	Sex (female/male)	-0.091 (0.425)	0.913	0.397 - 2.102	0.831
	Daily stable duties (yes/no)	-0.852 (0.536)	0.427	0.149 - 1.219	0.112
	Other sports (no/yes)	0.089 (0.419)	1.093	0.481 - 2.487	0.831
	Warm up (no/yes)	-0.286 (0.551)	0.751	0.255 - 2.212	0.603

	Weekly workload (up to 6h/7h or more)	0.024 (0.457)	1.024	0.418 - 2.510	0.959
	Constant	1.146 (1.036)	3.146		0.269

Note: B: unstandardized regression coefficient. SE: standard error. Adj. OR: adjusted odds ratio. Reference category for each variable is underlined.

Appendix 5 - Informed consent paper 3 and 4

Project Title

Characterization of the prevalence of low back pain in riders – proposal of a training program

We would like to invite you to voluntarily participate in a study on the characterization of the prevalence of lower back pain in equestrians. Please read the entire content of this document carefully. Do not hesitate to ask the lead investigator for more information if anything is unclear. Check if all the information is correct. If you find everything in order and agree with the proposal being presented to you, then sign this document.

1. I confirm that I am over 18 years old and under 60 years old. I confirm that I regularly practice horseback riding (more than three hours per week). I confirm that I have not had any acute injuries in the past 3 months. I confirm that I feel pain/discomfort in the lower back region.
2. I have been informed that the program aims to evaluate the effects of a specific training program on the incidence of lower back pain in riders.
3. My voluntary participation has been requested within the scope of this project.
4. This study aims to propose the adoption of complementary training practices to horseback riding, aimed at reducing the incidence of chronic injuries, reducing pain intensity, and contributing to the overall improvement of athletes' sportive health. It also aims to raise awareness among the target population about the importance of rider fitness training in reducing and managing pain and injuries, as well as potentially improving performance.
5. My participation will include the following evaluations:
    - Assessment of scores on certain movements from the Functional Movement Screening Test.
    - Superficial electromyography of the lumbar muscles while off the horse and riding, in the three natural gaits.
    - Kinematic analysis of the rider’s position at a walk, trot, and canter.

- Accelerometry of the rider's lower back movement while riding in the three natural gaits.
- A questionnaire with questions related to the rider's characterization, the incidence of lower back pain, and daily equestrian practices.
- Evaluation of height, weight, and body composition using a bioimpedance scale. If I am part of the experimental group, I will participate in a specific physical training program to strengthen the abdominal and lumbar muscles.

6. The research study is free of charge and involves the use of superficial electrodes, cameras, and accelerometers, as well as the completion of all tests indicated in point five of this informed consent.
7. I commit to scheduling, according to my availability, the assessment sessions indicated in point five of this informed consent with the lead investigator.
8. The research team does not foresee any inherent risks from participating in the study.
9. The research study is not responsible for damage or injuries caused by failure to follow, or differing from, the instructions and/or recommendations of the specialists involved in the study.
10. None of the specifications in this informed consent should be interpreted as a promise or guarantee of progress and/or results by the participant.
11. I understand that by participating, I will contribute to the advancement of scientific knowledge in this area, and it is also possible that, in the long term, the results of this study may help implement effective physical training programs for riders.
12. I understand that the information about me and my physical condition, collected for this study, will be used for the study's objectives and for additional related scientific research. The information will be stored in paper and electronic formats, with a code number to protect my privacy. Therefore, even if the study results are published, my identity will remain confidential.
13. I understand that regulatory authorities and members of the ethics committee may have access to the stored information and examine the records made during the study, and they are bound by confidentiality. By signing this form, I authorize direct access to these records as described here.

14. I understand that, through the lead investigator, I will have access to all the information collected about me and may request corrections of any inaccuracies I find. This access may be delayed if it could hinder the continuation of the study but will not be denied.

15. I have been informed that I will not be financially compensated for my participation in the research study.

16. I understand that I can approach the study investigators whenever I have questions.

17. I have read all the information above. The nature, risks, and benefits of the research study have been explained to me. I understand that I can withdraw my consent and stop participating at any time. By signing this consent, I am not waiving any legal rights, claims, medication, or treatment. I will be provided with a copy of this form.

____

Participant full name

______________________________________ __________

Participant signature Date

I certify that I have explained to the participant in this research study the nature, purpose, potential benefits, and risks associated with their participation. I have provided a copy of this form to the study participant.

______________________________________ __________

Investigator signature Date

Lead investigator: Carlota Rico Duarte

Contacts: carlota.beatriz.duarte@gmail.com Mobile: 00351911151409

Appendix 6 - Questionnaire paper 3 and 4

1 - Equestrian practices

(in this section there will be questions related only to your equestrian practices/ activities)

1.1 – For you equestrianism is:

(Please select the one that applies)

	Hobby
	Profession

(in case you are in an equestrian related study program select the option "profession")

1.2 – Years of equestrian practice

(Please write down your answer)

1.3 – Hours of equestrian practice per week (hours/week)

(Please select the one that applies)

	1 to 2
	3 to 4
	5 to 6
	7 to 12
	13 to 18
	More than 19

*(How many hours per week you ride **horses** (in case of doubt, think about the last year 2022-2023 to answer this question)*

1.4 – Equestrian discipline practiced:

(Please select all that apply)

	General equitation
	Dressage
	Show Jumping
	Eventing
	Endurance
	Other

You indicated that you practiced "other" equestrian discipline, witch one/ ones?

(Please write down your answer)

1.5 – What type of saddle do you use frequently (more than 50% of the time)?

(Please select all that apply)

Dressage	
Jumping/ eventing	
Mixed saddle	
Portuguese or Spanish saddle	
Endurance	

1.6.1 – Level of competition in Dressage in the last 12-monts

(Please select all that apply)

Festival	
National	
International	
Olympic	

1.6.2 – Level of competition in Show Jumping in the last 12-monts

(Please select all that apply)

Festival	
National	
International	
Olympic	

1.6.3 – Level of competition in Eventing in the last 12-monts

(Please select all that apply)

National	
International	
Olympic	

1.6.4 – Level of competition in Endurance in the last 12-monts

(Please select all that apply)

Festival	
National	
International	

1.5.4 – Level of competition in “Other” in the last 12-monts

(Please select all that apply)

Festival	
National	
International	

1.6 – Sporting license in the year 2022 or 2023:

(Please select all that apply)

	Practitioner license
	National competition license
	International competition license

1.7 – Beyond equestrian practice, do you also participate in activities inherent to treatment and management of horses?

(Please select the one that applies)

	Yes, daily
	Yes, sometimes
	No

(in case of doubt, think about the last year 2022-2023 to answer this question)

With treatment and management of horses we mean:

- *Cleaning and mucking out stalls*
- *Grooming, tacking and untacking horses*
- *Feeding of horses*
- *Management and maintenance of equestrian spaces*
- *Others*

2 – Sporting practices

(in this section you should answer about your practice of other sports not related with equestrian sports)

2.1 – Other than equitation, do you practice other sports or physical activities?

(Please select the one that applies)

	Yes
	No

3– Low Back Pain in equestrian practices

(Answer this category thinking about what you feel when you are developing equestrian activities)

(Answer the following questions regarding what you feel/ do when the ***pain in the lower back in present)***

3.1 – Do you feel the pain is worst/ feel more pain when you ride a horse?

(Please select the one that applies)

	Yes
	No

(with "ride a horse" we mean the direct practice of equitation, of being on a horse in the three gaits)

3.2 – Do you feel that pain harms your performance while riding?

(Please select the one that applies)

	Yes
	No

3.3 – When you are on a horse when is the pain, you feel stronger?

(Please select all that apply)

	Walk
	Rising trot/ posting trot
	Sitting trot
	Canter
	Canter in jumping position
	During jumps
	I do not feel pain when riding

Answer thinking about the circumstance when you feel more pain, or the pain gets worst, it is possible to choose more than one option, think about your answer.

Explanation:

"Canter" – siting on the saddle

"Canter in jumping position" – cantering with short stirrups in a jumping position, with seat off the saddle.

"During jumps" – in show jumping lessons, when you have to use the jumping position a lot over jumps.

3.4 – During horse grooming, in which situation do you feel more pain?

(Please select the one that applies)

	Cleaning the horse's body
	Cleaning the horse's hoofs
	During both
	Pain does not enhance

3.5 – When you are lunging a horse, do you feel discomfort or pain?

(Please select the one that applies)

	Yes
	No

3.6 – Do you feel pain cleaning or mucking out stalls?

(Please select the one that applies)

	Yes
	No
	Does not apply to me

3.7 – When you ride a horse, you feel pain:

(Please select the one that applies)

	Gets worst
	Is constant
	Gets worst in the beginning, but with the continuation of exercise it returns back to normal levels

	Decreases
	I do not feel pain when riding

3.8 – The pain you feel is constant, or accentuates in a specific season?

(Please select all that apply)

	Is constant
	Accentuates with cold
	Accentuates with humidity
	Accentuates with heat
	Other

With cold, humidity or heat we are referring to climatic conditions.

4 - The Roland-Morris Disability Questionnaire

When your back hurts, you may find it difficult to do some of the things you normally do. This list contains sentences that people have used to describe themselves when they have back pain. When you read them, you may find that some stand out because they describe you today. As you read the list, think of yourself today. When you read a sentence that describes you today, put a tick against it. If the sentence does not describe you, then leave the space blank and go on to the next one. Remember, only tick "yes" the sentence if you are sure it describes you today, if not answer "no".

	Yes	No
I stay at home most of the time because of my back.		
I change position frequently to try and get my back comfortable.		
I walk more slowly than usual because of my back.		
Because of my back I am not doing any of the jobs that I usually do around the house.		
Because of my back, I use a handrail to get upstairs.		
Because of my back, I lie down to rest more often.		
Because of my back, I have to hold on to something to get out of an easy chair.		
Because of my back, I try to get other people to do things for me.		
I get dressed more slowly then usual because of my back.		
I only stand for short periods of time because of my back.		
Because of my back, I try not to bend or kneel down.		
I find it difficult to get out of a chair because of my back.		
My back is painful almost all the time.		
I find it difficult to turn over in bed because of my back.		
My appetite is not very good because of my back pain.		
I have trouble putting on my socks (or stockings) because of the pain in my back.		
I only walk short distances because of my back.		
I sleep less well because of my back.		
Because of my back pain, I get dressed with help from someone else.		
I sit down for most of the day because of my back.		

I avoid heavy jobs around the house because of my back.		
Because of my back pain, I am more irritable and bad tempered with people than usual.		
Because of my back, I go upstairs more slowly than usual.		
I stay in bed most of the time because of my back.		

Appendix 7 - Data collection protocol – Papers of Chapter IV and V

This appendix outlines the structured data collection protocol employed for studies 3 and 4. The protocol systematically gathers essential participant information through a sequence of standardized assessments. The protocol comprises three key phases designed to evaluate both static and dynamic parameters:

1. Initial evaluation (Questionnaire, height, bioimpedance scale and functional movements)
2. Static surface electromyography assessment
3. Surface electromyography assessment on horseback

Before beginning, participants were presented with an informed consent form (**Appendix 3**) detailing the data collection protocol, study procedures, and design, which they reviewed and signed. All assessments and testing procedures were conducted in a single, continuous session for each participant, ensuring a comprehensive and consistent evaluation. To maintain accuracy and reliability, all assessments were performed by a single, specifically trained and certified examiner, proficient in the study protocols.

1. Initial evaluation

1.1. Questionnaire

Subjects were asked to fill up a questionnaire (available on **Appendix 4** of the present thesis). The questionnaire had 22 questions and took 5 minutes to complete. Questions covered equestrian sports experience, including years riding, training hours, discipline practiced, competition level, and saddle type. Additional topics explored involvement in other sports, pain experienced during equestrian activities to assess sport-specific limitations, and the Roland Morris Disability Questionnaire.

1.2. Body composition

First, participants were asked to remove their shoes for height measurement. A measuring tape, securely fixed to a wall at an appropriate location, provided a precise reference. Participants stood straight with their backs against the wall, looking forward, while a 50 cm ruler was used to accurately record their height at the crown of their head.

Next, participants removed their socks, any items from their pockets, and extra clothing, such as heavy jackets, in preparation for the bioimpedance assessment. Prior to the measurement, the TANITA software was set up by entering each participant's code name, date of birth, height, and sex. Once all information was inputted, participants stepped onto the scale, placing their feet on the designated marks. They were instructed to hold the handles with arms relaxed at their sides during the assessment to ensure accurate readings.

1.3. Functional movement screening tests

The guidelines for the Functional Movement Screening tests, as outlined in **Appendix 6**, were strictly followed. Materials for this assessment included a yoga mat, a wooden board (3.8 cm height x 14 cm width), and a 1.50 m wooden dowel. To facilitate future scoring, two cameras (phones mounted on tripods) captured frontal and lateral views of each participant. Camera height was adjusted for each test to ensure accurate and comprehensive image capture. The examiner demonstrated and explained each test to the participants, who then performed the tests without any practice trials. Each participant was given a maximum of three attempts per test.

Order of the Functional Movement Screening tests:

1 - Deep Squat – This test assesses overall functional mobility and stability, particularly of the hips, knees, and ankles, while also challenging the core and upper body.

2 - Trunk Stability Push-Up (TPU) – This test evaluates core stability in a closed kinetic chain, focusing on the ability to stabilize the spine while performing a symmetrical upper-body movement.

3 - TPU Clearing Test – This clearing test is conducted immediately after the Trunk Stability Push-Up to check for pain during spinal extension.

This sequence helps ensure that participants can proceed safely through the tests, particularly with the TPU clearing test identifying any potential discomfort in the lower back after core activation.

2. Static Surface Electromyography Assessment

The static sEMG assessment used the 8-channel biosignalsplux© kit and force platform to capture muscle activity at rest. The materials required for this part of the protocol included a marker, rubbing alcohol, cotton for alcohol application, conductive gel, electrodes, a stool, Kinesio tape, and the Biosignals kit with force platform.

Before electrode placement, careful skin preparation was performed, including cleaning with alcohol. Muscle locations were identified through palpation and marked with a marker. Each of the nine electrodes was prepared with conductive gel to improve data quality and then applied to the marked spots on the participant’s back. The reference electrode was placed over a thoracic or lumbar vertebrae. Finally, the electrodes were secured with Kinesio tape to ensure stable positioning throughout the assessment.

Participants were asked to sit on a stool placed over the Biosignals force platform. The electrodes were connected to their corresponding lead cables, which were then attached to the wireless 8-channel hub and subsequently linked to the platform. All cables and the wireless hub were marked with numbered labels to ensure consistency and organization throughout the protocol.

Two baseline activities were conducted on the force platform: sitting with eyes open and focusing on a point for one minute, followed by sitting with eyes closed for one minute. sEMG data was collected using the OpenSignals app for both computer and Android.

3. Surface Electromyography Assessment on Horseback

The dynamic sEMG protocol was conducted on horseback, incorporating both accelerometry and kinematic data collection. Participants continued wearing the securely placed electrodes from the static assessment, though cables were temporarily removed for comfort. Horses were prepared beforehand with the participant's usual tack, ensuring familiarity and consistency. In the arena, participants warmed up their horses for 5 minutes while the examiner set up for data collection. As shown in **Figure 1**, a 10-meter corridor with four vertical markers spaced 2 meters apart was established, and a camera (iPhone 14 Pro Max) was positioned 10 meters from the corridor, centered on a tripod for optimal recording.

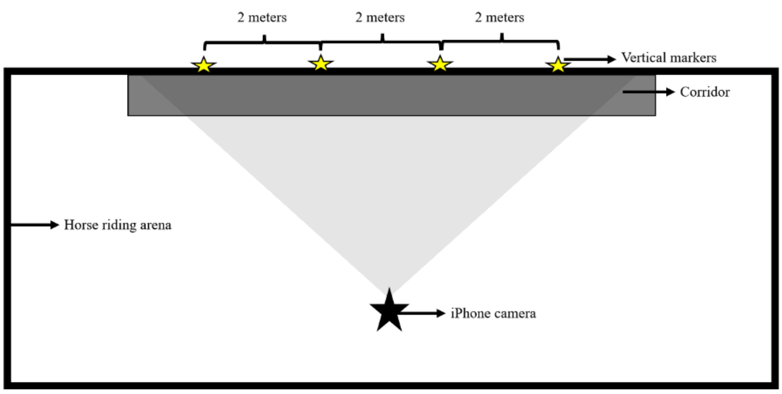


Figure 1. *Set up of the riding arena*

Before beginning the riding assessment, electrodes were reconnected to their lead cables, which were attached to the wireless 8-channel hub. The biosignalsplux© wireless hub, along with mobile devices running the OpenSignals and Movesense© apps, were secured in a waist pack worn by the rider to maintain a stable Bluetooth connection.

Data collection commenced with all devices activated for simultaneous recording (sEMG, ACC, and video). The riding assessment included four activities across three gaits, conducted in both directions (left and right rein): medium walk, rising trot, sitting trot, and canter, each performed through the marked corridor. To conclude, devices and recordings were reviewed to confirm data completeness and integrity.

The protocol was finalized by disconnecting and safely removing all electrodes and equipment from the participants.

2. Data collection protocol check list

Data collection protocol - Check list			
Room with table, chairs and space for yoga mat and camera set up			
Prepare room, devices and setups			
Initial evaluation			
Informed consent			
Questionnaire			
Height			
Date of birth			
Bioimpedance scale			
FMS (with videos)			
	1st Attempt	2nd Attempt	3rd Attempt
Deep squat			
Trunk Push-up			
TPU – Clearing test			
Static surface electromyography			
Place electrodes	MF (4 channels)		
	ESI (4 channels)		
	Reference electrode		
Exercises	Sitting with eyes open		
	Sitting with eyes closed		
Surface Electromyography Assessment on Horseback			
Participant warms up the horse			
Prepare arena set up	Markers (2-2-2-2)		
	Camera on tripod		
To start the assessment			
Connect all electrodes, cables and hub			
Turn on the OpenSignals app			
Turn on the Movesense app			
Turn of the iPhone camera			
Exercises	Walk to the right		
	Walk to the left		
	Rising trot to the right		
	Rising trot to the left		
	Sitting trot to the right		
	Sitting trot to the left		
	Canter to the right		

	Canter to the left	
Show sEMG and ACC times on the iPhone video for future synchronization		
Retain and organize all materials used		

Appendix 8 - Functional movement screening tests evaluation protocol

6.1. Deep squat (Cook, Burton and Hoogenboom[1] pages 66 and 67)

6.1.1. Purpose

The squat is a movement needed in most athletic events. It is the ready position and is required for most power movements involving the lower extremities. The deep squat is a test that challenges total body mechanics when performed properly. The deep squat is used to assess bilateral, symmetrical, functional mobility of the hips, knees, and ankles. The dowel held overhead assesses bilateral, symmetrical mobility of the shoulders as well as the thoracic spine.

6.1.2. Description

The individual assumes the starting position by placing his/her feet approximately shoulder width apart and the feet aligned in the sagittal plane. The individual then adjusts their hands on the dowel to assume a 90-degree angle of the elbows with the dowel overhead. Next, the dowel is pressed overhead with the shoulders flexed and abducted, and the elbows extended. The individual is then instructed to descend slowly into a squat position. The squat position should be assumed with the heels on the floor, head and chest facing forward, and the dowel maximally pressed overhead. As many as three repetitions may be performed. If the criteria for a score of III is not achieved, the athlete is then asked to perform the test with a 2x6 block under their heels. (Figures 1- 4)

Tips for Testing:

• When in doubt, score the subject low.

• Try not to interpret the score while testing.

• Make sure if you have a question to view individual from the side.

6.1.3. Clinical Implications for Deep Squat

The ability to perform the deep squat requires closed kinetic chain dorsiflexion of the ankles, flexion of the knees and hips, extension of the thoracic spine, and flexion and abduction of the shoulders.

Poor performance of this test can be the result of several factors. Limited mobility in the upper torso can be attributed to poor glenohumeral and thoracic spine mobility.

Limited mobility in the lower extremity including poor closed-kinetic chain dorsiflexion of the ankles or poor flexion of the hips may also cause poor test performance.

III

- Upper torso is parallel with tibia or toward vertical
- Femur below horizontal
- Knees are aligned over feet
- Dowel aligned over feet

Figure 1. *Deep squat anterior view.*

Figure 2. *Deep squat lateral view.*

Figure 3. *Deep squat anterior view.*

Figure 4. *Deep squat anterior view.*

II

- Upper torso is parallel with tibia or toward vertical
- Femur is below horizontal
- Knees are aligned over feet
- Dowel is aligned over feet
- 2x6 board required under feet

I

- Tibia and upper torso are not parallel
- Femur is not below horizontal
- Knees are not aligned over feet
- Lumbar flexion is noted
- 2x6 board required under feet

Figure A. *Example and explanation of how to score the Deep squat (retrieved from[1], page 66 and 67)*

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using standard goniometric measurements. Previous testing has identified that when an athlete achieves a score of II, minor limitations most often exist either with closed kinetic chain dorsiflexion of the ankle or extension of the thoracic spine. When an athlete achieves a score of I or less, gross limitations may exist with the motions just mentioned, as well as flexion of the hip.

6.2. Trunk stability Push-up (Cook, Burton and Hoogenboom[2] pages 136 and 137)

6.2.1. Purpose

The trunk stability push-up tests the ability to stabilize the spine in an anterior and posterior plane during a closed-chain upper body movement. The test assesses trunk stability in the sagittal plane while a symmetrical upper-extremity motion is performed.

6.2.2. Description

The individual assumes a prone position with the feet together. The hands are then placed shoulder width apart at the appropriate position per the criteria described later. The knees are then fully extended and the ankles are dorsiflexed. The individual is asked to perform one push-up in this position. The body should be lifted as a unit; no "lag" should occur in the lumbar spine when performing this push-up. If the individual cannot perform a push-up in this position, the hands are lowered to the appropriate position per the established criteria (Figures 8-10).

Figure 8. *Trunk Stab Push Up III (male)*

III

• Males perform one repetition with thumbs aligned with the top of the forehead
• Females perform one repetition with thumbs aligned with chin

Figure 9. *Trunk Stab Push Up II (male)*

II

• Males perform one repetition with thumbs aligned with chin
• Females perform one repetition with thumbs aligned with clavicle

Figure 10. *Trunk Stab Push Up II (male)*

I

• Males are unable to perform one repetition with hands aligned with chin
• Females are unable to perform one repetition with thumbs aligned with clavicle

Figure 11. *Spinal Extension Clearing Test*

Figure B. *Example and explanation of how to score the Trunk stability push-up test (retrieved from[2], page 136 and 137)*

Tips for Testing:

• Tell them to lift the body as a unit

• Make sure original hand position is maintained and the hands do not slide down when they prepare to lift

• Make sure their chest and stomach come off the floor at the same instance

• When in doubt score it low

• The clearing test overrides the test score

6.2.3. Clearing exam

A clearing exam is performed at the end of the trunk stability push-up test. This movement is not scored; the test is simply performed to observe a pain response. If pain is produced, a score of zero is given for the entire push-up test. This clearing exam is necessary because back pain can sometimes go undetected during movement screening.

Spinal extension can be cleared by performing a press-up in the push-up position (**Figure 11**). If pain is associated with this motion, a zero is given and a more thorough evaluation should be performed.

