

Universidade de Évora - Instituto de Investigação e Formação Avançada

Programa de Doutoramento em Motricidade Humana

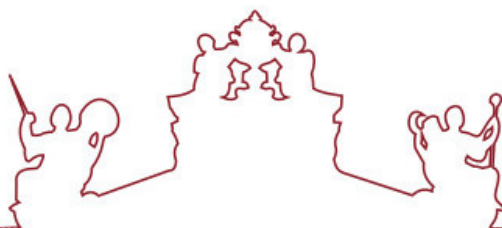
Tese de Doutoramento

**Effects of the Ashtanga-Vinyasa Yoga Supta practice on the
performance of aviation pilots of the Portuguese Airforce**

Sara Alexandra Gonçalves Santos

Orientador(es) | Jose Alberto Parraca
Orlando de Jesus Fernandes
Filipe Manuel Soares de Melo

Évora 2025



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