6.2.4. Clinical Implications for Trunk Stability Push-up

The ability to perform the trunk stability push-up requires symmetric trunk stability in the sagittal plane during a symmetric upper extremity movement. Many functional activities in sport require the trunk stabilizers to transfer force symmetrically from the upper extremities to the lower extremities and vice versa. Movements such as rebounding in basketball, overhead blocking in volleyball, or pass blocking in football are common examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed and lead to poor functional performance, as well as increased potential for micro traumatic injury.

Poor performance during this test can be attributed simply to poor stability of the trunk stabilizers. When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using test by Kendall6 or Richardson et al8 for upper and lower abdominal and trunk strength. However, the test by Kendall6 requires a concentric contraction while a push-up requires an isometric stabilizing reaction to avoid spinal hyperextension. A stabilizing contraction of the core musculature is more fundamental and appropriate than a simple strength test, which may isolate one or two key muscles. At this point, the muscular deficit should not necessarily be diagnosed. The screening exam simply implies poor trunk stability in the presence of a trunk extension force, and further examination at a later time is needed to formulate a diagnosis.

8.3. References

1. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function–part 1. *N Am J Sports Phys Ther*. 2006; 1(2), 62.

2. Cook G, Burton L, Hoogenboom B. Pre-participation screening: The use of fundamental movements as an assessment of function–Part 2. *N Am J Sports Phys Ther*. 2006; 1(3), 132.

Appendix 9 - Warm-up and stretching program (WSP)

Warm-up and stretching program layout: The WSP was printed and delivered to the experimental group participants in a dossier with the STP. The printed layout is shown in **Figure A5.1**, as an example. The WSP had three warm-up and 3 stretching programs, the participants had to choose a program to do before and after the STP of the day.

Figure A5.1. *WSP layout*

Introductory note WSP

(page 1 Figure A5.1.)

You'll find three different warm-up plans and three different stretching plans. You can choose to do any of them, and if there are exercises you can't do, you can swap them for another exercise from one of the other plans described here. If any exercise causes you pain, don't do it and let me know.

Before each 'rider back, no pain and gain program' you should do a full warm-up and at the end a full stretching plan.

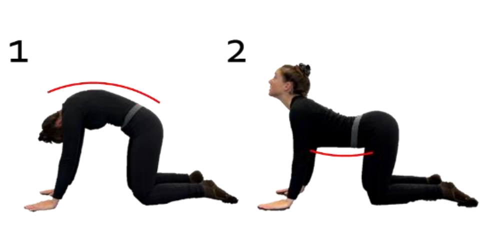
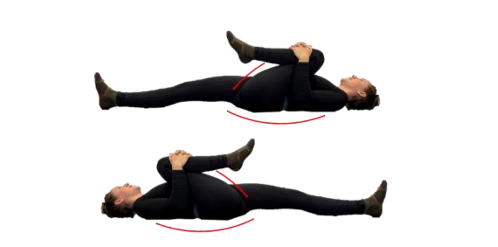
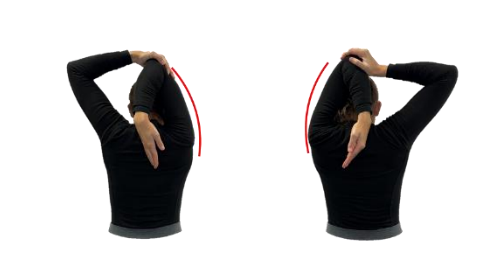
The exercises have been chosen with the aim of warming up and stretching the main muscle groups used in the 'Rider back, no pain and gain program'.

Each image shows, through the red lines, which area of your body you should feel stretching. All the exercises in this plan should be performed slowly and gently so as not to create unwanted injuries.

If you have any questions, please get in touch so we can help you.

Happy training!

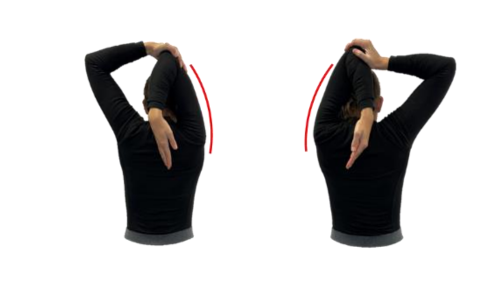
Warm-up plan 1

I		IV	
II		V	
III		VI	

Exercise	Details
I	Back stretch, designed to stretch and strengthen the spine, increase lumbar flexibility and relieve back pain. 1 - Exhale while stretching, you should feel the extension of the back muscles (from the neck to the lower back). 2 - Inhale as you stretch, you should feel the stretch in your abdominal muscles. Do 5 reps, hold each position (1 and 2) for 3 seconds.
II	Stretching the arms

	Help (gently) with the opposite hand in order to feel the stretch in the triceps. Hold for 15 to 30 seconds, each arm.
III	Stretching the legs, abdominal muscles and pelvis To optimize the stretch when holding your foot, contract your glutes and rotate your pelvis forwards. Hold for 15 to 30 seconds each leg.
IV	Stretch the glutes, lower back and groin. Keep the heel of the extending leg in contact with the floor at all times and keep your spine straight. Hold for 15 to 30 seconds each leg.
V	Stretching the oblique abdominal muscles Start lying on your back, legs together. Bend your knees and rotate until your lower leg rests on the floor. Always keep your shoulders in contact with the floor. Hold for 10 to 15 seconds and do the opposite side.
VI	Stretching the muscles of the spine and legs Start in a seated position with your legs spread apart (as in the picture). Extend your arms and try to reach as far as possible until you feel the stretch in your back. Hold for 5 seconds and repeat 3 times.

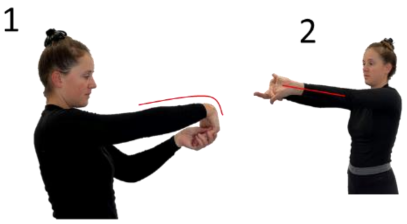
Warm-up plan 2

I		IV	
II		V	
III		VI	

Exercise	Details
I	Stretching the back and leg muscles Start standing, feet shoulder-width apart. Bend your knees and, with your arms crossed, grasp the back of your knee (as shown in the picture). Then extend your knees, which will make you feel a stretch in your entire spine and leg muscles. Always keep your neck relaxed. Hold for 5 seconds, repeat 3 times.
II	Stretching the abdominal muscles Start lying on your stomach, hands resting under your shoulders. In one movement, lift your torso off the floor until your arms are at maximum extension. Hold for 5 seconds, repeat 2 times.

III	Stretching the oblique abdominal muscles, chest, glutes and legs Sit on the floor with your left leg extended. Cross your right leg over your left, with your knee bent. Place your left elbow on the outside of your right knee. Exhale and push your elbow against your knee. Hold for 10 to 20 seconds on each side.
IV	Stretching the muscles of the cervical region Standing or sitting with your legs crossed, drop your head forwards until you feel the muscles in your neck stretch. Be careful not to let your torso lean forwards and keep your back straight. If you wish, you can rock your head slowly to the right and left. Hold for 5 seconds and repeat 3 times.
V	Stretching the oblique abdominal muscles, arms and pelvis Do the exercise standing up, paying attention and always keeping your body perpendicular to the floor (don't lean forwards or backwards). Hold for 5 to 10 seconds, do 2 repetitions and then do the other side.
VI	Shoulder and arm stretch Place your arms as in the picture and gently pull your elbow down with your top hand to optimize the stretch. Hold for 5 seconds, do 2 reps and then do the same exercise with the other arm.

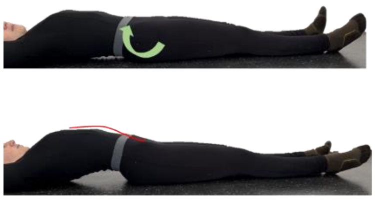
Warm-up plan 3

I		IV	
II		V	
III		VI	

Exercise	Details
I	Stretching the abdominal muscles Start lying on your stomach, hands resting under your shoulders. In one movement, lift your torso off the floor until your arms are at maximum extension. Hold for 5 seconds, repeat 2 times.
II	Stretching the forearm, wrists and shoulders 1 - To optimize the stretch, gently pull the fingers towards you with the opposite hand. Always keep the arm in full extension. Hold for 5 seconds and do with the opposite hand. 2 - Interlace your fingers with your palms pointing forwards. And extend your arms. Hold for 5 seconds, do 2 times.
III	Stretching the oblique abdominal muscles and legs

	Start lying on your back, arms as shown and legs extended. Then cross one leg over the other (as shown in the picture). Hold for 10 to 15 seconds and do the other leg.
IV	Stretching the shoulders and arms Keep the arm stretching always in extension and with the opposite arm help by pulling it towards you (as shown in the image). Hold for 10 to 15 seconds and do with the other arm.
V	Stretching the abdominal and pectoral muscles While standing, place your hands under your buttocks for support. Then lean back as far as possible. Hold for 5 seconds, repeat 2 times.
VI	Stretching the oblique abdominal muscles, arms and pelvis Do the exercise standing up, paying attention and always keeping your body perpendicular to the floor (don't lean forwards or backwards). Hold for 5 to 10 seconds, do 2 x and then do the other side.

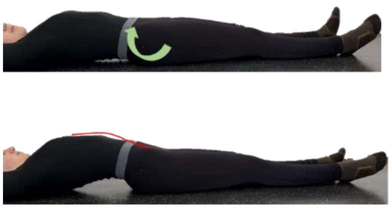
Stretching plan 1

I		IV	
II		V	
III		VI	

Exercise	Details
I	Stretching the abdominal muscles Lie on your back with your arms extended (next to your ears) in contact with the floor. Inhale, filling your chest cavity while rotating your pelvis upwards (thus increasing your lumbar arch). Hold for 10 to 20 seconds.
II	Stretching the oblique abdominal muscles, pelvis and legs To begin stretching, start on your knees, then place your left buttock on the floor and rotate your torso. Your right hand on your left knee will help you stretch more effectively. Hold for 15 to 30 seconds and do the other side.
III	Stretching the abdominal muscles, legs, arms and pelvis

	To perform this stretch, lie on your stomach on the floor. Bend your knees and grab your feet with your hands. Simultaneously lift your chest off the floor and your thighs as high as possible, creating an arc with your body. Hold for 5 to 15 seconds.
IV	Leg and shoulder stretches Start standing with your legs parallel. Raise your arms towards the ceiling. Exhale while bending forwards, with your back always straight, if necessary, you can bend your knees. Keep your torso and arms parallel to the floor. Look at the floor. Hold for 5 to 10 seconds, do 2 times.
V	Stretching the gluteal muscles Starting on your hands and knees, bring one leg forward, placing the (bent) knee between your hands. Place the foot (of the bent leg) on the outside of the thigh of the leg that is in extension. This will create a slight rotation in the pelvis and knee. Lean on your elbows and make sure your pelvis is always centred and parallel to the floor. Hold for 15 to 30 seconds (on each leg)
VI	Stretching the pelvic and gluteal muscles When stretching, keep your back straight and lower your pelvis as much as possible. Hold for 15 to 30 seconds and do with the opposite leg.

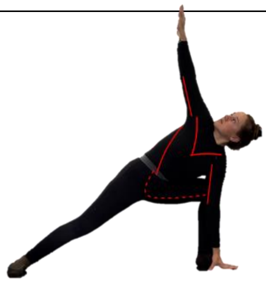
Stretching plan 2

I		IV	
II		V	
III		VI	

Exercise	Details
I	Stretching the abdominal muscles To improve stretching, rotate your pelvis by contracting your glutes and bring your navel forward as far as possible. Hold for 15 to 30 seconds
II	Stretching the muscles of the pelvis and legs Start in the lunge position, bend the knee of the back leg and hold with the opposite hand to activate the stretch. Hold for 10 to 20 seconds and do with the opposite leg.
III	Stretching the abdominal muscles

	Lie on your back with your arms extended (by your ears) in contact with the floor. Inhale, filling your chest cavity while rotating your pelvis upwards (thus increasing your lumbar arch). Hold for 10 to 20 seconds.
IV	Stretching the pectoral muscles, oblique abdominals, legs and arms Start standing, step forwards with your left leg, then bend your knee and place your hands on the floor (on the inside of your foot). Raise your right arm towards the ceiling. Hold for 10 to 20 seconds and do the other side.
V	Stretching the chest and arm muscles Standing with your back and shoulders straight, interlace your fingers behind your back, thumbs pointing to the floor. To perform the stretch, move your arms away from your back until you feel the stretch in your chest and arms. Always keep your back and elbows straight. Hold for 5 to 10 seconds, repeat 2 times.
VI	Stretching the legs and abdominal muscles Start lying on your stomach, bend one knee, bringing your heel towards your back. Hold the foot with the hand on the same side and gently apply force. Hold for 10 to 20 seconds and do with the opposite leg.

Stretching plan 3

I		IV	
II		V	
III		VI	

Exercise	Details
I	Stretching the posterior muscles of the body Start with your feet shoulder-width apart, lower into a squat (touch your thighs to your calves), keeping your feet flat on the floor. Place your hands on your head and flex your neck and spine forwards. Hold for 20 to 30 seconds.
II	Stretching the pectoral muscles, oblique abdominals, legs and arms Start standing, step forward with your left leg, then bend your knee and place your hands on the floor (on the inside of your foot). Raise your right arm towards the ceiling. Hold for 10 to 20 seconds and do the other side.
III	Stretching the pelvic and gluteal muscles When stretching, keep your back straight and lower your pelvis as much as possible.

	Hold for 15 to 30 seconds and do with the opposite leg.
IV	Stretching the oblique abdominal muscles, pelvis and legs To begin stretching, start on your knees, then place your left buttock on the floor and rotate your torso. Your right hand on your left knee will help you stretch more effectively. Hold for 15 to 30 seconds and do the other side.
V	Stretching the oblique abdominal muscles, chest, glutes and legs Sit on the floor with your left leg extended. Cross your right leg over your left, with your knee bent. Place your left elbow on the outside of your right knee. Exhale and push your elbow against your knee. Hold for 10 to 20 seconds on each side.
VI	Stretching the abdominal muscles To improve stretching, rotate your pelvis by contracting your glutes and push your navel forward as far as possible. Hold for 15 to 30 seconds

Appendix 10 - Specific training program

Training program layout: The STP was printed and delivered to the experimental group participants in a dossier. The printed layout of week one is shown in **Figure A6.1**, as an example. The STP layout was the same for every week, only the exercise content changed.

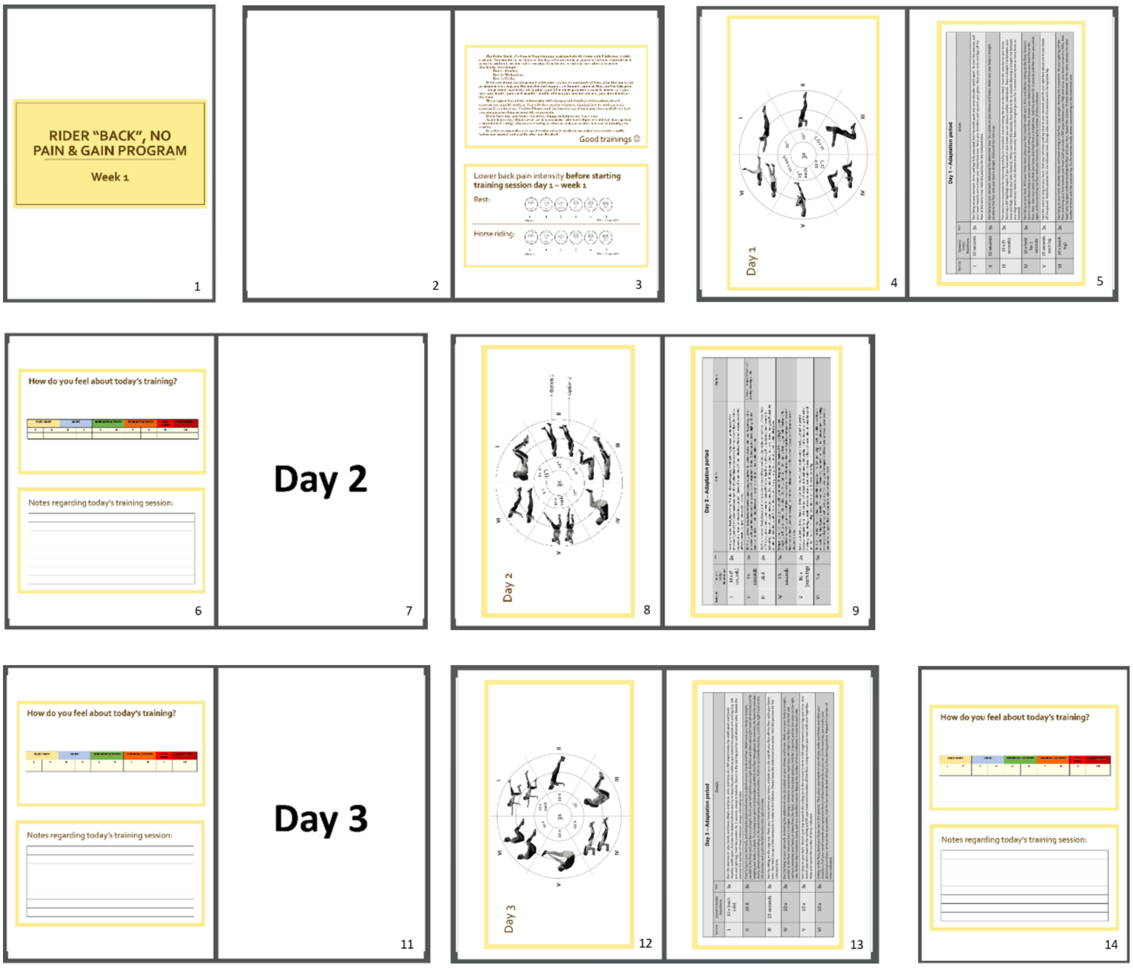


Figure A6.1. *STP layout*

Rider "back", no pain & gain program - Introductory note

(Figure A6.1 – page 3)

The Rider 'Back', No Pain & Gain training program lasts 12 weeks with 3 different weekly sessions. You can do the sessions on the days of your choice at your convenience. Our advice is to do the training sessions with rest days in between so that you have time to recover physically, for example:

Day 1 - Monday

Day 2 - Wednesday

Day 3 - Friday

If you are doing this program, it is because you have complaints of back pain, the aim of the program is to strengthen the muscles that support the lumbar region so that you feel less pain.

It's possible that in the initial phase you'll feel more pain due to muscle soreness. If you have any doubts, pain or discomfort outside of what you consider normal, you should contact the team.

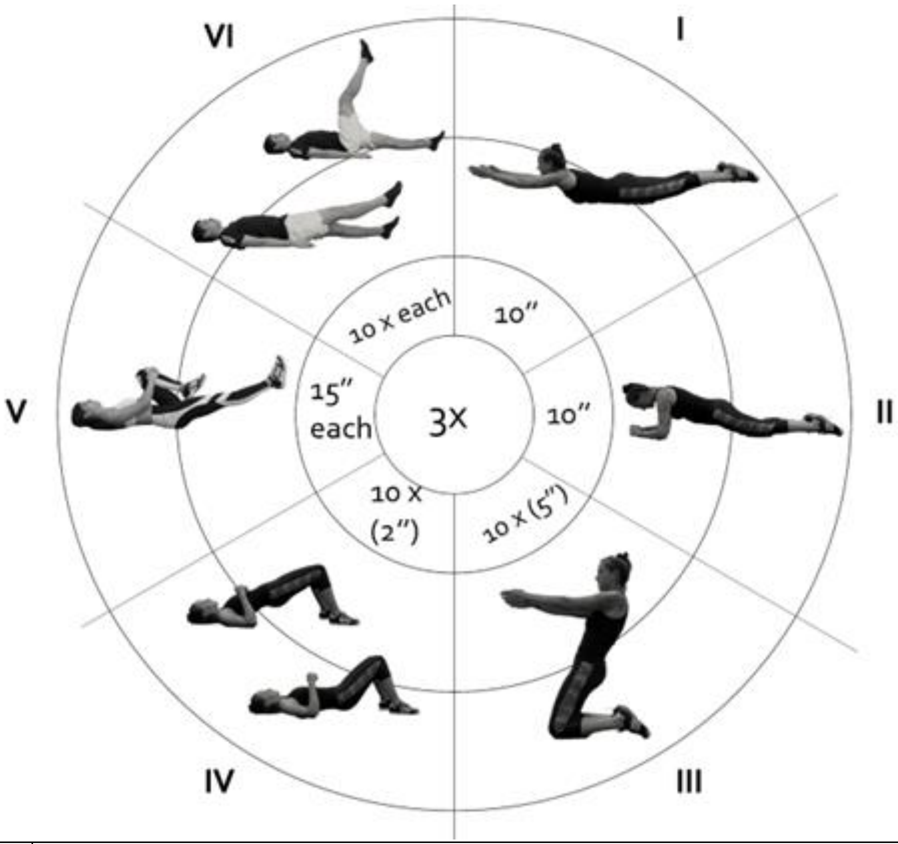
The program has all the information with images and detailed explanations of each exercise you should perform. You will also receive videos explaining how to perform each exercise if you have any doubts. Please read the description of each exercise carefully so that you can perform them as correctly as possible.

If you have any questions, I'm always happy to help in any way I can.

At the beginning of each week, we ask you to rate the level of perceived lower back pain at rest and when riding. After each training session, we ask you to rate how you felt during the session.

In order to assess the average duration of each workout, we asked you to take a selfie before you started and a selfie after you finished.

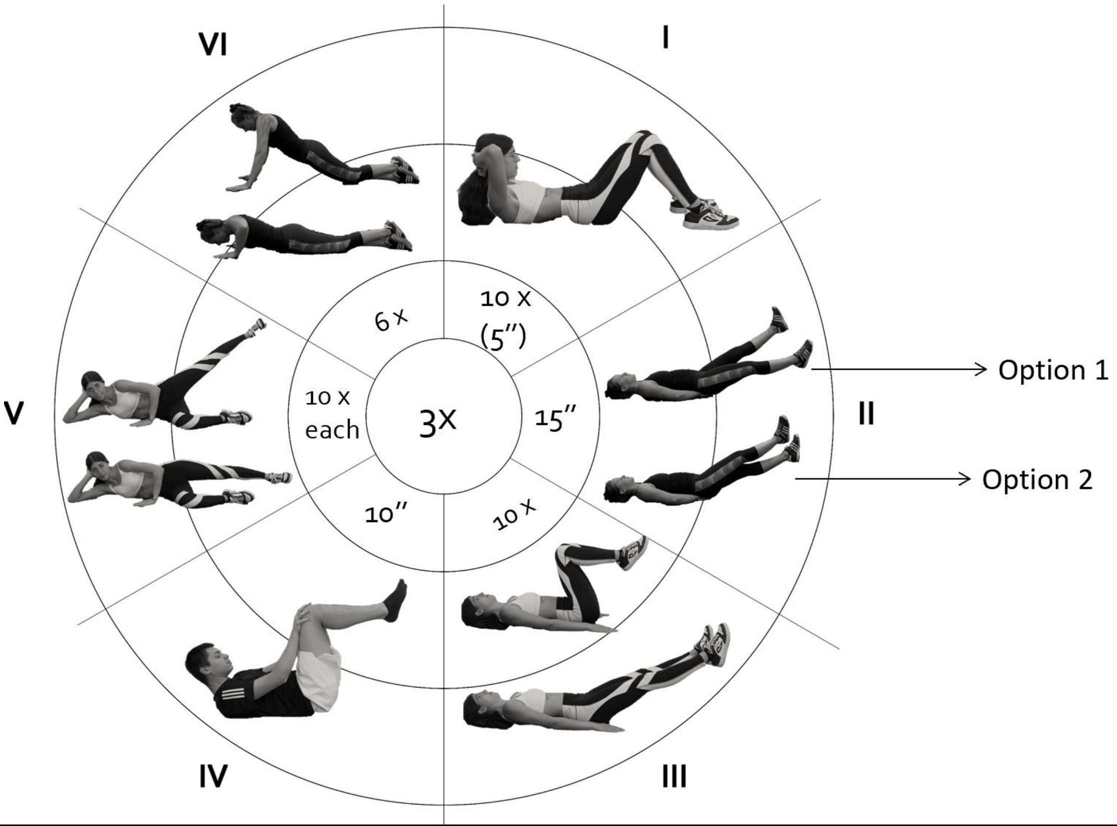
Week 1 – Day 1 – Adaptation period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate your abdominal area. Relax your shoulders and squeeze your glutes. Raise your arms and legs off the floor at the same time. Hold this position for the indicated time.
II	Start lying on your stomach. Activating the abdominal area. Do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Hold until the time is up.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (5 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Start lying on your back. With your knees bent, place your feet shoulder-width apart. Arms and elbows resting on the floor, forearms bent or straight (depending on your preference). Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Next, raise your pelvis so that your torso and thigh form a straight line, hold this position for 2 seconds and then lower your pelvis again, without touching the floor with your buttocks, repeating the number of times indicated.
V	Start the exercise lying on your back. Hold your left knee and leg close to your stomach and lift your right foot about one to two palms off the ground. Hold this position for the indicated time. Change sides and do the exercise with the opposite leg.
VI	Start lying on your back, shoulder blades and head resting on the floor. Legs straight. Starting the movement, lift your right leg off the floor and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching the floor with your foot. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

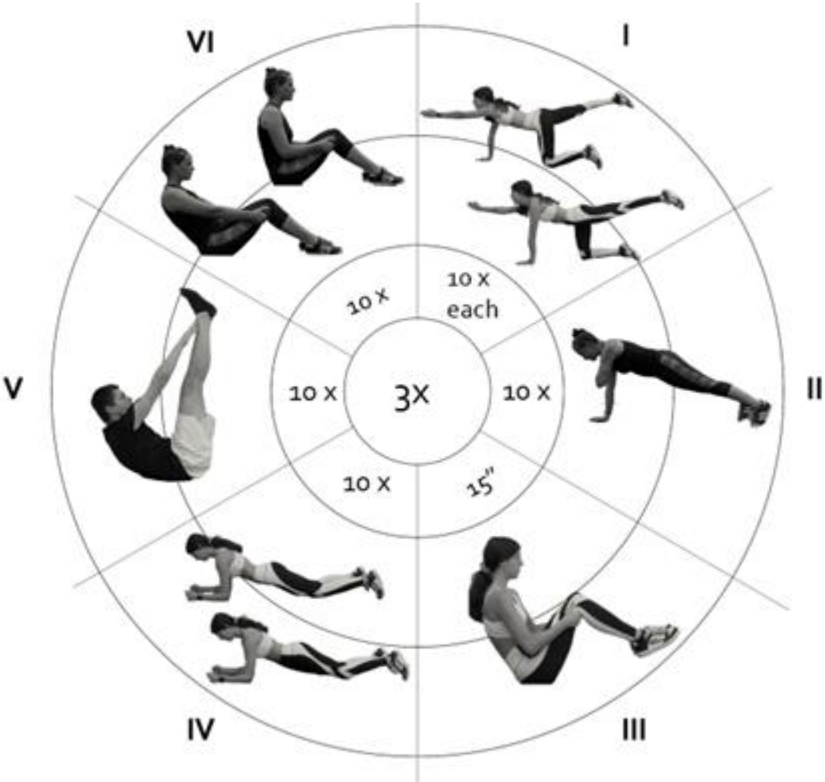
Week 1 – Day 2 – Adaptation period



Exercise	Details
I	Start lying on your back, knees bent, feet shoulder-width apart, hands behind your head. At the start of the movement, activate the abdominals and raise the shoulder blades so that they don't touch the floor, hold for 5 seconds and return to the starting position. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head on the floor. As you begin the movement, lift your feet about one to two palms off the ground. Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly and always concentrating on the abdominal area.
III	Start lying on your back, knees bent. Arms at your sides and head and shoulder blades on the floor. Lift your feet off the ground and bend your

	knees to make a 90º angle (leg/thigh and torso/thigh), starting the movement, extend your legs so that your heels are about two feet off the ground, hold for a second and flex again. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle (leg/thigh and torso/thigh). Raise your shoulder blades so that they don't touch the floor, activating your abdominal area. Be careful not to strain your neck and shoulders. Place your hands on your knees and push (hand against knee and knee against hand, without moving). Hold for the indicated time. Do the exercise always concentrating on the abdominal area.
V	Lie on your side with your legs slightly bent at the knee. Activate the abdominal area by pulling the navel in towards the spine. Arms in the position of the picture. Straightening the top leg, lift it without moving the rest of the body. Keep the leg at maximum extension and overhead for 1 second. Repeat the number of times indicated and then switch sides doing the same exercise with the opposite leg.
VI	Start lying on your stomach, hands shoulder-width apart, ladies with thumbs aligned with shoulder/clavicle and men with thumbs aligned with chin. Feet crossed and knees flat on the floor. Raise the body as a unit, stretching the arms and performing a pull-up on your knees. Bend your arms again and lower your torso as low as possible without touching the floor. Repeat the number of times indicated.

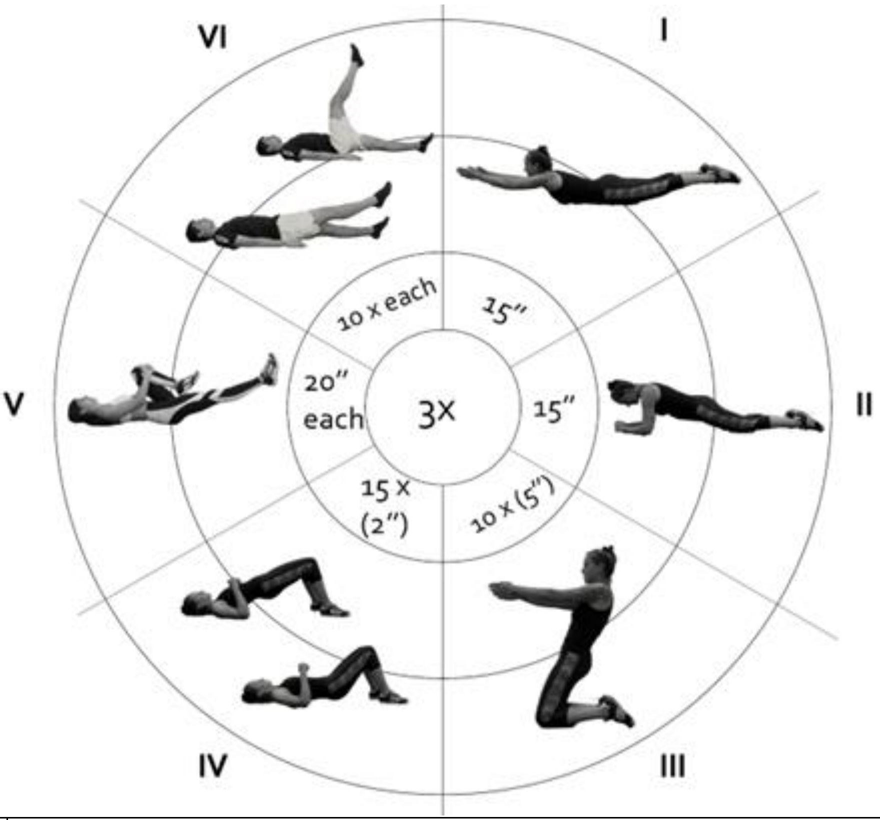
Week 1 – Day 3 – Adaptation period



Exercise	Details
I	Start the exercise on your hands and knees (thighs and torso; arms and torso at a 90º angle) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the opposite arm and leg (e.g. left arm and right leg). Hold the position for 2 seconds, always in balance. Return to the starting position and alternate sides. Repeat the exercise the number of times indicated, always alternating sides.
II	Start lying on your stomach, activating the abdominal area do a plank on your hands and feet. Make sure your body is straight, parallel to the floor and your back is straight. Touch your left hand to your right shoulder and alternate (right hand left shoulder) while keeping your body in a plank. Try to keep your pelvis and shoulders parallel to the floor throughout the exercise. Perform the exercise slowly, always concentrating on the abdominal area, pelvis and shoulders. Perform 10 shoulder touches, 5 with

	the right hand on the left shoulder and 5 with the left hand on the right shoulder.
III	Start by sitting on the yoga mat. Place your hands behind your knees, activate your abs and lift your feet off the floor with your knees bent. Your back can go a little backwards in order to find balance. Always keep the abdominal area active. Hold this position for the indicated time.
IV	Start by lying on your stomach. Activating the abdominal area, do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or knees from the floor), return to the plank position, hold for 1 second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 5 times for each side.
V	Start lying on your back. Stretch your legs towards the ceiling (as in the picture) to form a 90º angle between your legs and torso. Also stretch your arms towards the ceiling and lift your head and shoulders off the floor, trying to touch your toes with your fingertips. Relax and repeat the number of times indicated.
VI	Sitting on the floor, bend your knees (as in the picture). Then place your hands on your thighs under your knees and relax your shoulders. Pull your navel towards your spine and slowly roll backwards as far as you can (in this exercise, use mostly your abdominals and your arms as few as possible), hold for two seconds and roll back to the starting position. Repeat the number of times indicated.

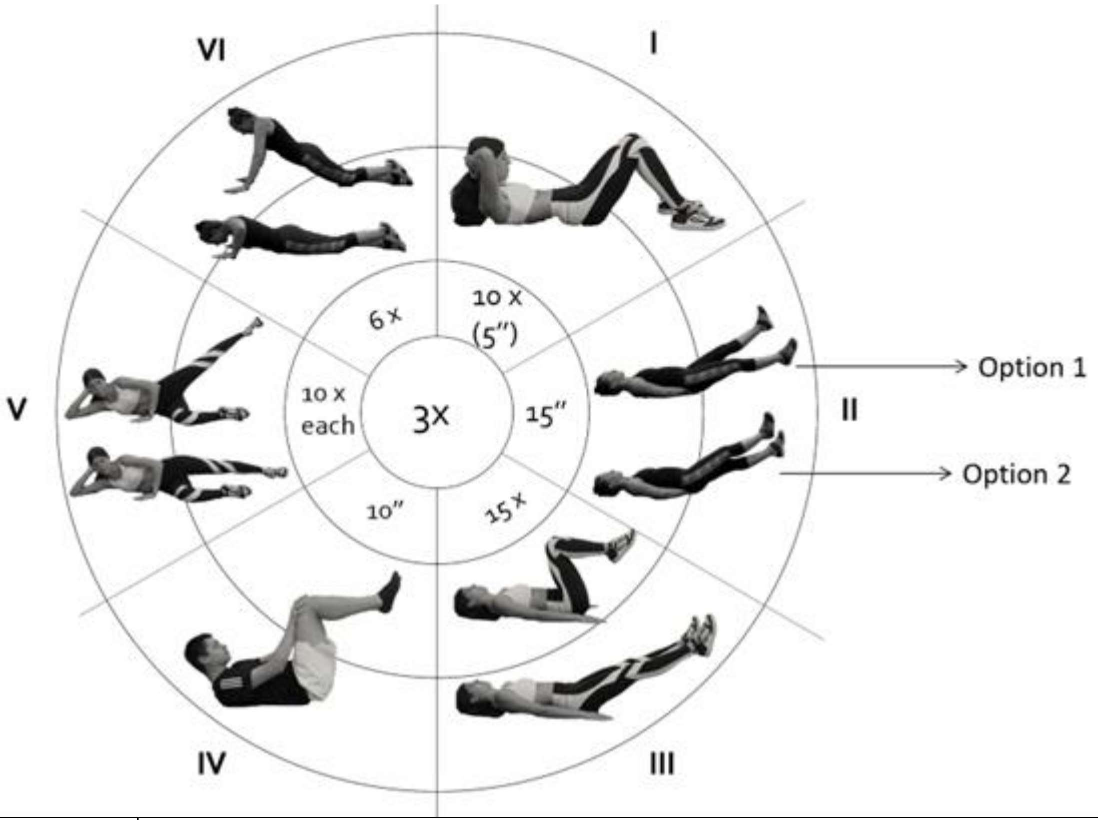
Week 2 – Day 1 – Adaptation period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate your abdominal area. Relax your shoulders and squeeze your glutes. Raise your arms and legs off the floor at the same time. Hold this position for the indicated time.
II	Start lying on your stomach. Activating the abdominal area. Do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Hold until the time is up.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (5 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Start lying on your back. With your knees bent, place your feet shoulder-width apart. Arms and elbows resting on the floor, forearms bent or straight (depending on your preference). Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Next, raise your pelvis so that your torso and thigh form a straight line, hold this position for 2 seconds and then lower your pelvis again, without touching the floor with your buttocks, repeating the number of times indicated.
V	Start the exercise lying on your back. Hold your left knee and leg close to your stomach and lift your right foot about one to two palms off the ground. Hold this position for the indicated time. Change sides and do the exercise with the opposite leg.
VI	Start lying on your back, shoulder blades and head resting on the floor. Legs straight. Starting the movement, lift your right leg off the floor and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching the floor with your foot. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

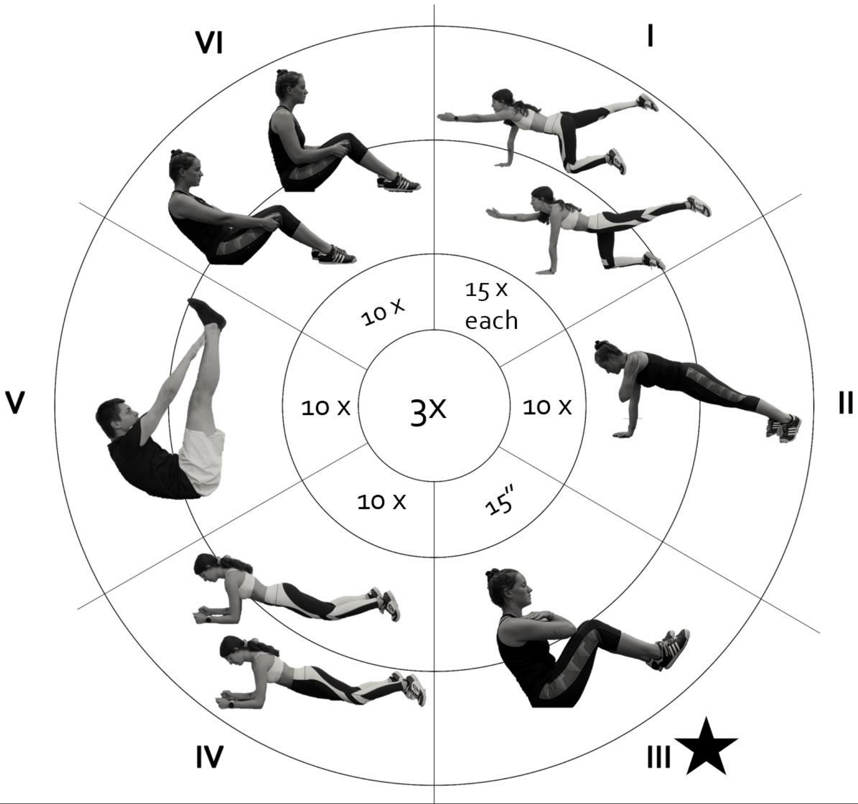
Week 2 – Day 2 – Adaptation period



Exercise	Details
I	Start lying on your back, knees bent, feet shoulder-width apart, hands behind your head. At the start of the movement, activate the abdominals and raise the shoulder blades so that they don't touch the floor, hold for 5 seconds and return to the starting position. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head on the floor. As you begin the movement, lift your feet about one to two hands off the ground. Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly and always concentrating on the abdominal area.
III	Start lying on your back, knees bent. Arms at your sides and head and shoulder blades on the floor. Lift your feet off the ground and bend your

	knees to make a 90º angle (leg/thigh and torso/thigh), starting the movement, extend your legs so that your heels are about two feet off the ground, hold for a second and flex again. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle (leg/thigh and torso/thigh). Raise your shoulder blades so that they don't touch the floor, activating your abdominal area. Be careful not to strain your neck and shoulders. Place your hands on your knees and push (hand against knee and knee against hand, without moving). Hold for the indicated time. Do the exercise always concentrating on the abdominal area.
V	Lie on your side with your legs slightly bent at the knee. Activate the abdominal area by pulling the navel in towards the spine. Arms in the position of the picture. Straightening the top leg, lift it without moving the rest of the body. Keep the leg at maximum extension and overhead for 1 second. Repeat the number of times indicated and then switch sides doing the same exercise with the opposite leg.
VI	Start lying on your stomach, hands shoulder-width apart, ladies with thumbs aligned with shoulder/clavicle and men with thumbs aligned with chin. Feet crossed and knees flat on the floor. Raise the body as a unit, stretching the arms and performing a pull-up on your knees. Bend your arms again and lower your torso as low as possible without touching the floor. Repeat the number of times indicated.

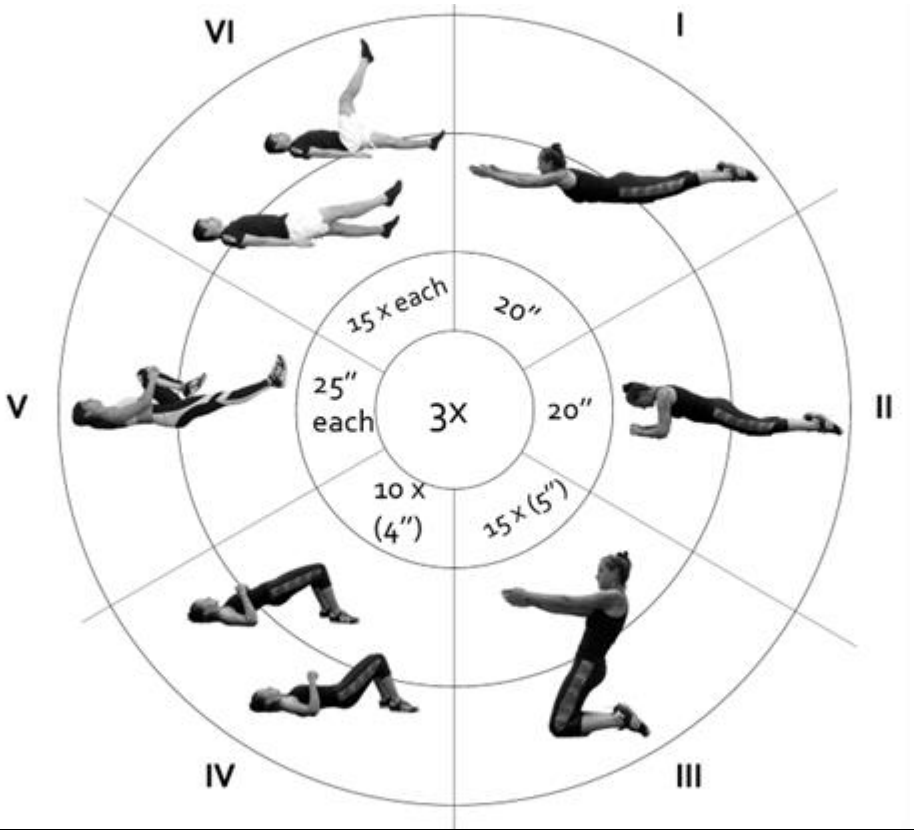
Week 2 – Day 3 – Adaptation period



Exercise	Details
I	Start the exercise on your hands and knees (thighs and torso; arms and torso at a 90º angle) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the opposite arm and leg (e.g. left arm and right leg). Hold the position for 2 seconds, always in balance. Return to the starting position and alternate sides. Repeat the exercise the number of times indicated, always alternating sides.
II	Start lying on your stomach, activating the abdominal area do a plank on your hands and feet. Make sure your body is straight, parallel to the floor and your back is straight. Touch your left hand to your right shoulder and alternate (right hand left shoulder) while keeping your body in a plank. Try to keep your pelvis and shoulders parallel to the floor throughout the exercise. Perform the exercise slowly, always concentrating on the abdominal area, pelvis and shoulders. Perform 10 shoulder touches, 5 with

	the right hand on the left shoulder and 5 with the left hand on the right shoulder.
★ III	Start by sitting on the yoga mat. Place your hands crossed at the shoulders, touching with your elbows on your knees as in the picture, activating your abdominals and lifting your feet off the floor with your knees bent. Your back can go a little backwards in order to find balance. Always keep the abdominal area active. Hold this position for the indicated time.
IV	Start by lying on your stomach. Activating the abdominal area, do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or knees from the floor), return to the plank position, hold for 1 second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 5 times for each side.
V	Start lying on your back. Stretch your legs towards the ceiling (as in the picture) to form a 90º angle between your legs and torso. Also stretch your arms towards the ceiling and lift your head and shoulders off the floor, trying to touch your toes with your fingertips. Relax and repeat the number of times indicated.
VI	Sitting on the floor, bend your knees (as in the picture). Then place your hands on your thighs under your knees and relax your shoulders. Pull your navel towards your spine and slowly roll backwards as far as you can (in this exercise, use mostly your abdominals and your arms as few as possible), hold for two seconds and roll back to the starting position. Repeat the number of times indicated.

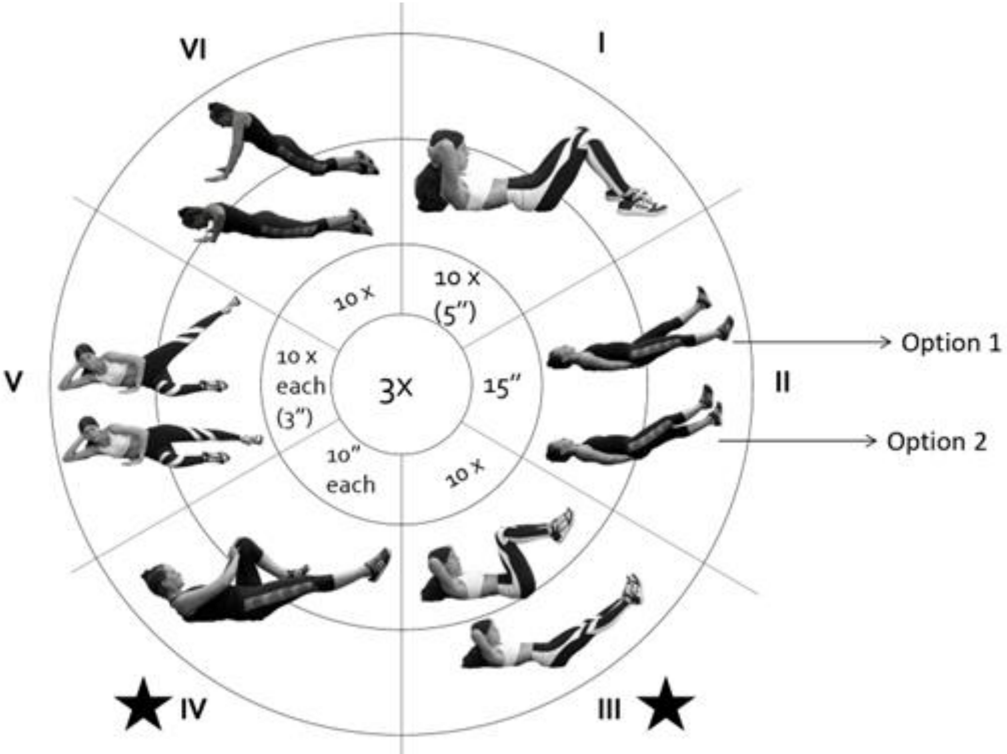
Week 3 – Day 1 – Improvement period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate your abdominal area. Relax your shoulders and squeeze your glutes. Raise your arms and legs off the floor at the same time. Hold this position for the indicated time.
II	Start lying on your stomach. Activating the abdominal area. Do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Hold until the time is up.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (5 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Start lying on your back. With your knees bent, place your feet shoulder-width apart. Arms and elbows resting on the floor, forearms bent or straight (depending on your preference). Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Next, raise your pelvis so that your torso and thigh form a straight line, hold this position for 4 seconds and then lower your pelvis again, without touching the floor with your buttocks, repeating the number of times indicated.
V	Start the exercise lying on your back. Hold your left knee and leg close to your stomach and lift your right foot about one to two palms off the ground. Hold this position for the indicated time. Change sides and do the exercise with the opposite leg.
VI	Start lying on your back, shoulder blades and head resting on the floor. Legs straight. Starting the movement, lift your right leg off the floor and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching the floor with your foot. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

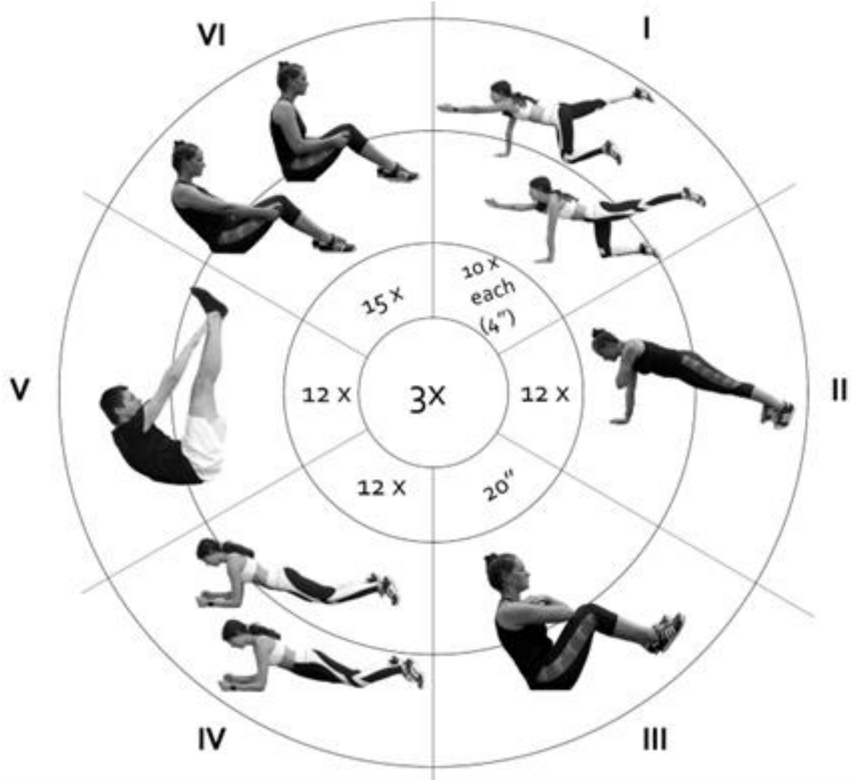
Week 3 – Day 2 – Improvement period



Exercise	Details
I	Start lying on your back, knees bent, feet shoulder-width apart, hands behind your head. At the start of the movement, activate the abdominals and raise the shoulder blades so that they don't touch the floor, hold for 5 seconds and return to the starting position. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head on the floor. As you begin the movement, lift your feet about one to two hands off the ground. Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly and always concentrating on the abdominal area.
III ★	Start lying on your back, knees bent. Arms supporting the head, activating the abdominal area, lift the head and shoulder blades off the floor as in the image. Lift your feet off the ground and bend your knees to make a 90º

	angle (leg/thigh and torso/thigh), starting the movement, extend your legs so that your heels are about two palms off the ground, hold for a second and flex again. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
IV ★	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle (leg/thigh and trunk/thigh). Raise your shoulder blades so that they don't touch the floor, activating your abdominal area. Be careful not to strain your neck and shoulders. Place your hands on your left knee, push (hand against knee and knee against hand, without moving), and extend your right leg. Hold for the indicated time and then do the same with the opposite leg. Do the exercise always concentrating on the abdominal area.
V	Lie on your side with your legs slightly bent at the knee. Activate the abdominal area by pulling the navel in towards the spine. Arms in the position of the picture. Straightening the top leg, lift it without moving the rest of the body. Keep the leg at maximum extension and overhead for 1 second. Repeat the number of times indicated and then switch sides doing the same exercise with the opposite leg.
VI	Start lying on your stomach, hands shoulder-width apart, ladies with thumbs aligned with shoulder/clavicle and men with thumbs aligned with chin. Feet crossed and knees flat on the floor. Raise the body as a unit, stretching the arms and performing a pull-up on your knees. Bend your arms again and lower your torso as low as possible without touching the floor. Repeat the number of times indicated.

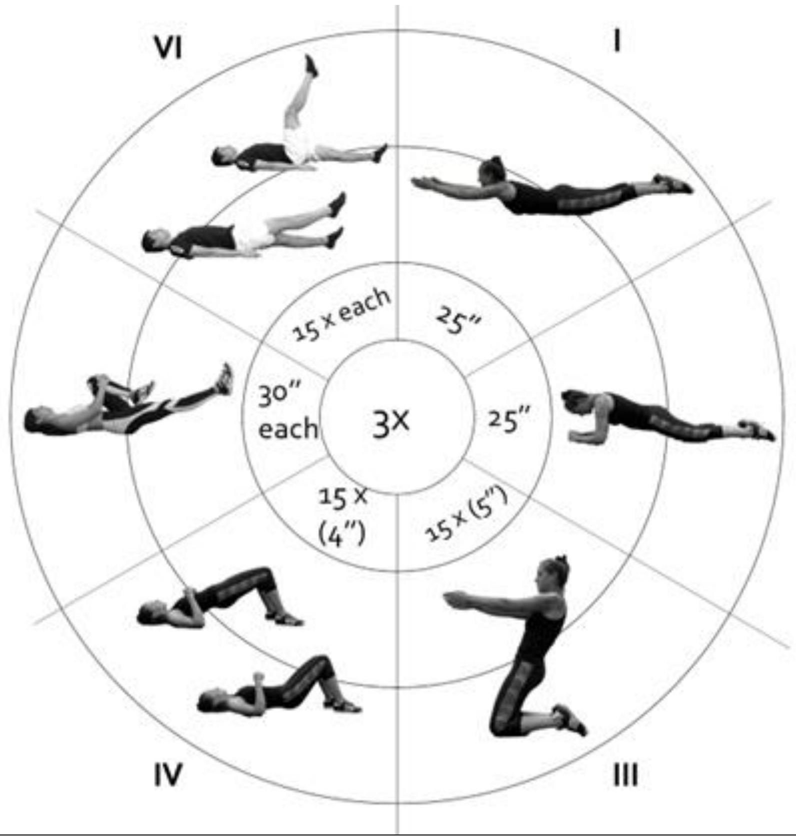
Week 3 – Day 3 – Improvement period



Exercise	Details
I	Start the exercise on your hands and knees (thighs and torso; arms and torso at a 90º angle) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the opposite arm and leg (e.g. left arm and right leg). Hold the position for 4 seconds, always in balance. Return to the starting position and alternate sides. Repeat the exercise the number of times indicated, always alternating sides.
II	Start lying on your stomach, activating the abdominal area do a plank on your hands and feet. Make sure your body is straight, parallel to the floor and your back is straight. Touch your left hand to your right shoulder and alternate (right hand left shoulder) while keeping your body in a plank. Try to keep your pelvis and shoulders parallel to the floor throughout the exercise. Perform the exercise slowly, always concentrating on the abdominal area, pelvis and shoulders. Perform 12 shoulder touches, 6 with

	the right hand on the left shoulder and 6 with the left hand on the right shoulder.
III	Start by sitting on the yoga mat. Place your hands crossed at the shoulders, touching with your elbows on your knees as in the picture, activating your abdominals and lifting your feet off the floor with your knees bent. Your back can go a little backwards in order to find balance. Always keep the abdominal area active. Hold this position for the indicated time.
IV	Start by lying on your stomach. Activating the abdominal area, do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or knees from the floor), return to the plank position, hold for 1 second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 6 times for each side.
V	Start lying on your back. Stretch your legs towards the ceiling (as in the picture) to form a 90º angle between your legs and torso. Also stretch your arms towards the ceiling and lift your head and shoulders off the floor, trying to touch your toes with your fingertips. Relax and repeat the number of times indicated.
VI	Sitting on the floor, bend your knees (as in the picture). Then place your hands on your thighs under your knees and relax your shoulders. Pull your navel towards your spine and slowly roll backwards as far as you can (in this exercise, use mostly your abdominals and your arms as few as possible), hold for two seconds and roll back to the starting position. Repeat the number of times indicated.

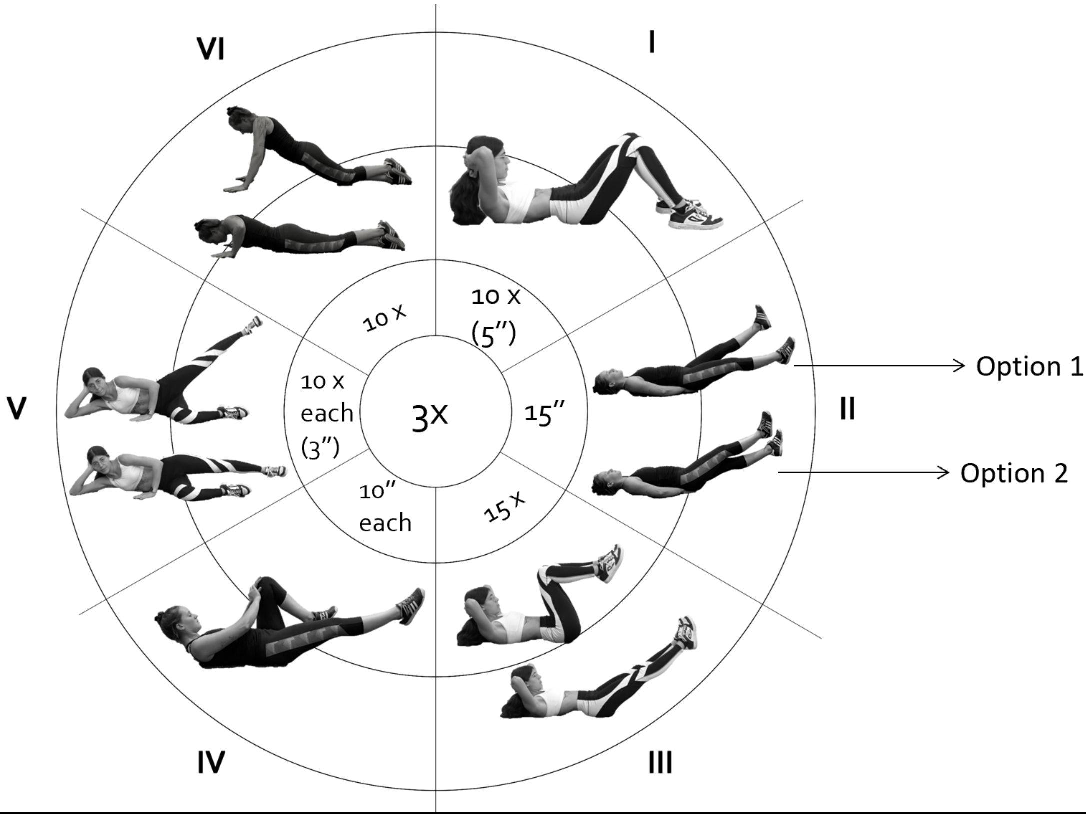
Week 4 – Day 1 – Improvement period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate your abdominal area. Relax your shoulders and squeeze your glutes. Raise your arms and legs off the floor at the same time. Hold this position for the indicated time.
II	Start lying on your stomach. Activating the abdominal area. Do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Hold until the time is up.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (5 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Start lying on your back. With your knees bent, place your feet shoulder-width apart. Arms and elbows resting on the floor, forearms bent or straight (depending on your preference). Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Next, raise your pelvis so that your torso and thigh form a straight line, hold this position for 4 seconds and then lower your pelvis again, without touching the floor with your buttocks, repeating the number of times indicated.
V	Start the exercise lying on your back. Hold your left knee and leg close to your stomach and lift your right foot about one to two palms off the ground. Hold this position for the indicated time. Change sides and do the exercise with the opposite leg.
VI	Start lying on your back, shoulder blades and head resting on the floor. Legs straight. Starting the movement, lift your right leg off the floor and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching the floor with your foot. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

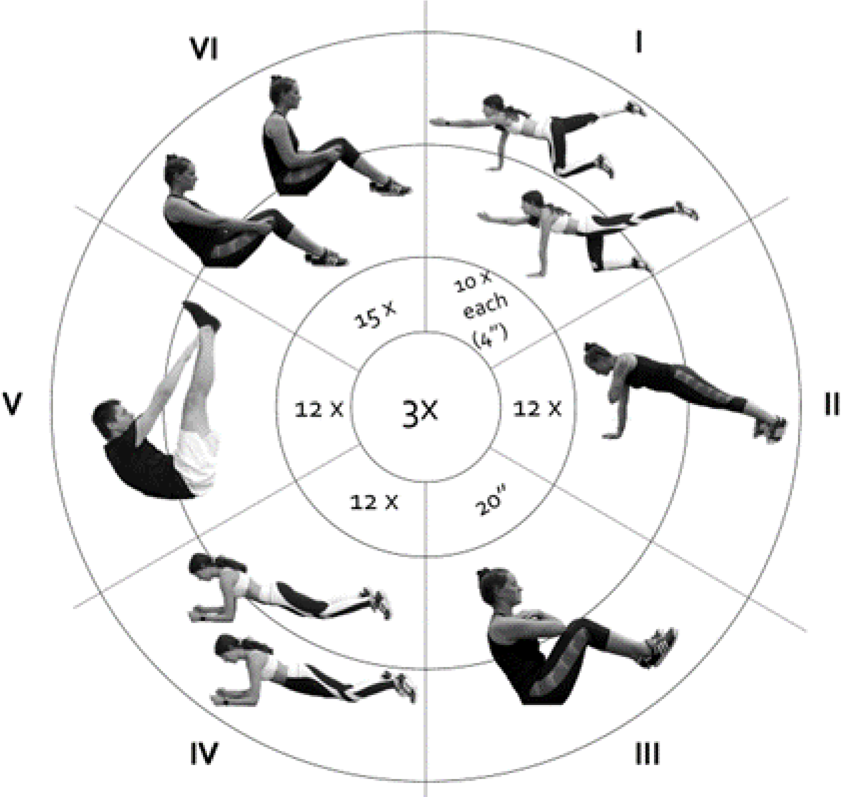
Week 4 – Day 2 – Improvement period



Exercise	Details
I	Start lying on your back, knees bent, feet shoulder-width apart, hands behind your head. At the start of the movement, activate the abdominals and raise the shoulder blades so that they don't touch the floor, hold for 5 seconds and return to the starting position. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head on the floor. As you begin the movement, lift your feet about one to two palms off the ground. Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly and always concentrating on the abdominal area.
III	Start lying on your back, knees bent. Arms supporting the head, activating the abdominal area, lift the head and shoulder blades off the floor as in the

	image. Lift your feet off the ground and bend your knees to make a 90º angle (leg/thigh and torso/thigh), starting the movement, extend your legs so that your heels are about two palms off the ground, hold for a second and flex again. Repeat the number of times indicated. Perform the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle (leg/thigh and trunk/thigh). Raise your shoulder blades so that they don't touch the floor, activating your abdominal area. Be careful not to strain your neck and shoulders. Place your hands on your left knee, push (hand against knee and knee against hand, without moving), and extend your right leg. Hold for the indicated time and then do the same with the opposite leg. Do the exercise always concentrating on the abdominal area.
V	Lie on your side with your legs slightly bent at the knee. Activate the abdominal area by pulling the navel in towards the spine. Arms in the position of the picture. Straightening the top leg, lift it without moving the rest of the body. Keep the leg at maximum extension and overhead for 1 second. Repeat the number of times indicated and then switch sides doing the same exercise with the opposite leg.
VI	Start lying on your stomach, hands shoulder-width apart, ladies with thumbs aligned with shoulder/clavicle and men with thumbs aligned with chin. Feet crossed and knees flat on the floor. Raise the body as a unit, stretching the arms and performing a pull-up on your knees. Bend your arms again and lower your torso as low as possible without touching the floor. Repeat the number of times indicated.

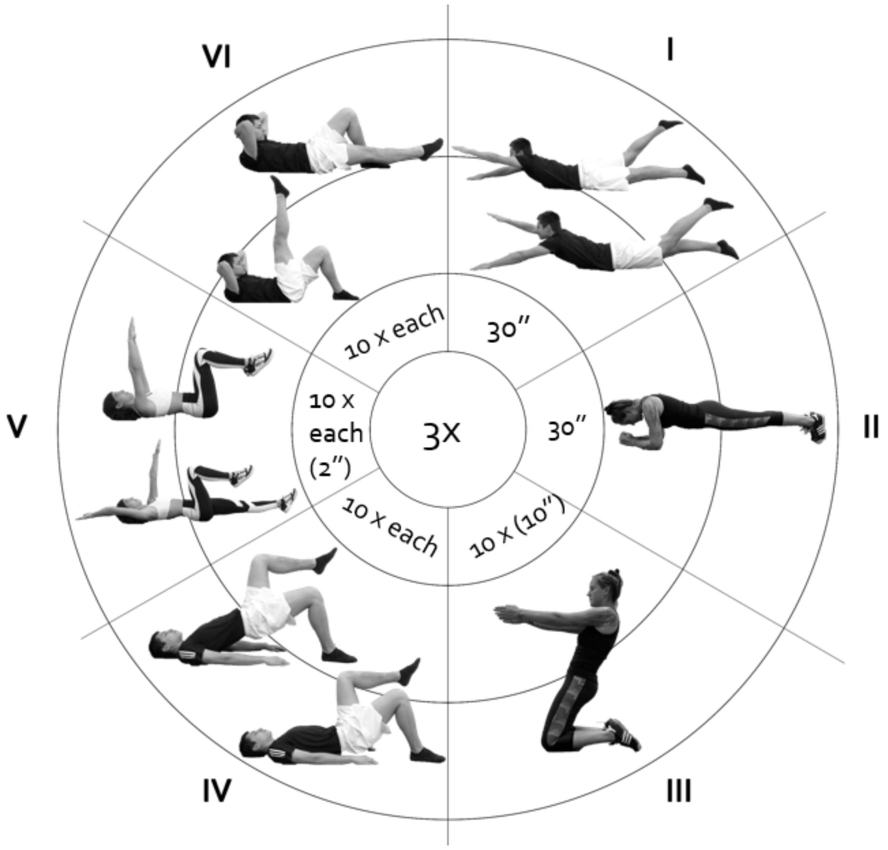
Week 4 – Day 3 – Improvement period



Exercise	Details
I	Start the exercise on your hands and knees (thighs and torso; arms and torso at a 90º angle) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the opposite arm and leg (e.g. left arm and right leg). Hold the position for 4 seconds, always in balance. Return to the starting position and alternate sides. Repeat the exercise the number of times indicated, always alternating sides.
II	Start lying on your stomach, activating the abdominal area do a plank on your hands and feet. Make sure your body is straight, parallel to the floor and your back is straight. Touch your left hand to your right shoulder and alternate (right hand left shoulder) while keeping your body in a plank. Try to keep your pelvis and shoulders parallel to the floor throughout the exercise. Perform the exercise slowly, always concentrating on the abdominal area, pelvis and shoulders. Perform 12 shoulder touches, 6 with

	the right hand on the left shoulder and 6 with the left hand on the right shoulder.
III	Start by sitting on the yoga mat. Place your hands crossed at the shoulders, touching with your elbows on your knees as in the picture, activating your abdominals and lifting your feet off the floor with your knees bent. Your back can go a little backwards in order to find balance. Always keep the abdominal area active. Hold this position for the indicated time.
IV	Start by lying on your stomach. Activating the abdominal area, do a plank on your elbows and knees. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or knees from the floor), return to the plank position, hold for 1 second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 6 times for each side.
V	Start lying on your back. Stretch your legs towards the ceiling (as in the picture) to form a 90º angle between your legs and torso. Also stretch your arms towards the ceiling and lift your head and shoulders off the floor, trying to touch your toes with your fingertips. Relax and repeat the number of times indicated.
VI	Sitting on the floor, bend your knees (as in the picture). Then place your hands on your thighs under your knees and relax your shoulders. Pull your navel towards your spine and slowly roll backwards as far as you can (in this exercise, use mostly your abdominals and your arms as few as possible), hold for two seconds and roll back to the starting position. Repeat the number of times indicated.

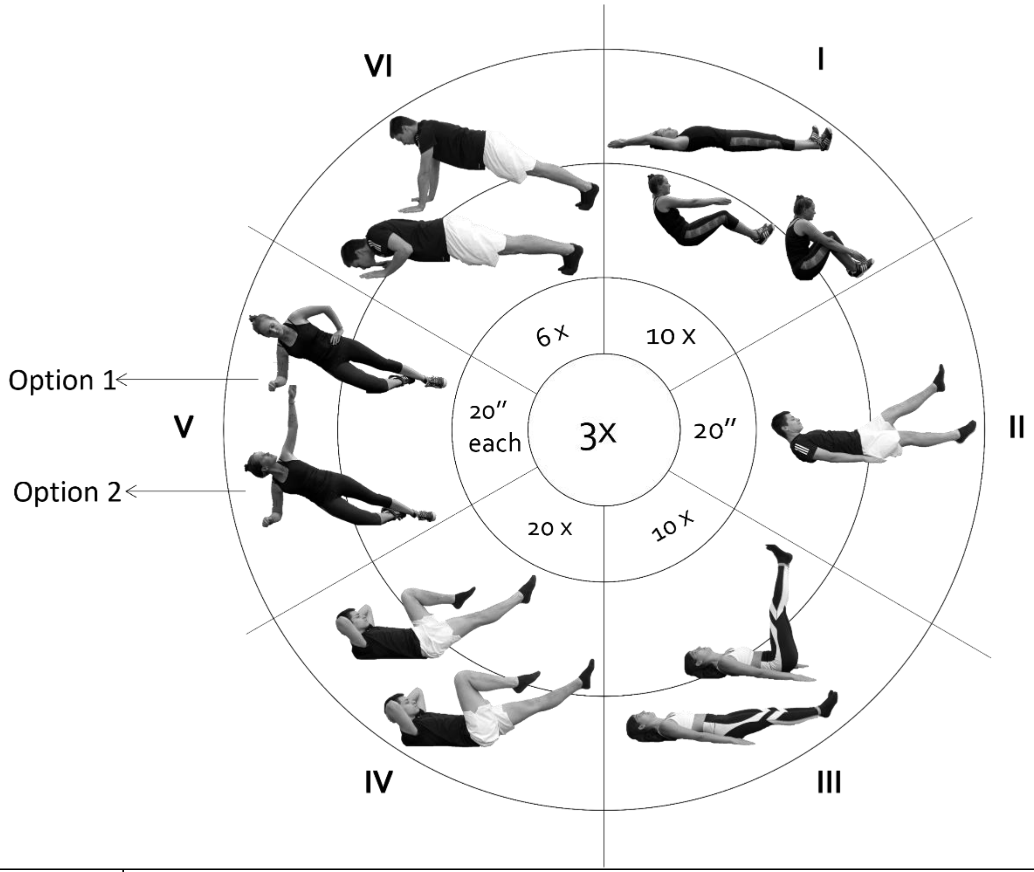
Week 5 – Day 1 – Improvement period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate the abdominal area. Lift your right arm and left leg off the floor and alternate. Relax your shoulders while raising your arm and squeeze your glutes to raise your leg. Alternate until the time is up.
II	Start by lying on your stomach. Activate the abdominal area. Do a plank on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far

	as possible (keeping a straight line between your thigh and torso). Hold for the allotted time (10 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lie on your back. With your knees bent, place your feet shoulder-width apart on the floor. Arms and elbows resting on the floor, forearms bent. Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Lift the left foot (keeping the knee bent as shown in the image). To start the exercise, lift your pelvis so that you are in a straight line with your torso and thigh and lower it again without touching with your back to the floor. Do the number of repetitions indicated with the left leg and then do the same with the right leg.
V	Start the exercise lying on your back. Bend your knees at a 90º angle with your feet off the floor. Stretch your arms towards the ceiling. Curl your navel in towards your spine and your back flat on the floor (try to keep it that way throughout the exercise). Starting the exercise, stretch your left arm back and your right leg forwards (without touching the floor). Hold for 2 seconds. Alternate arm and leg. Do the indicated repetitions.
VI	Start lying on your back, shoulder blades and head off the floor, hands supporting your head behind the back of your head. Left leg bent with foot flat on the floor and right leg straight. Starting the movement, lift your right leg off the ground and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching your foot to the ground. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

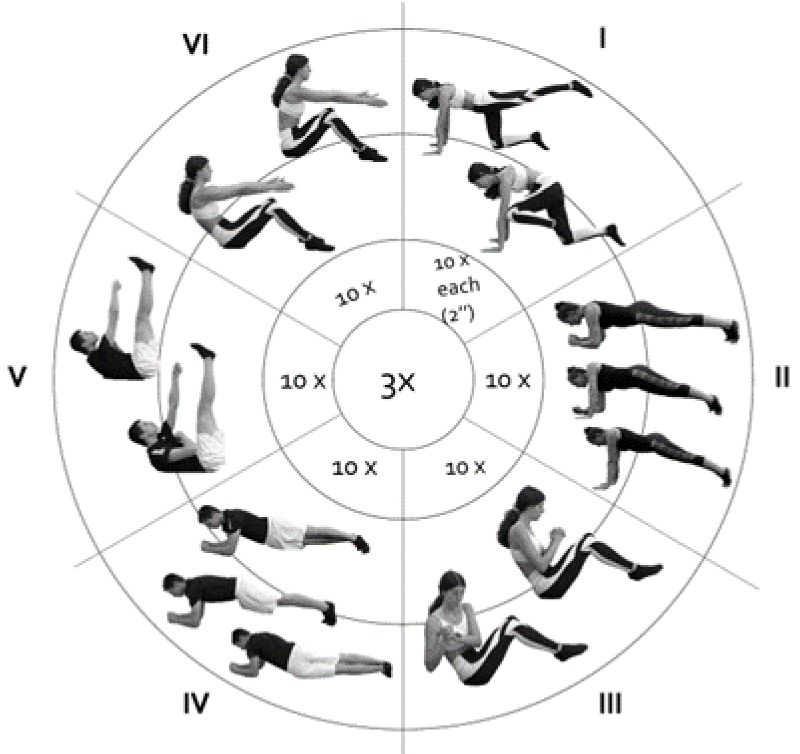
Week 5 – Day 2 – Improvement period



Exercise	Details
I	Start lying on your back, knees fully extended, feet shoulder-width apart, arms stretched out as in the image. Starting the movement, activate the abdominal area and lift the torso (as a unit) and touch your hands to the tips of your feet (legs will flex as the torso lifts, feet always in contact with the ground). Come back down to the starting position, always slowly in a controlled movement. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head and shoulder blades off the floor with your abdominal area active. Starting the movement, lift your feet about one to two palms off the ground (always keeping your legs extended). Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms at your sides and head and shoulder blades on the floor. Starting the movement, lift your feet off the floor (always keeping your legs extended) and bring your feet towards your head (until you make a 90º thigh/trunk angle, if necessary, your knees can flex a little), return to the starting position without touching your feet to the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the floor) so that there is a 90º angle between your thigh and leg, and another between your back and torso. Place your hands behind your head and lift your head and shoulder blades so that they don't touch the floor, activating the abdominal area. Extend your left knee. Return to the bent-leg position. Alternate extending legs. Do the exercise slowly, always concentrating on the abdominal area. 10 repetitions with each leg
V	Lie on your side with your bottom leg bent (at an angle of more than 90º) and your top leg fully extended. Lean on the elbow that is in contact with the floor, as in the picture, and place your other hand on your waist. To start the movement, lift your body (especially your torso) as one unit, trying to keep it straight. Activate the abdominal area by pulling the navel in towards the spine. Maintain the indicated time. Repeat the exercise on the opposite side for the same amount of time. Option 2: if you have the ease and balance to perform the exercise, you can stretch your arm towards the ceiling, trying to reach it as far as possible.
VI	Start by lying on your stomach, with hands shoulder-width apart, ladies with thumbs aligned with the shoulder/collarbone and men with thumbs aligned with the chin, lift the body as a unit, straightening the arms and perform a push-up. Then bend the arms again, lower the body as low as possible, without touching the ground. Repeat the indicated number of times.

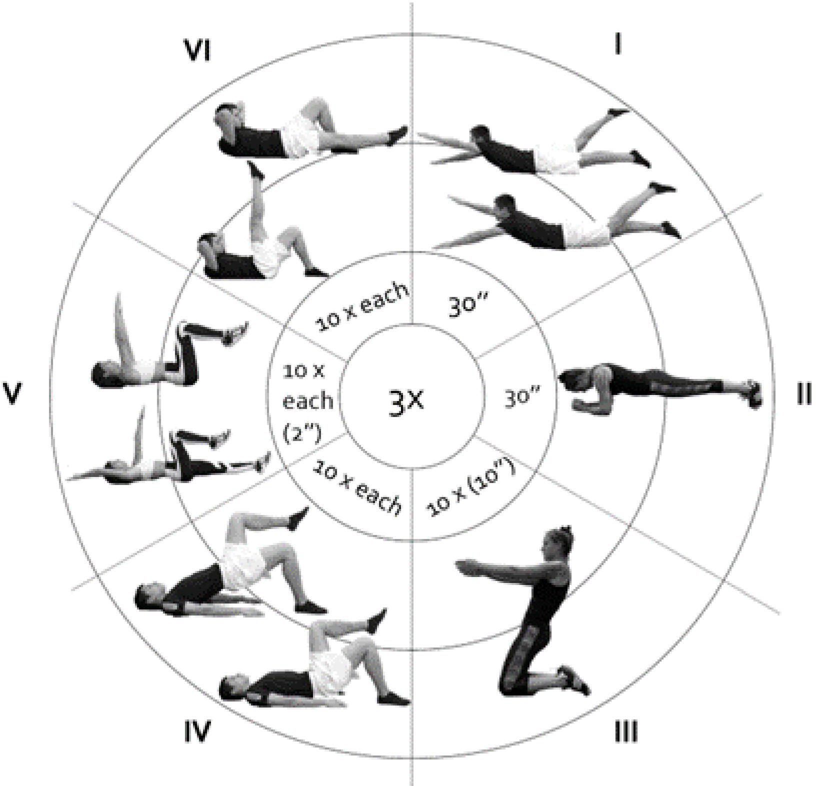
Week 5 – Day 3 – Improvement period



Exercise	Details
I	Start the exercise on your hands and knees (thigh and torso; and arms and torso making a 90º angle), with knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable throughout the exercise. Lift the left leg, touch it to the left elbow (or as close as possible without altering the stability of the torso), and then extend the leg back. Repeat the indicated number of times and then switch sides. In this exercise, the hands always remain on the ground. Perform the movements slowly and in a controlled manner, always maintaining balance.
II	Start by lying on your stomach, activating the abdominal area. Perform a plank supported on the elbows and feet. Be aware that the body is straight, parallel to the ground, back straight. From the elbow plank, rise to a hand plank, hold for a second and then lower back down, holding for a second. Repeat the indicated number of times. Perform the exercise slowly, always focusing on the abdominal area.

III	Start by sitting on the yoga mat. Activate your abdominals and lift your feet off the ground with knees bent. Join hands and interlace fingers, pressing one palm against the other (or if you prefer, you can hold a light, small object). Maintaining the position and keeping the abdominal area activated, pass the object (real or imaginary) from the right side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat) to the left side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat). Perform the exercise slowly, always focusing on the abdominal area. Repeat the indicated number of times.
IV	Start by lying on your stomach. Activate the abdominal area and perform a plank supported on the elbows and knees. Be aware that the body is straight, parallel to the ground, back straight. Starting a rotational movement, touch the left thigh to the ground on the left side (without lifting hands or knees off the ground), return to the plank position, hold for one second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the indicated number of times, 5 times for each side.
V	Start by lying on your back. Stretch your legs (together) towards the ceiling, forming a 90º angle between your legs and torso. Stretch your arms towards the ceiling and imagine pulling a rope (your head and shoulders also lift off the ground). Perform the indicated number of times.
VI	Sit on the floor with your knees bent (as shown in the image). Then stretch your arms forward and relax your shoulders. Draw your navel towards your spine, and slowly roll back without letting your lower back touch the ground, hold for a second, and roll back to the starting position. Perform the exercise slowly and in a controlled manner, always activating the abdominal region. Repeat the indicated number of times.

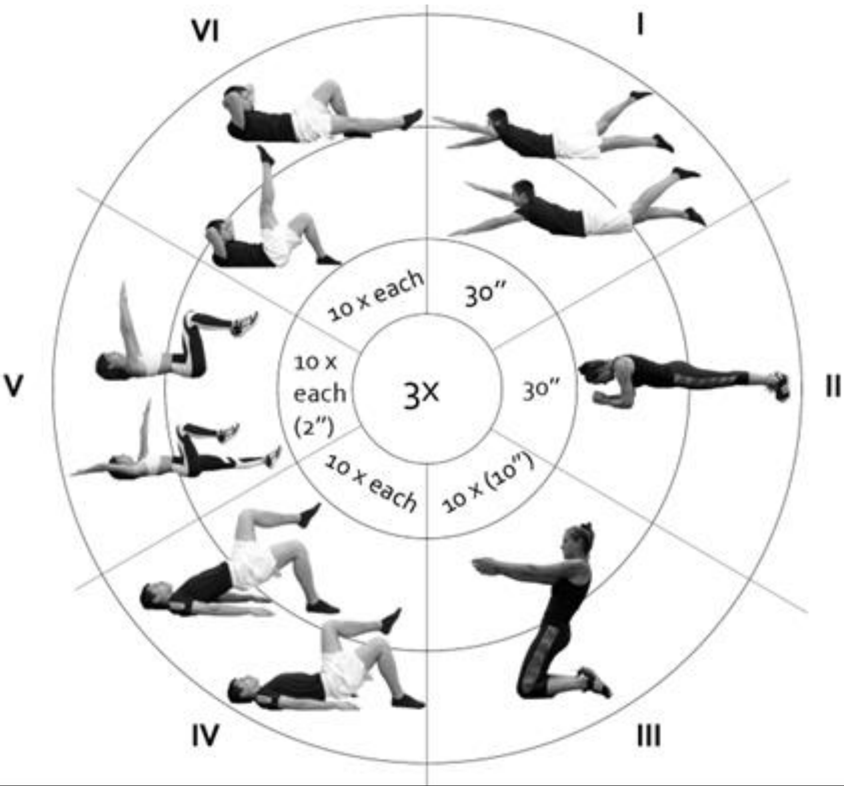
Week 6 – Day 1 – Improvement period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate the abdominal area. Lift your right arm and left leg off the floor and alternate. Relax your shoulders while raising your arm and squeeze your glutes to raise your leg. Alternate until the time is up.
II	Start by lying on your stomach. Activate the abdominal area. Do a plank on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (10 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lie on your back. With your knees bent, place your feet shoulder-width apart on the floor. Arms and elbows resting on the floor, forearms bent. Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Lift the left foot (keeping the knee bent as shown in the image). To start the exercise, lift your pelvis so that you are in a straight line with your torso and thigh and lower it again without touching with your back to the floor. Do the number of repetitions indicated with the left leg and then do the same with the right leg.
V	Start the exercise lying on your back. Bend your knees at a 90º angle with your feet off the floor. Stretch your arms towards the ceiling. Curl your navel in towards your spine and your back flat on the floor (try to keep it that way throughout the exercise). Starting the exercise, stretch your left arm back and your right leg forwards (without touching the floor). Hold for 2 seconds. Alternate arm and leg. Do the indicated repetitions.
VI	Start lying on your back, shoulder blades and head off the floor, hands supporting your head behind the back of your head. Left leg bent with foot flat on the floor and right leg straight. Starting the movement, lift your right leg off the ground and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching your foot to the ground. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

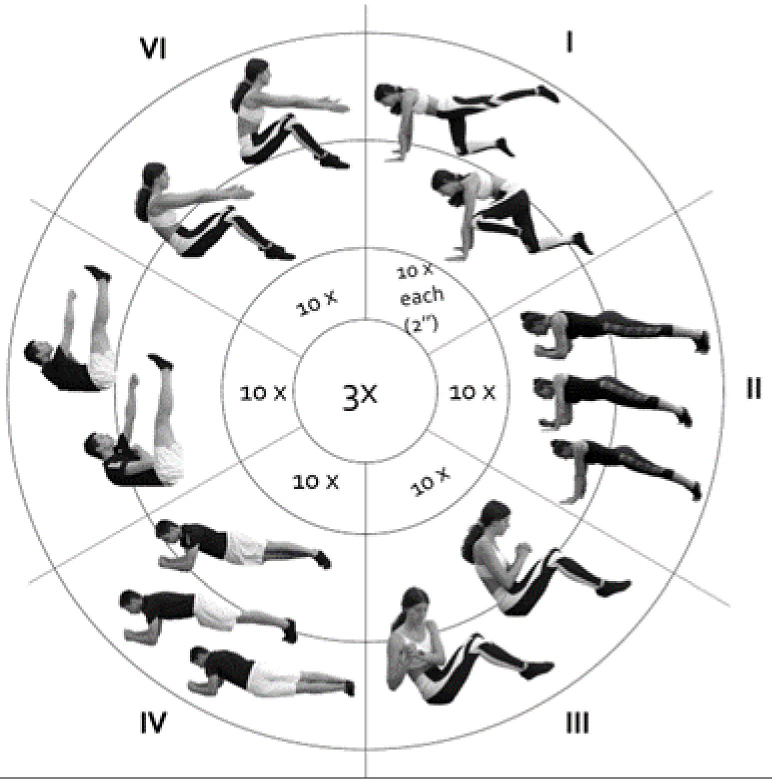
Week 6 – Day 2 – Improvement period



Exercise	Details
I	Start lying on your back, knees fully extended, feet shoulder-width apart, arms stretched out as in the image. Starting the movement, activate the abdominal area and lift the torso (as a unit) and touch your hands to the tips of your feet (legs will flex as the torso lifts, feet always in contact with the ground). Come back down to the starting position, always slowly in a controlled movement. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head and shoulder blades off the floor with your abdominal area active. Starting the movement, lift your feet about one to two palms off the ground (always keeping your legs extended). Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms at your sides and head and shoulder blades on the floor. Starting the movement, lift your feet off the floor (always keeping your legs extended) and bring your feet towards your head (until you make a 90º thigh/trunk angle, if necessary, your knees can flex a little), return to the starting position without touching your feet to the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the floor) so that there is a 90º angle between your thigh and leg, and another between your back and torso. Place your hands behind your head and lift your head and shoulder blades so that they don't touch the floor, activating the abdominal area. Extend your left knee. Return to the bent-leg position. Alternate extending legs. Do the exercise slowly, always concentrating on the abdominal area. 10 repetitions with each leg
V	Lie on your side with your bottom leg bent (at an angle of more than 90º) and your top leg fully extended. Lean on the elbow that is in contact with the floor, as in the picture, and place your other hand on your waist. To start the movement, lift your body (especially your torso) as one unit, trying to keep it straight. Activate the abdominal area by pulling the navel in towards the spine. Maintain the indicated time. Repeat the exercise on the opposite side for the same amount of time. Option 2: if you have the ease and balance to perform the exercise, you can stretch your arm towards the ceiling, trying to reach it as far as possible.
VI	Start by lying on your stomach, with hands shoulder-width apart, ladies with thumbs aligned with the shoulder/collarbone and men with thumbs aligned with the chin, lift the body as a unit, straightening the arms and perform a push-up. Then bend the arms again, lower the body as low as possible, without touching the ground. Repeat the indicated number of times.

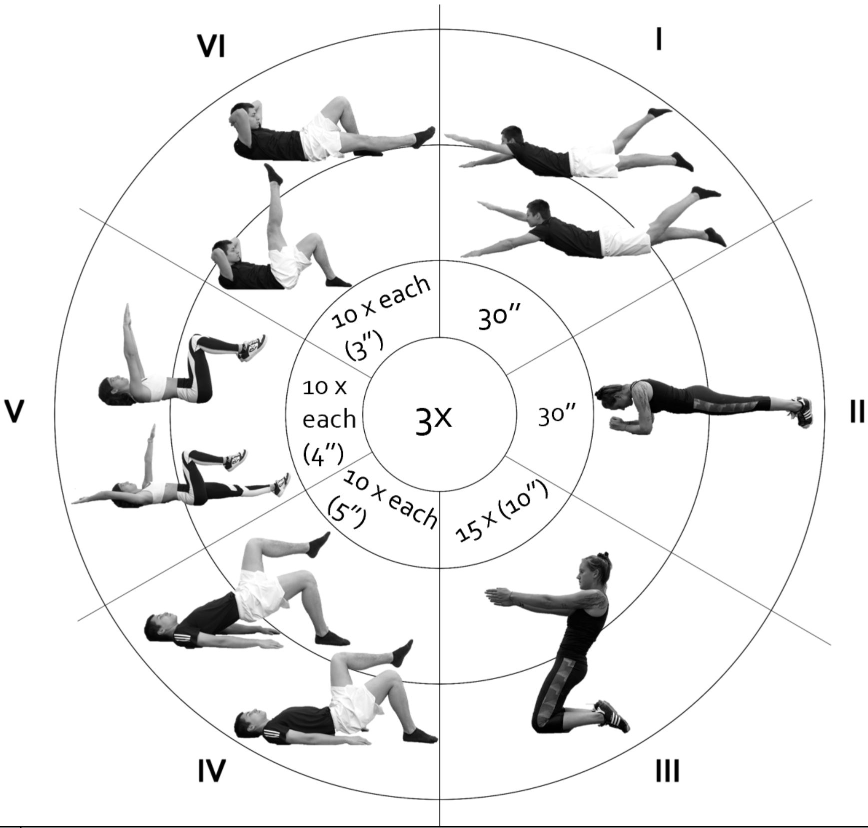
Week 6 – Day 3 – Improvement period



Exercise	Details
I	Start the exercise on your hands and knees (thigh and torso; and arms and torso making a 90º angle), with knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable throughout the exercise. Lift the left leg, touch it to the left elbow (or as close as possible without altering the stability of the torso), and then extend the leg back. Repeat the indicated number of times and then switch sides. In this exercise, the hands always remain on the ground. Perform the movements slowly and in a controlled manner, always maintaining balance.
II	Start by lying on your stomach, activating the abdominal area. Perform a plank supported on the elbows and feet. Be aware that the body is straight, parallel to the ground, back straight. From the elbow plank, rise to a hand plank, hold for a second and then lower back down, holding for a second. Repeat the indicated number of times. Perform the exercise slowly, always focusing on the abdominal area.

III	Start by sitting on the yoga mat. Activate your abdominals and lift your feet off the ground with knees bent. Join hands and interlace fingers, pressing one palm against the other (or if you prefer, you can hold a light, small object). Maintaining the position and keeping the abdominal area activated, pass the object (real or imaginary) from the right side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat) to the left side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat). Perform the exercise slowly, always focusing on the abdominal area. Repeat the indicated number of times.
IV	Start by lying on your stomach. Activate the abdominal area and perform a plank supported on the elbows and knees. Be aware that the body is straight, parallel to the ground, back straight. Starting a rotational movement, touch the left thigh to the ground on the left side (without lifting hands or knees off the ground), return to the plank position, hold for one second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the indicated number of times, 5 times for each side.
V	Start by lying on your back. Stretch your legs (together) towards the ceiling, forming a 90º angle between your legs and torso. Stretch your arms towards the ceiling and imagine pulling a rope (your head and shoulders also lift off the ground). Perform the indicated number of times.
VI	Sit on the floor with your knees bent (as shown in the image). Then stretch your arms forward and relax your shoulders. Draw your navel towards your spine, and slowly roll back without letting your lower back touch the ground, hold for a second, and roll back to the starting position. Perform the exercise slowly and in a controlled manner, always activating the abdominal region. Repeat the indicated number of times.

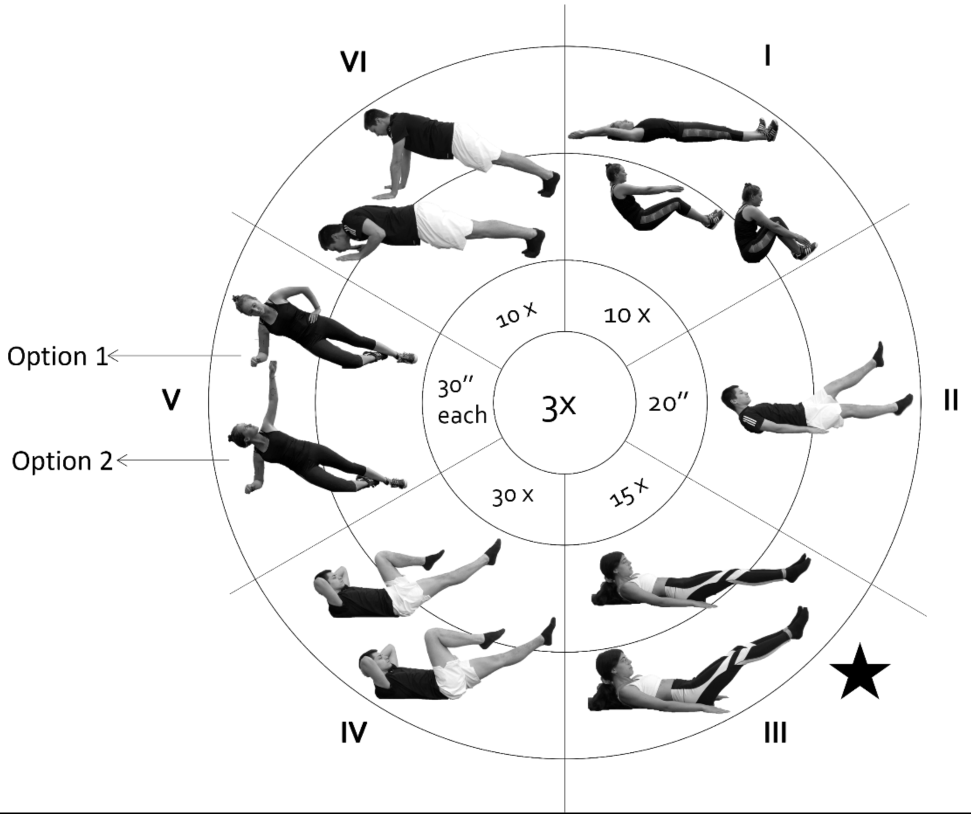
Week 7 – Day 1 – Improvement period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate the abdominal area. Lift your right arm and left leg off the floor and alternate. Relax your shoulders while raising your arm and squeeze your glutes to raise your leg. Alternate until the time is up.
II	Start by lying on your stomach. Activate the abdominal area. Do a plank on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (10 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lie on your back. With your knees bent, place your feet shoulder-width apart on the floor. Arms and elbows resting on the floor, forearms bent. Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Lift the left foot (keeping the knee bent as shown in the image). To start the exercise, lift your pelvis so that you are in a straight line with your torso and thigh and lower it again without touching with your back to the floor. Do the number of repetitions indicated with the left leg and then do the same with the right leg.
V	Start the exercise lying on your back. Bend your knees at a 90º angle with your feet off the floor. Stretch your arms towards the ceiling. Curl your navel in towards your spine and your back flat on the floor (try to keep it that way throughout the exercise). Starting the exercise, stretch your left arm back and your right leg forwards (without touching the floor). Hold for 4 seconds. Alternate arm and leg. Do the indicated repetitions.
VI	Start lying on your back, shoulder blades and head off the floor, hands supporting your head behind the back of your head. Left leg bent with foot flat on the floor and right leg straight. Starting the movement, lift your right leg off the ground and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching your foot to the ground. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

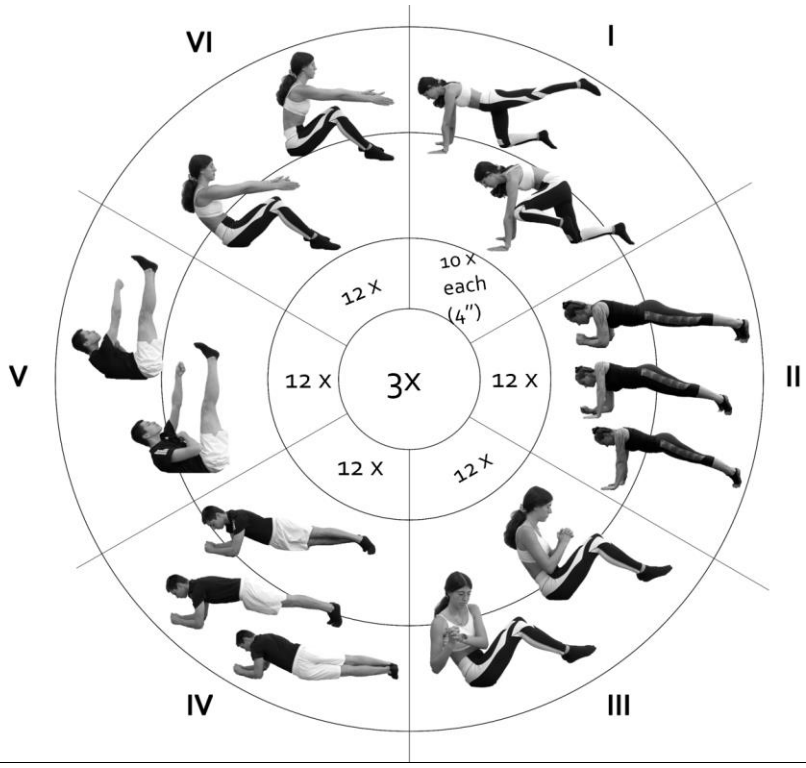
Week 7 – Day 2 – Improvement period



Exercise	Details
I	Start lying on your back, knees fully extended, feet shoulder-width apart, arms stretched out as in the image. Starting the movement, activate the abdominal area and lift the torso (as a unit) and touch your hands to the tips of your feet (legs will flex as the torso lifts, feet always in contact with the ground). Come back down to the starting position, always slowly in a controlled movement. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head and shoulder blades off the floor with your abdominal area active. Starting the movement, lift your feet about one to two palms off the ground (always keeping your legs extended). Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly, always concentrating on the abdominal area.

III ★	Start lying on your back, legs stretched out, arms at your sides and head and shoulder blades off the floor. Starting the movement, lift your feet off the floor (always keeping your legs extended) and bring your feet towards your head (until you make a 90º thigh/trunk angle, if necessary, your knees can flex a little), return to the starting position without touching your feet to the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the floor) so that there is a 90º angle between your thigh and leg, and another between your back and torso. Place your hands behind your head and lift your head and shoulder blades so that they don't touch the floor, activating the abdominal area. Extend your left knee. Return to the bent-leg position. Alternate extending legs. Do the exercise slowly, always concentrating on the abdominal area. 10 repetitions with each leg
V	Lie on your side with your bottom leg bent (at an angle of more than 90º) and your top leg fully extended. Lean on the elbow that is in contact with the floor, as in the picture, and place your other hand on your waist. To start the movement, lift your body (especially your torso) as one unit, trying to keep it straight. Activate the abdominal area by pulling the navel in towards the spine. Maintain the indicated time. Repeat the exercise on the opposite side for the same amount of time. Option 2: if you have the ease and balance to perform the exercise, you can stretch your arm towards the ceiling, trying to reach it as far as possible.
VI	Start by lying on your stomach, with hands shoulder-width apart, ladies with thumbs aligned with the shoulder/collarbone and men with thumbs aligned with the chin, lift the body as a unit, straightening the arms and perform a push-up. Then bend the arms again, lower the body as low as possible, without touching the ground. Repeat the indicated number of times.

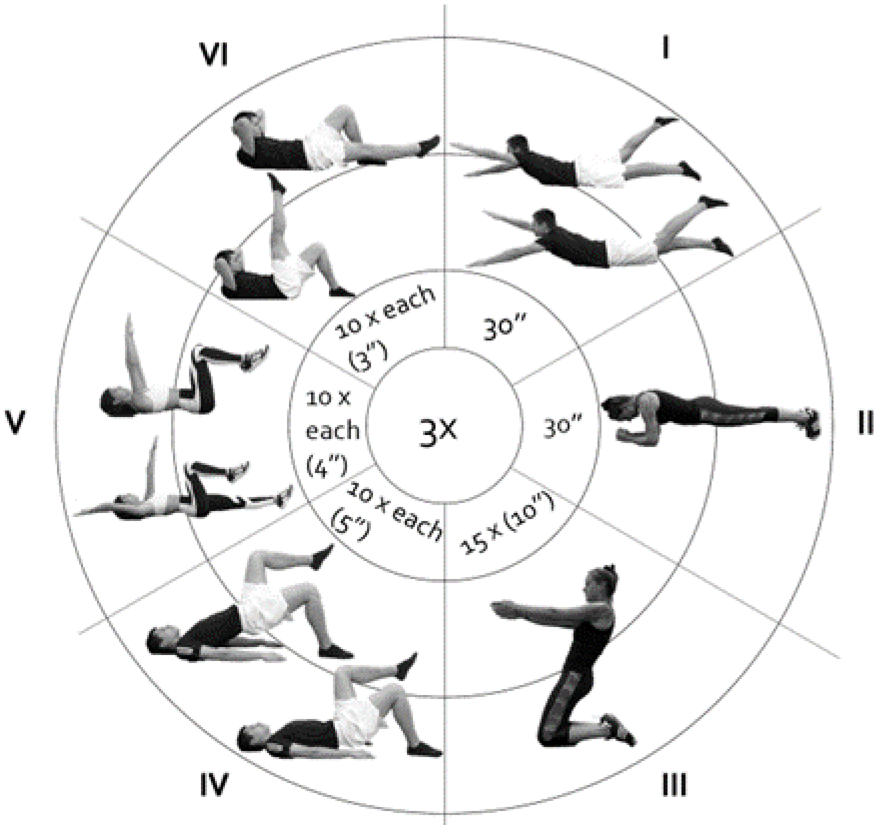
Week 7 – Day 3 – Improvement period



Exercise	Details
I	Start the exercise on your hands and knees (thigh and torso; and arms and torso making a 90º angle), with knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable throughout the exercise. Lift the left leg, touch it to the left elbow (or as close as possible without altering the stability of the torso), and then extend the leg back. Repeat the indicated number of times and then switch sides. In this exercise, the hands always remain on the ground. Perform the movements slowly and in a controlled manner, always maintaining balance.
II	Start by lying on your stomach, activating the abdominal area. Perform a plank supported on the elbows and feet. Be aware that the body is straight, parallel to the ground, back straight. From the elbow plank, rise to a hand plank, hold for a second and then lower back down, holding for a second. Repeat the indicated number of times. Perform the exercise slowly, always focusing on the abdominal area.

III	Start by sitting on the yoga mat. Activate your abdominals and lift your feet off the ground with knees bent. Join hands and interlace fingers, pressing one palm against the other (or if you prefer, you can hold a light, small object). Maintaining the position and keeping the abdominal area activated, pass the object (real or imaginary) from the right side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat) to the left side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat). Perform the exercise slowly, always focusing on the abdominal area. Repeat the indicated number of times.
IV	Start by lying on your stomach. Activate the abdominal area and perform a plank supported on the elbows and knees. Be aware that the body is straight, parallel to the ground, back straight. Starting a rotational movement, touch the left thigh to the ground on the left side (without lifting hands or knees off the ground), return to the plank position, hold for one second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the indicated number of times, 6 times for each side.
V	Start by lying on your back. Stretch your legs (together) towards the ceiling, forming a 90º angle between your legs and torso. Stretch your arms towards the ceiling and imagine pulling a rope (your head and shoulders also lift off the ground). Perform the indicated number of times.
VI	Sit on the floor with your knees bent (as shown in the image). Then stretch your arms forward and relax your shoulders. Draw your navel towards your spine, and slowly roll back without letting your lower back touch the ground, hold for a second, and roll back to the starting position. Perform the exercise slowly and in a controlled manner, always activating the abdominal region. Repeat the indicated number of times.

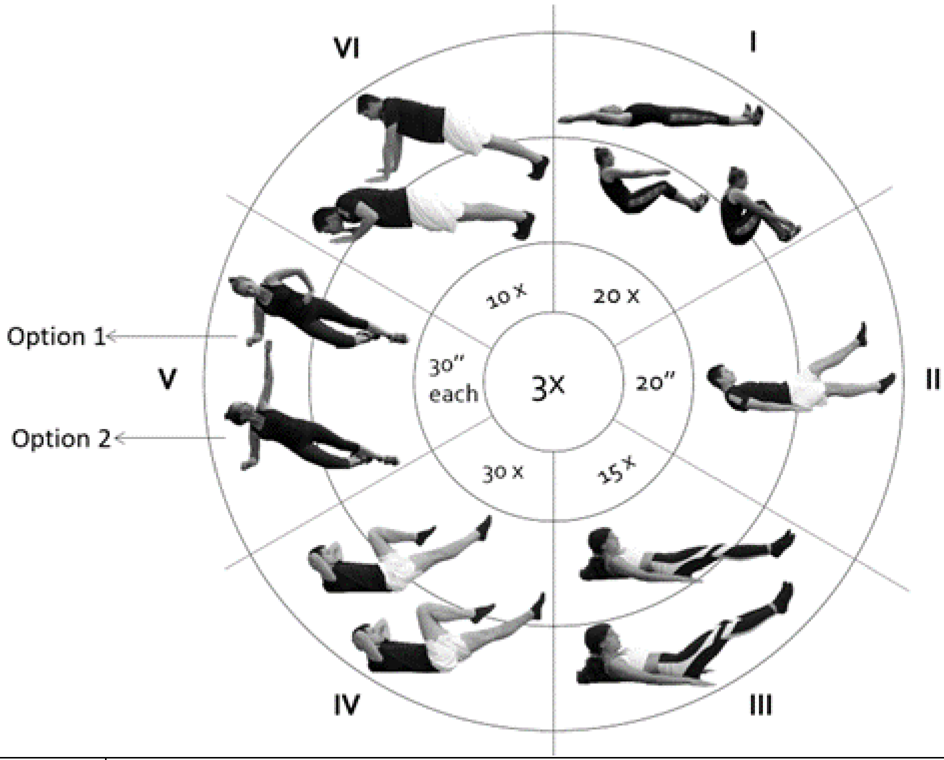
Week 8 – Day 1 – Improvement period



Exercise	Details
I	Start lying on your stomach. Arms and legs fully extended, feet hip-width apart and arms shoulder-width apart. To start the exercise, pull your navel inwards and activate the abdominal area. Lift your right arm and left leg off the floor and alternate. Relax your shoulders while raising your arm and squeeze your glutes to raise your leg. Alternate until the time is up.
II	Start by lying on your stomach. Activate the abdominal area. Do a plank on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (10 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lie on your back. With your knees bent, place your feet shoulder-width apart on the floor. Arms and elbows resting on the floor, forearms bent. Head resting on the floor. Activate your abdominals and keep your back flat on the floor. Lift the left foot (keeping the knee bent as shown in the image). To start the exercise, lift your pelvis so that you are in a straight line with your torso and thigh and lower it again without touching with your back to the floor. Do the number of repetitions indicated with the left leg and then do the same with the right leg.
V	Start the exercise lying on your back. Bend your knees at a 90º angle with your feet off the floor. Stretch your arms towards the ceiling. Curl your navel in towards your spine and your back flat on the floor (try to keep it that way throughout the exercise). Starting the exercise, stretch your left arm back and your right leg forwards (without touching the floor). Hold for 4 seconds. Alternate arm and leg. Do the indicated repetitions.
VI	Start lying on your back, shoulder blades and head off the floor, hands supporting your head behind the back of your head. Left leg bent with foot flat on the floor and right leg straight. Starting the movement, lift your right leg off the ground and bring your foot towards your head (until you make a 90º angle between your thigh and torso, your knee can bend a little), then lower your leg again without touching your foot to the ground. Repeat the number of times indicated. Do the same exercise the same number of times with the opposite leg. Do the exercise slowly, always concentrating on the abdominal area.

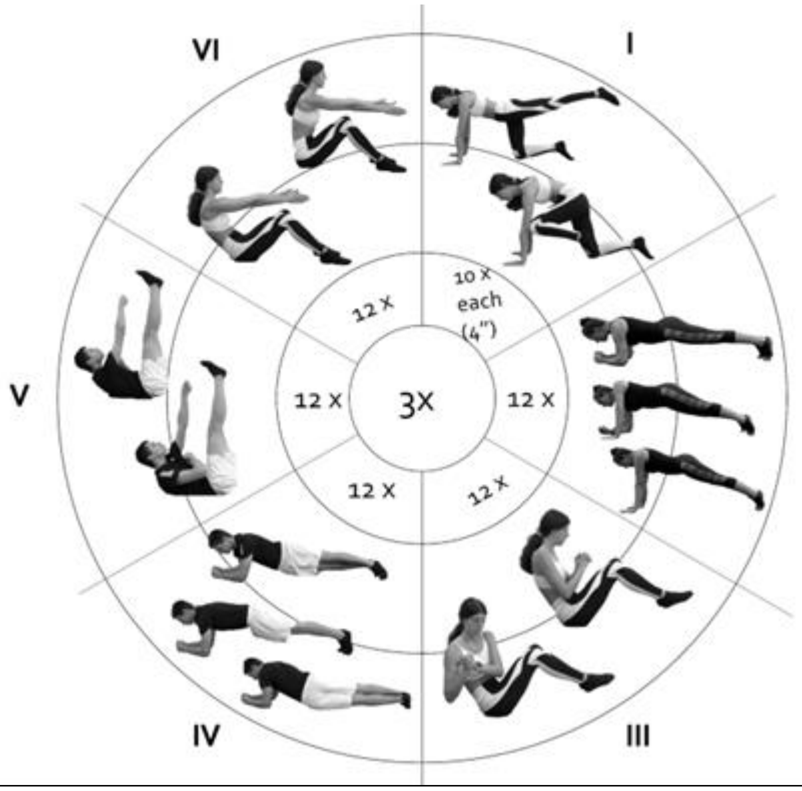
Week 8 – Day 2 – Improvement period



Exercise	Details
I	Start lying on your back, knees fully extended, feet shoulder-width apart, arms stretched out as in the image. Starting the movement, activate the abdominal area and lift the torso (as a unit) and touch your hands to the tips of your feet (legs will flex as the torso lifts, feet always in contact with the ground). Come back down to the starting position, always slowly in a controlled movement. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start lying on your back, knees extended, hands supporting your tailbone, head and shoulder blades off the floor with your abdominal area active. Starting the movement, lift your feet about one to two palms off the ground (always keeping your legs extended). Option 1: kick up and down slightly. Option 2: Kick up and down with your legs crossing a little. Do the exercise for the indicated time, slowly, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms at your sides and head and shoulder blades off the floor. Starting the movement, lift your feet off the floor (always keeping your legs extended) and bring your feet towards your head (until you make a 90º thigh/trunk angle, if necessary, your knees can flex a little), return to the starting position without touching your feet to the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the floor) so that there is a 90º angle between your thigh and leg, and another between your back and torso. Place your hands behind your head and lift your head and shoulder blades so that they don't touch the floor, activating the abdominal area. Extend your left knee. Return to the bent-leg position. Alternate extending legs. Do the exercise slowly, always concentrating on the abdominal area. 10 repetitions with each leg
V	Lie on your side with your bottom leg bent (at an angle of more than 90º) and your top leg fully extended. Lean on the elbow that is in contact with the floor, as in the picture, and place your other hand on your waist. To start the movement, lift your body (especially your torso) as one unit, trying to keep it straight. Activate the abdominal area by pulling the navel in towards the spine. Maintain the indicated time. Repeat the exercise on the opposite side for the same amount of time. Option 2: if you have the ease and balance to perform the exercise, you can stretch your arm towards the ceiling, trying to reach it as far as possible.
VI	Start by lying on your stomach, with hands shoulder-width apart, ladies with thumbs aligned with the shoulder/collarbone and men with thumbs aligned with the chin, lift the body as a unit, straightening the arms and perform a push-up. Then bend the arms again, lower the body as low as possible, without touching the ground. Repeat the indicated number of times.

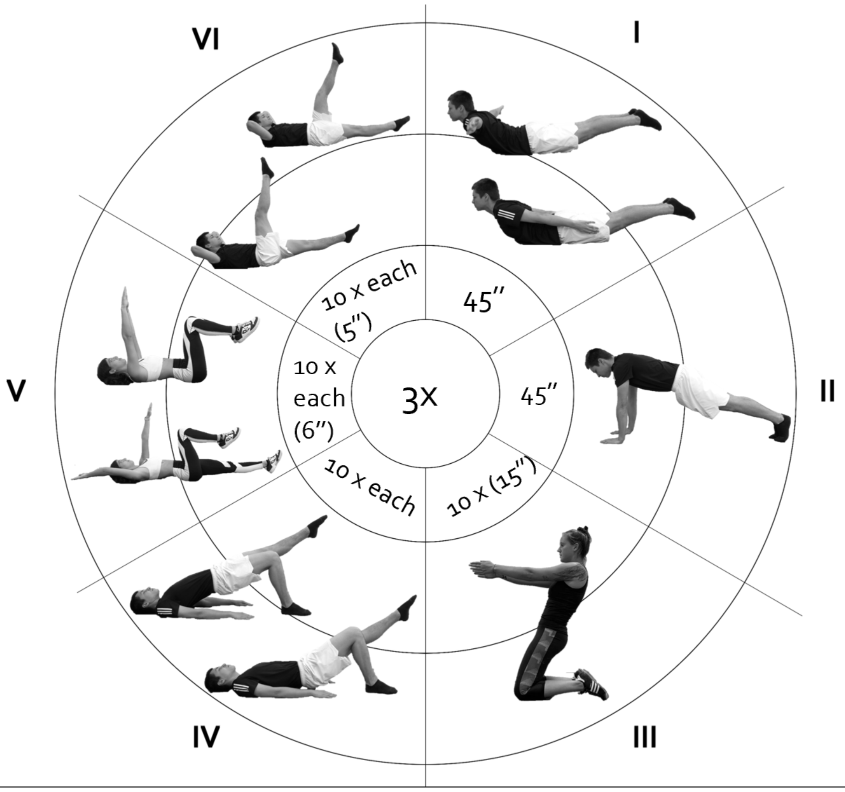
Week 8 – Day 3 – Improvement period



Exercise	Details
I	Start the exercise on your hands and knees (thigh and torso; and arms and torso making a 90º angle), with knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable throughout the exercise. Lift the left leg, touch it to the left elbow (or as close as possible without altering the stability of the torso), and then extend the leg back. Repeat the indicated number of times and then switch sides. In this exercise, the hands always remain on the ground. Perform the movements slowly and in a controlled manner, always maintaining balance.
II	Start by lying on your stomach, activating the abdominal area. Perform a plank supported on the elbows and feet. Be aware that the body is straight, parallel to the ground, back straight. From the elbow plank, rise to a hand plank, hold for a second and then lower back down, holding for a second. Repeat the indicated number of times. Perform the exercise slowly, always focusing on the abdominal area.

III	Start by sitting on the yoga mat. Activate your abdominals and lift your feet off the ground with knees bent. Join hands and interlace fingers, pressing one palm against the other (or if you prefer, you can hold a light, small object). Maintaining the position and keeping the abdominal area activated, pass the object (real or imaginary) from the right side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat) to the left side (reaching as close to the ground as possible without causing imbalance in the pelvis and seat). Perform the exercise slowly, always focusing on the abdominal area. Repeat the indicated number of times.
IV	Start by lying on your stomach. Activate the abdominal area and perform a plank supported on the elbows and knees. Be aware that the body is straight, parallel to the ground, back straight. Starting a rotational movement, touch the left thigh to the ground on the left side (without lifting hands or knees off the ground), return to the plank position, hold for one second, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the indicated number of times, 6 times for each side.
V	Start by lying on your back. Stretch your legs (together) towards the ceiling, forming a 90º angle between your legs and torso. Stretch your arms towards the ceiling and imagine pulling a rope (your head and shoulders also lift off the ground). Perform the indicated number of times.
VI	Sit on the floor with your knees bent (as shown in the image). Then stretch your arms forward and relax your shoulders. Draw your navel towards your spine, and slowly roll back without letting your lower back touch the ground, hold for a second, and roll back to the starting position. Perform the exercise slowly and in a controlled manner, always activating the abdominal region. Repeat the indicated number of times.

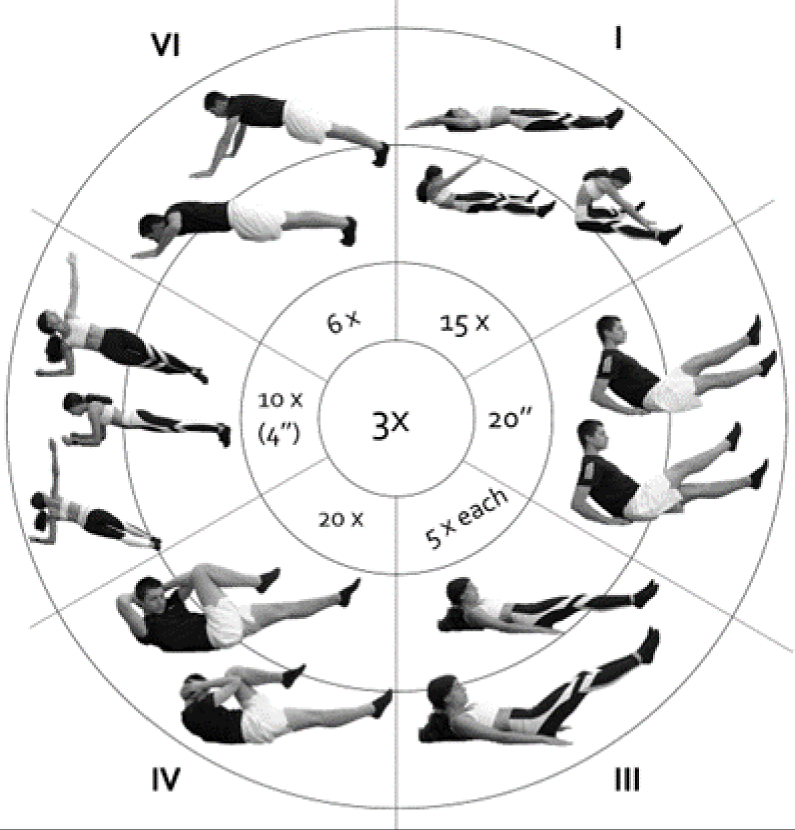
Week 9 – Day 1 – Consolidation period



Exercise	Details
I	Start lying on your stomach. Arms close to the torso and legs fully extended, feet together. To start the exercise, pull the navel in and activate the abdominal area. Lift the shoulders and torso as much as possible (always using the abdominal area) and squeeze the glutes to lift the legs off the ground as much as possible, arms varying between being open and close to the torso. Maintain the exercise for the indicated time.
II	Start lying on your stomach. Activate the abdominal area. Perform a plank on your hands and feet. Be aware that the body is straight, parallel to the ground, back straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (15 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lying on your back. With knees bent, place feet shoulder-width apart. Arms and elbows lying on the ground, forearm bent or extended as preferred. Head on the ground. Activate the abdominal region and keep the back flat on the ground. Extend the right leg, keeping the thighs parallel. Then, lift the pelvis to form a straight line with the torso and thigh. Lower without touching the glutes to the ground and repeat the indicated number of times. Then perform the same exercise with the other leg, the same number of times.
V	Start the exercise lying on your back. Bend your knees to create a 90º angle between torso/thigh and thigh/leg. Stretch your arms towards the ceiling. Pull the navel in and keep the back flat in contact with the ground (try to always maintain this during the exercise). Starting the exercise, stretch the left arm back and the right leg forward (without touching the ground). Hold for 6 seconds. Return to the original position and alternate the arm and leg. Perform the indicated repetitions.
VI	Start lying on your back, legs extended, shoulder blades and head off the ground, hands behind the head for support. Starting the movement, lift both legs stretched and about two palms off the ground, then bring the right leg toward the head (until making a 90º angle leg/torso, knee may bend slightly) hold for 5 seconds and return to the initial position (without touching the foot on the ground). Alternate the leg. Perform the exercise slowly, always focusing on the abdominal area.

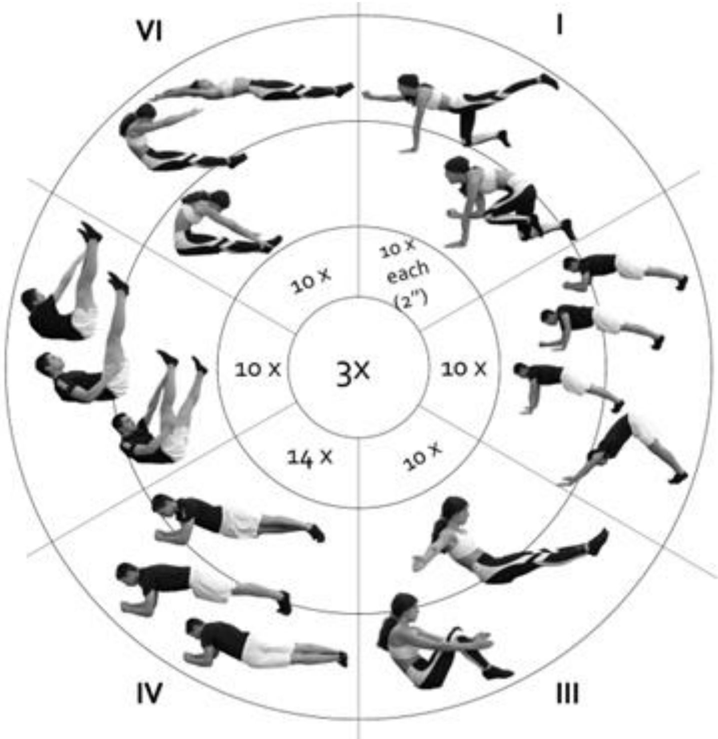
Week 9 – Day 2 – Consolidation period



Exercise	Details
I	Start lying on your back, legs stretched out, feet shoulder-width apart, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit) and as the torso lifts open the legs. Touch your hands as far as possible, and in a slow, controlled movement return to the starting position, closing your legs as your torso approaches the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start in a seated position, legs stretched out, hands on the floor behind your back to support you, activate the abdominal region and tilt your torso backwards. At the start of the movement, lift your feet about one to two palms off the ground (always keep your legs extended). Option 1: Perform small kicks up and down. Option 2: Kick up and down with your legs crossing a little. Perform the exercise for the indicated time, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms close to your body and shoulder blades off the ground, activating the abdominal area. Starting the movement, lift your feet off the floor. Keep your feet close together and draw circles with your feet. You don't need to make large circles, just keep the movement controlled. Do 5 x clockwise and 5 x anticlockwise. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle between your thigh/leg and thigh/trunk. Place your hands behind your head and lift your shoulder blades off the floor, activating your abdominal area. Extend your left knee and touch your right knee with your left elbow. Do the same exercise with the other leg and elbow. Alternate and do the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
V	Start the exercise in an elbow plank (hold the plank for 4 seconds). Turn your body to the left, balancing your weight on your left arm/elbow and the side of your left foot (right foot on top of left). Stretch your right arm up towards the ceiling. Hold the position for 4 seconds and return to elbow plank (4 seconds). Do the exercise on the opposite side. Repeat the exercise alternating sides (5x each side) and holding each position for 4 seconds.
VI	Start lying on your stomach, hands at the most convenient width, ladies with thumbs aligned with chin and men with thumbs aligned with eyes or forehead, lift body as a unit, stretching arms and doing a push-up. Flex your arms again and lower your body as low as possible without touching the floor. Repeat the number of times indicated.

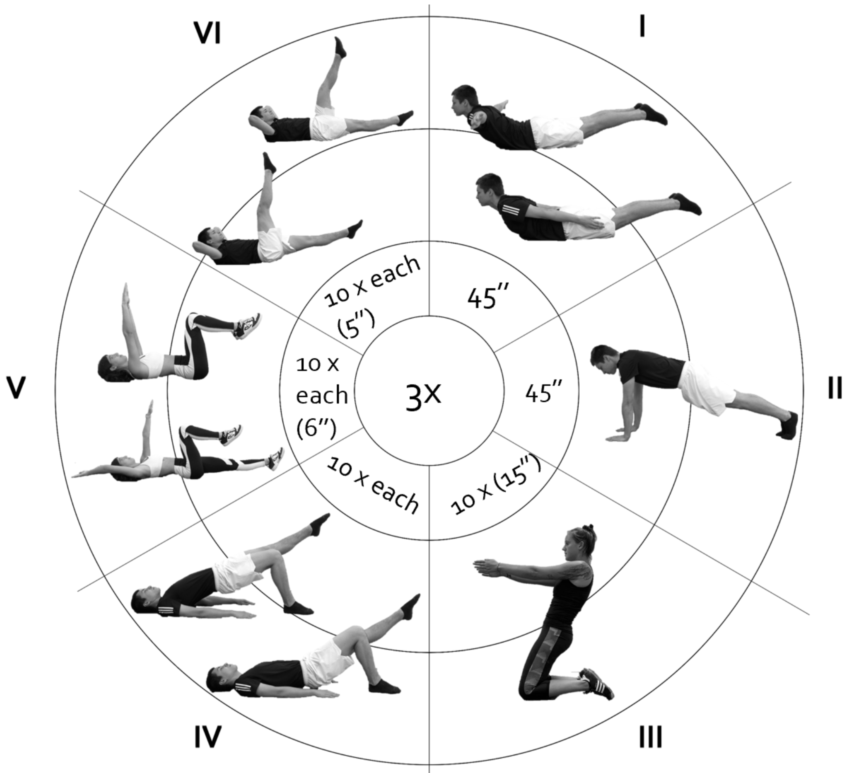
Week 9 – Day 3 – Consolidation period



Exercise	Details
I	Start the exercise on your hands and knees (90º angle thigh/trunk and arms/trunk) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the left arm and right leg. Hold the position for 2 seconds, always in balance. Then touch your right knee to your left elbow underneath your body without losing your balance or the stability of your torso; then extend your leg and arm again (hold for 2 seconds). Repeat the number of times indicated without touching the floor with your hand or knee. When the set is finished, alternate and do the same number of repetitions on the opposite side.
II	Start lying on your stomach. Activating the abdominal area. The exercise starts with a hand and foot plank, then do a "downwards dog" hold for 1 second, return to hand plank, hold for 1 second, and descend to elbow plank hold for 1 second, return to hand plank (hold for 1 second) where you complete one set. Repeat the complete set the number of times indicated. Do the exercise slowly, always concentrating on the abdominal

	area. When doing planks, make sure your body is straight, parallel to the floor and your back is straight.
III	Start sitting on the yoga mat. Activate your abdominals, bring your torso back a little to find balance and lift your feet off the ground with your knees bent. Then extend your legs (keeping your heels above the line of your pelvis), bring your torso back a little more and open your arms. Return to the original position (with your feet always off the ground). Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Start lying on your stomach. Activating the abdominal area, do a plank resting on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or feet from the floor), return to the plank position, hold for 2 seconds, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 7 times for each side.
V	Start lying on your back. Stretch your legs (apart) towards the ceiling, forming a 90º angle between your legs and torso. Activating the abdominal area, move your head, shoulder blades and part of your torso off the floor while alternately trying to touch your right foot with your left hand and your right hand with your left foot. Do the number of times indicated (5 touches with each hand on each foot).
VI	Start lying on your back, legs stretched out, feet together, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit), always keeping the arms as close to the ears as possible, touch the feet with the hands, and in a slow, controlled movement return to the starting position. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.

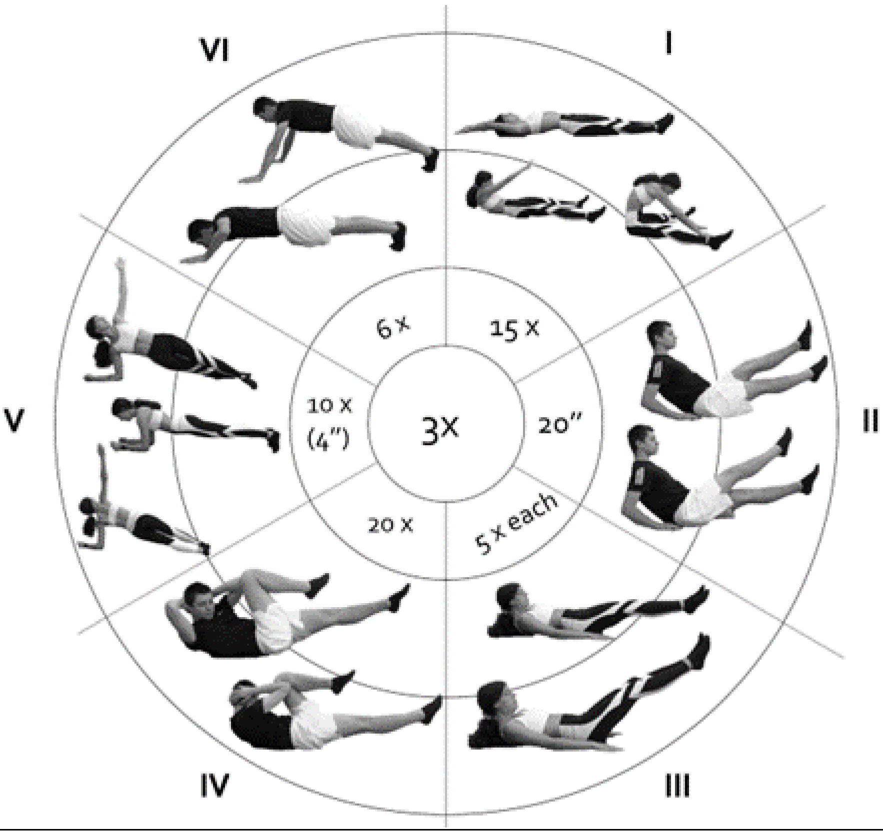
Week 10 – Day 1 – Consolidation period



Exercise	Details
I	Start lying on your stomach. Arms close to the torso and legs fully extended, feet together. To start the exercise, pull the navel in and activate the abdominal area. Lift the shoulders and torso as much as possible (always using the abdominal area) and squeeze the glutes to lift the legs off the ground as much as possible, arms varying between being open and close to the torso. Maintain the exercise for the indicated time.
II	Start lying on your stomach. Activate the abdominal area. Perform a plank on your hands and feet. Be aware that the body is straight, parallel to the ground, back straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for

	the allotted time (15 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lying on your back. With knees bent, place feet shoulder-width apart. Arms and elbows lying on the ground, forearm bent or extended as preferred. Head on the ground. Activate the abdominal region and keep the back flat on the ground. Extend the right leg, keeping the thighs parallel. Then, lift the pelvis to form a straight line with the torso and thigh. Lower without touching the glutes to the ground and repeat the indicated number of times. Then perform the same exercise with the other leg, the same number of times.
V	Start the exercise lying on your back. Bend your knees to create a 90º angle between torso/thigh and thigh/leg. Stretch your arms towards the ceiling. Pull the navel in and keep the back flat in contact with the ground (try to always maintain this during the exercise). Starting the exercise, stretch the left arm back and the right leg forward (without touching the ground). Hold for 6 seconds. Return to the original position and alternate the arm and leg. Perform the indicated repetitions.
VI	Start lying on your back, legs extended, shoulder blades and head off the ground, hands behind the head for support. Starting the movement, lift both legs stretched and about two palms off the ground, then bring the right leg toward the head (until making a 90º angle leg/torso, knee may bend slightly) hold for 5 seconds and return to the initial position (without touching the foot on the ground). Alternate the leg. Perform the exercise slowly, always focusing on the abdominal area.

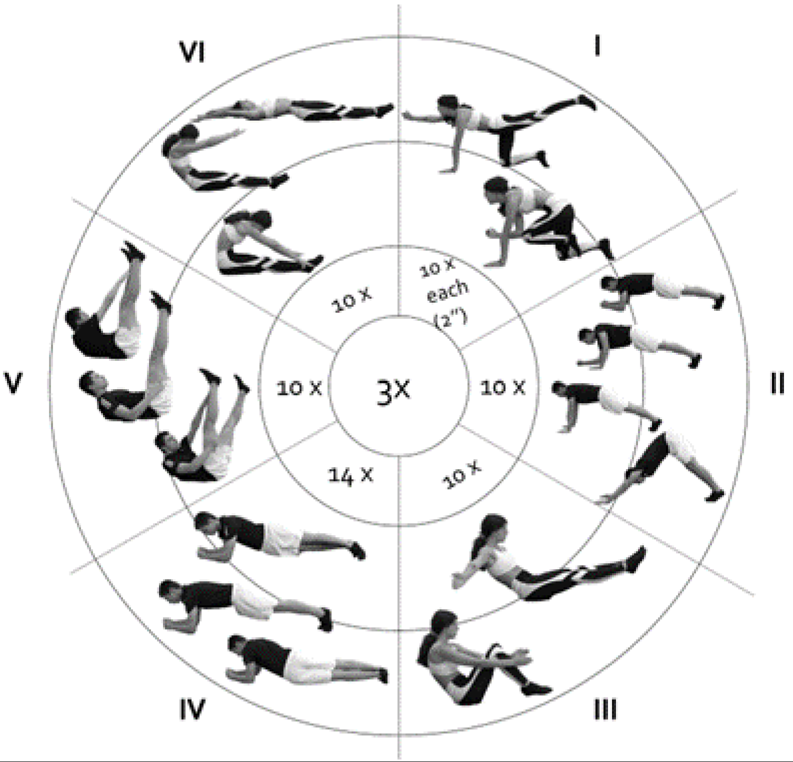
Week 10 – Day 2 – Consolidation period



Exercise	Details
I	Start lying on your back, legs stretched out, feet shoulder-width apart, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit) and as the torso lifts open the legs. Touch your hands as far as possible, and in a slow, controlled movement return to the starting position, closing your legs as your torso approaches the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start in a seated position, legs stretched out, hands on the floor behind your back to support you, activate the abdominal region and tilt your torso backwards. At the start of the movement, lift your feet about one to two palms off the ground (always keep your legs extended). Option 1: Perform small kicks up and down. Option 2: Kick up and down with your legs crossing a little. Perform the exercise for the indicated time, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms close to your body and shoulder blades off the ground, activating the abdominal area. Starting the movement, lift your feet off the floor. Keep your feet close together and draw circles with your feet. You don't need to make large circles, just keep the movement controlled. Do 5 x clockwise and 5 x anticlockwise. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle between your thigh/leg and thigh/trunk. Place your hands behind your head and lift your shoulder blades off the floor, activating your abdominal area. Extend your left knee and touch your right knee with your left elbow. Do the same exercise with the other leg and elbow. Alternate and do the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
V	Start the exercise in an elbow plank (hold the plank for 4 seconds). Turn your body to the left, balancing your weight on your left arm/elbow and the side of your left foot (right foot on top of left). Stretch your right arm up towards the ceiling. Hold the position for 4 seconds and return to elbow plank (4 seconds). Do the exercise on the opposite side. Repeat the exercise alternating sides (5x each side) and holding each position for 4 seconds.
VI	Start lying on your stomach, hands at the most convenient width, ladies with thumbs aligned with chin and men with thumbs aligned with eyes or forehead, lift body as a unit, stretching arms and doing a push-up. Flex your arms again and lower your body as low as possible without touching the floor. Repeat the number of times indicated.

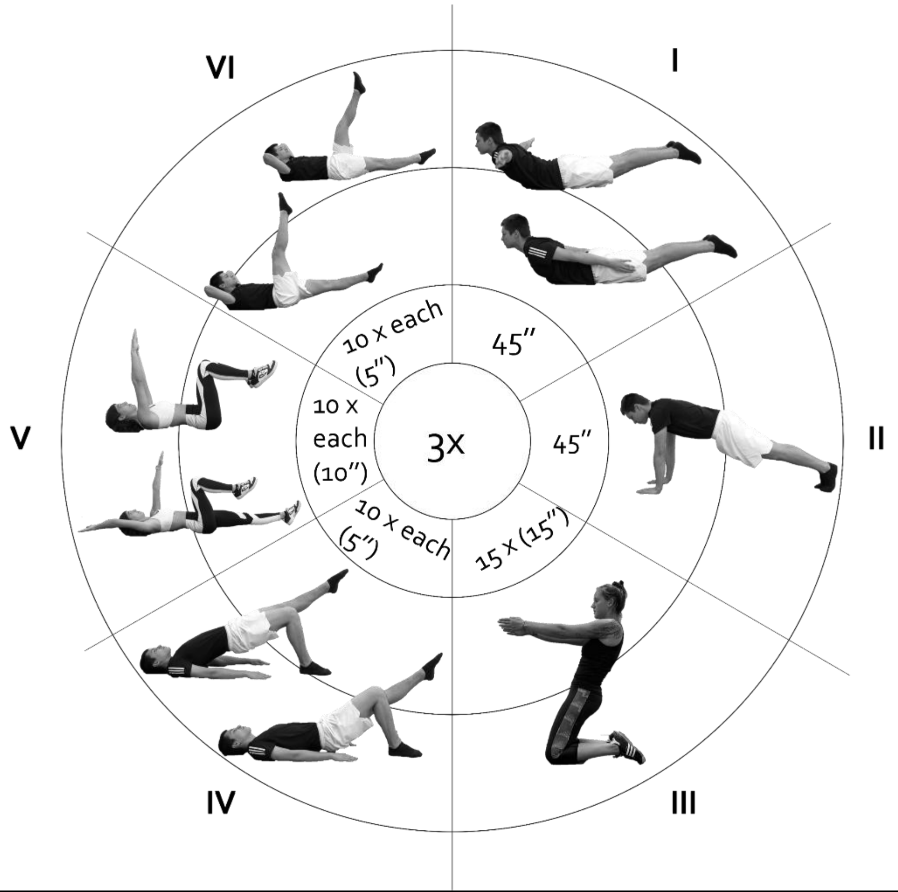
Week 10 – Day 3 – Consolidation period



Exercise	Details
I	Start the exercise on your hands and knees (90º angle thigh/trunk and arms/trunk) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the left arm and right leg. Hold the position for 2 seconds, always in balance. Then touch your right knee to your left elbow underneath your body without losing your balance or the stability of your torso; then extend your leg and arm again (hold for 2 seconds). Repeat the number of times indicated without touching the floor with your hand or knee. When the set is finished, alternate and do the same number of repetitions on the opposite side.
II	Start lying on your stomach. Activating the abdominal area. The exercise starts with a hand and foot plank, then do a “downwards dog” hold for 1 second, return to hand plank, hold for 1 second, and descend to elbow plank hold for 1 second, return to hand plank (hold for 1 second) where you complete one set. Repeat the complete set the number of times indicated. Do the exercise slowly, always concentrating on the abdominal

	area. When doing planks, make sure your body is straight, parallel to the floor and your back is straight.
III	Start sitting on the yoga mat. Activate your abdominals, bring your torso back a little to find balance and lift your feet off the ground with your knees bent. Then extend your legs (keeping your heels above the line of your pelvis), bring your torso back a little more and open your arms. Return to the original position (with your feet always off the ground). Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Start lying on your stomach. Activating the abdominal area, do a plank resting on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or feet from the floor), return to the plank position, hold for 2 seconds, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 7 times for each side.
V	Start lying on your back. Stretch your legs (apart) towards the ceiling, forming a 90º angle between your legs and torso. Activating the abdominal area, move your head, shoulder blades and part of your torso off the floor while alternately trying to touch your right foot with your left hand and your right hand with your left foot. Do the number of times indicated (5 touches with each hand on each foot).
VI	Start lying on your back, legs stretched out, feet together, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit), always keeping the arms as close to the ears as possible, touch the feet with the hands, and in a slow, controlled movement return to the starting position. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.

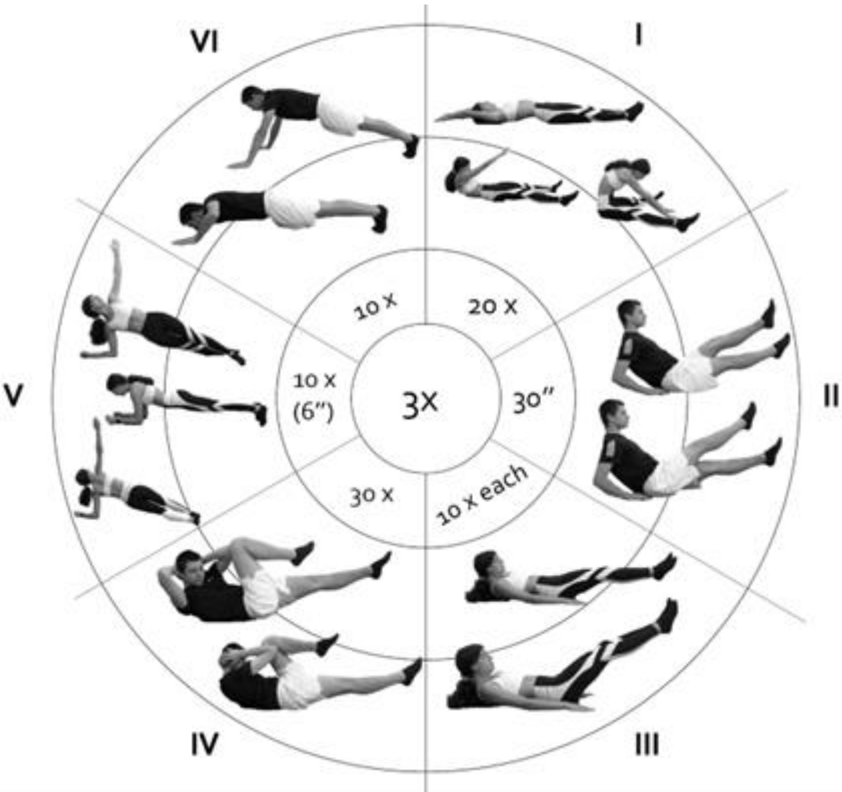
Week 11 – Day 1 – Consolidation period



Exercise	Details
I	Start lying on your stomach. Arms close to the torso and legs fully extended, feet together. To start the exercise, pull the navel in and activate the abdominal area. Lift the shoulders and torso as much as possible (always using the abdominal area) and squeeze the glutes to lift the legs off the ground as much as possible, arms varying between being open and close to the torso. Maintain the exercise for the indicated time.
II	Start lying on your stomach. Activate the abdominal area. Perform a plank on your hands and feet. Be aware that the body is straight, parallel to the ground, back straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90° leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh.

	Stretch your arms forwards. When you start the exercise, lean back as far as possible (keeping a straight line between your thigh and torso). Hold for the allotted time (15 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lying on your back. With knees bent, place feet shoulder-width apart. Arms and elbows lying on the ground, forearm bent or extended as preferred. Head on the ground. Activate the abdominal region and keep the back flat on the ground. Extend the right leg, keeping the thighs parallel. Then, lift the pelvis to form a straight line with the torso and thigh. Lower without touching the glutes to the ground and repeat the indicated number of times. Then perform the same exercise with the other leg, the same number of times.
V	Start the exercise lying on your back. Bend your knees to create a 90º angle between torso/thigh and thigh/leg. Stretch your arms towards the ceiling. Pull the navel in and keep the back flat in contact with the ground (try to always maintain this during the exercise). Starting the exercise, stretch the left arm back and the right leg forward (without touching the ground). Hold for 10 seconds. Return to the original position and alternate the arm and leg. Perform the indicated repetitions.
VI	Start lying on your back, legs extended, shoulder blades and head off the ground, hands behind the head for support. Starting the movement, lift both legs stretched and about two palms off the ground, then bring the right leg toward the head (until making a 90º angle leg/torso, knee may bend slightly) hold for 5 seconds and return to the initial position (without touching the foot on the ground). Alternate the leg. Perform the exercise slowly, always focusing on the abdominal area.

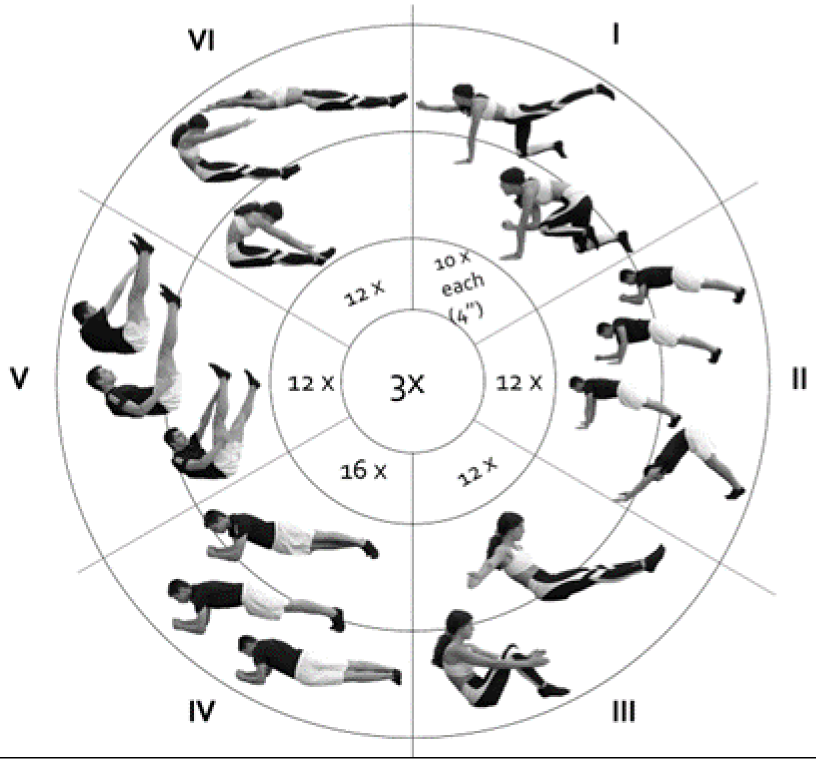
Week 11 – Day 2 – Consolidation period



Exercise	Details
I	Start lying on your back, legs stretched out, feet shoulder-width apart, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit) and as the torso lifts open the legs. Touch your hands as far as possible, and in a slow, controlled movement return to the starting position, closing your legs as your torso approaches the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start in a seated position, legs stretched out, hands on the floor behind your back to support you, activate the abdominal region and tilt your torso backwards. At the start of the movement, lift your feet about one to two palms off the ground (always keep your legs extended). Option 1: Perform small kicks up and down. Option 2: Kick up and down with your legs crossing a little. Perform the exercise for the indicated time, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms close to your body and shoulder blades off the ground, activating the abdominal area. Starting the movement, lift your feet off the floor. Keep your feet close together and draw circles with your feet. You don't need to make large circles, just keep the movement controlled. Do 5 x clockwise and 5 x anticlockwise. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle between your thigh/leg and thigh/trunk. Place your hands behind your head and lift your shoulder blades off the floor, activating your abdominal area. Extend your left knee and touch your right knee with your left elbow. Do the same exercise with the other leg and elbow. Alternate and do the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
V	Start the exercise in an elbow plank (hold the plank for 6 seconds). Turn your body to the left, balancing your weight on your left arm/elbow and the side of your left foot (right foot on top of left). Stretch your right arm up towards the ceiling. Hold the position for 6 seconds and return to elbow plank (6 seconds). Do the exercise on the opposite side. Repeat the exercise alternating sides (5x each side) and holding each position for 6 seconds.
VI	Start lying on your stomach, hands at the most convenient width, ladies with thumbs aligned with chin and men with thumbs aligned with eyes or forehead, lift body as a unit, stretching arms and doing a push-up. Flex your arms again and lower your body as low as possible without touching the floor. Repeat the number of times indicated.

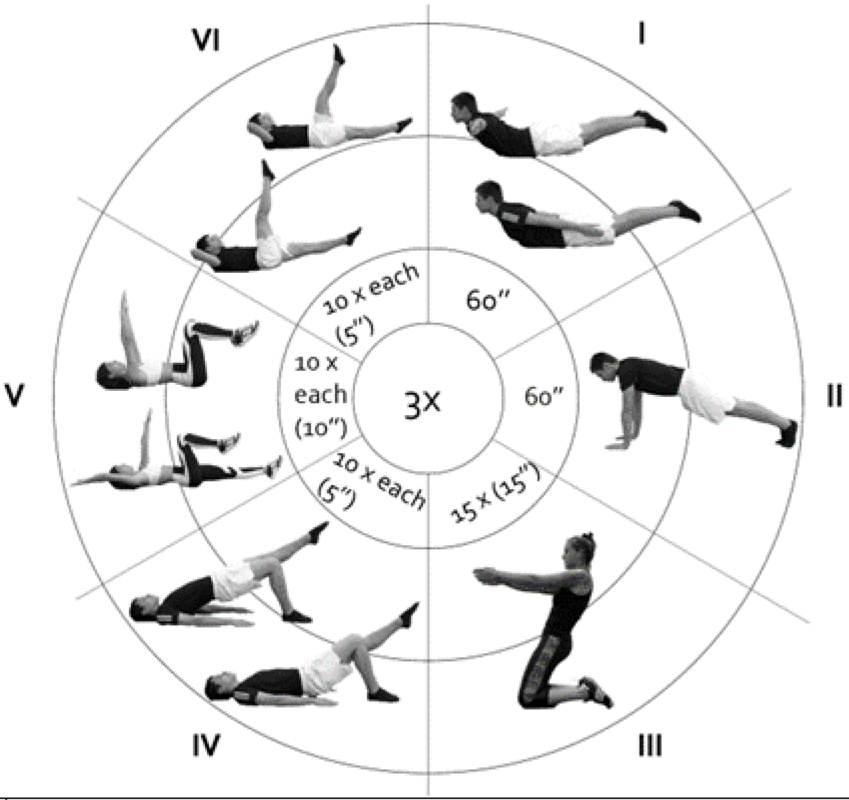
Week 11 – Day 3 – Consolidation period



Exercise	Details
I	Start the exercise on your hands and knees (90° angle thigh/trunk and arms/trunk) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the left arm and right leg. Hold the position for 4 seconds, always in balance. Then touch your right knee to your left elbow underneath your body without losing your balance or the stability of your torso; then extend your leg and arm again (hold for 4 seconds). Repeat the number of times indicated without touching the floor with your hand or knee. When the set is finished, alternate and do the same number of repetitions on the opposite side.
II	Start lying on your stomach. Activating the abdominal area. The exercise starts with a hand and foot plank, then do a “downwards dog” hold for 1 second, return to hand plank, hold for 1 second, and descend to elbow plank hold for 1 second, return to hand plank (hold for 1 second) where you complete one set. Repeat the complete set the number of times indicated. Do the exercise slowly, always concentrating on the abdominal

	area. When doing planks, make sure your body is straight, parallel to the floor and your back is straight.
III	Start sitting on the yoga mat. Activate your abdominals, bring your torso back a little to find balance and lift your feet off the ground with your knees bent. Then extend your legs (keeping your heels above the line of your pelvis), bring your torso back a little more and open your arms. Return to the original position (with your feet always off the ground). Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Start lying on your stomach. Activating the abdominal area, do a plank resting on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or feet from the floor), return to the plank position, hold for 2 seconds, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 8 times for each side.
V	Start lying on your back. Stretch your legs (apart) towards the ceiling, forming a 90º angle between your legs and torso. Activating the abdominal area, move your head, shoulder blades and part of your torso off the floor while alternately trying to touch your right foot with your left hand and your right hand with your left foot. Do the number of times indicated (6 touches with each hand on each foot).
VI	Start lying on your back, legs stretched out, feet together, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit), always keeping the arms as close to the ears as possible, touch the feet with the hands, and in a slow, controlled movement return to the starting position. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.

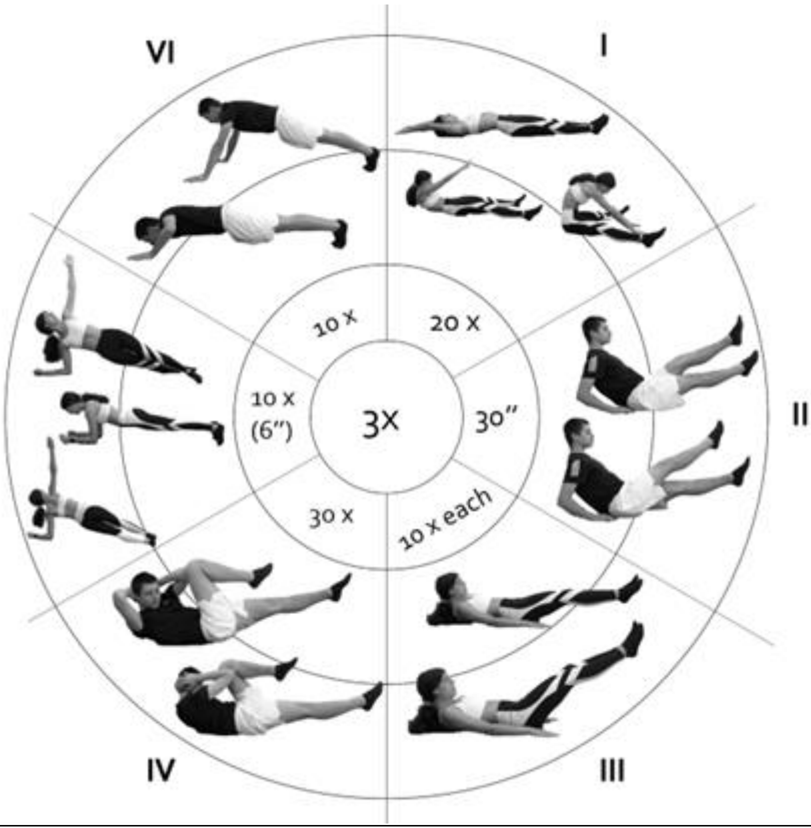
Week 12 – Day 1 – Consolidation period



Exercise	Details
I	Start lying on your stomach. Arms close to the torso and legs fully extended, feet together. To start the exercise, pull the navel in and activate the abdominal area. Lift the shoulders and torso as much as possible (always using the abdominal area) and squeeze the glutes to lift the legs off the ground as much as possible, arms varying between being open and close to the torso. Maintain the exercise for the indicated time.
II	Start lying on your stomach. Activate the abdominal area. Perform a plank on your hands and feet. Be aware that the body is straight, parallel to the ground, back straight. Hold for the indicated time.
III	This exercise is important for improving mobility on horseback and activating the abs on horseback. Start the exercise on your knees (forming a 90º leg/thigh angle), if you have pain in your knees, you can place a cushion underneath. Keep a straight line between your torso and thigh. Stretch your arms forwards. When you start the exercise, lean back as far

	as possible (keeping a straight line between your thigh and torso). Hold for the allotted time (15 seconds). Return to the original position for 1 second and repeat as many times as indicated.
IV	Lying on your back. With knees bent, place feet shoulder-width apart. Arms and elbows lying on the ground, forearm bent or extended as preferred. Head on the ground. Activate the abdominal region and keep the back flat on the ground. Extend the right leg, keeping the thighs parallel. Then, lift the pelvis to form a straight line with the torso and thigh. Lower without touching the glutes to the ground and repeat the indicated number of times. Then perform the same exercise with the other leg, the same number of times.
V	Start the exercise lying on your back. Bend your knees to create a 90º angle between torso/thigh and thigh/leg. Stretch your arms towards the ceiling. Pull the navel in and keep the back flat in contact with the ground (try to always maintain this during the exercise). Starting the exercise, stretch the left arm back and the right leg forward (without touching the ground). Hold for 10 seconds. Return to the original position and alternate the arm and leg. Perform the indicated repetitions.
VI	Start lying on your back, legs extended, shoulder blades and head off the ground, hands behind the head for support. Starting the movement, lift both legs stretched and about two palms off the ground, then bring the right leg toward the head (until making a 90º angle leg/torso, knee may bend slightly) hold for 5 seconds and return to the initial position (without touching the foot on the ground). Alternate the leg. Perform the exercise slowly, always focusing on the abdominal area.

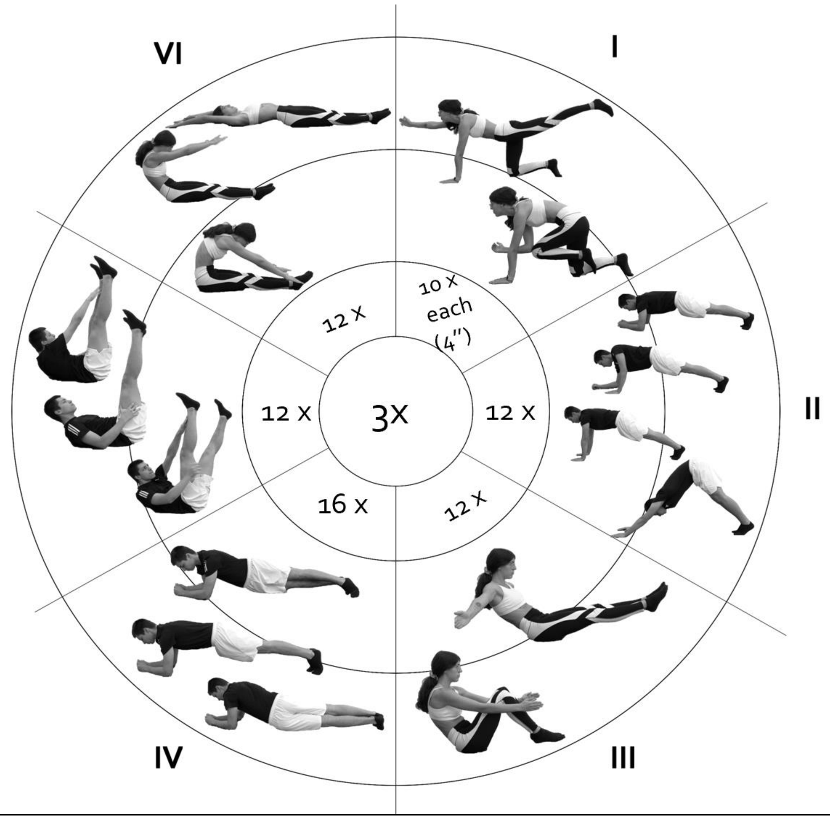
Week 12 – Day 2 – Consolidation period



Exercise	Details
I	Start lying on your back, legs stretched out, feet shoulder-width apart, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit) and as the torso lifts open the legs. Touch your hands as far as possible, and in a slow, controlled movement return to the starting position, closing your legs as your torso approaches the floor. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
II	Start in a seated position, legs stretched out, hands on the floor behind your back to support you, activate the abdominal region and tilt your torso backwards. At the start of the movement, lift your feet about one to two palms off the ground (always keep your legs extended). Option 1: Perform small kicks up and down. Option 2: Kick up and down with your legs crossing a little. Perform the exercise for the indicated time, always concentrating on the abdominal area.

III	Start lying on your back, legs stretched out, arms close to your body and shoulder blades off the ground, activating the abdominal area. Starting the movement, lift your feet off the floor. Keep your feet close together and draw circles with your feet. You don't need to make large circles, just keep the movement controlled. Do 5 x clockwise and 5 x anticlockwise. Do the exercise slowly, always concentrating on the abdominal area.
IV	Lying on your back, bend your knees (with your feet off the ground) to make a 90º angle between your thigh/leg and thigh/trunk. Place your hands behind your head and lift your shoulder blades off the floor, activating your abdominal area. Extend your left knee and touch your right knee with your left elbow. Do the same exercise with the other leg and elbow. Alternate and do the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
V	Start the exercise in an elbow plank (hold the plank for 6 seconds). Turn your body to the left, balancing your weight on your left arm/elbow and the side of your left foot (right foot on top of left). Stretch your right arm up towards the ceiling. Hold the position for 6 seconds and return to elbow plank (6 seconds). Do the exercise on the opposite side. Repeat the exercise alternating sides (5x each side) and holding each position for 6 seconds.
VI	Start lying on your stomach, hands at the most convenient width, ladies with thumbs aligned with chin and men with thumbs aligned with eyes or forehead, lift body as a unit, stretching arms and doing a push-up. Flex your arms again and lower your body as low as possible without touching the floor. Repeat the number of times indicated.

Week 12 – Day 3 – Consolidation period



Exercise	Details
I	Start the exercise on your hands and knees (90º angle thigh/trunk and arms/trunk) knees hip-width apart and hands shoulder-width apart. Activate the abdominal area and try to keep the pelvis stable as you extend the left arm and right leg. Hold the position for 4 seconds, always in balance. Then touch your right knee to your left elbow underneath your body without losing your balance or the stability of your torso; then extend your leg and arm again (hold for 4 seconds). Repeat the number of times indicated without touching the floor with your hand or knee. When the set is finished, alternate and do the same number of repetitions on the opposite side.
II	Start lying on your stomach. Activating the abdominal area. The exercise starts with a hand and foot plank, then do a "downwards dog" hold for 1 second, return to hand plank, hold for 1 second, and descend to elbow plank hold for 1 second, return to hand plank (hold for 1 second) where you complete one set. Repeat the complete set the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area. When

	doing planks, make sure your body is straight, parallel to the floor and your back is straight.
III	Start sitting on the yoga mat. Activate your abdominals, bring your torso back a little to find balance and lift your feet off the ground with your knees bent. Then extend your legs (keeping your heels above the line of your pelvis), bring your torso back a little more and open your arms. Return to the original position (with your feet always off the ground). Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.
IV	Start lying on your stomach. Activating the abdominal area, do a plank resting on your elbows and feet. Make sure your body is straight, parallel to the floor and your back is straight. Starting a rotational movement, touch your left thigh to the floor on the left side (without removing your hands or feet from the floor), return to the plank position, hold for 2 seconds, and do the same on the right side. Perform the movement slowly and in a controlled manner. Repeat the number of times indicated, 8 times for each side.
V	Start lying on your back. Stretch your legs (apart) towards the ceiling, forming a 90º angle between your legs and torso. Activating the abdominal area, move your head, shoulder blades and part of your torso off the floor while alternately trying to touch your right foot with your left hand and your right hand with your left foot. Do the number of times indicated (6 touches with each hand on each foot).
VI	Start lying on your back, legs stretched out, feet together, arms stretched out behind you. Starting the movement activate the abdominal area and lift the torso (as a unit), always keeping the arms as close to the ears as possible, touch the feet with the hands, and in a slow, controlled movement return to the starting position. Repeat the number of times indicated. Do the exercise slowly, always concentrating on the abdominal area.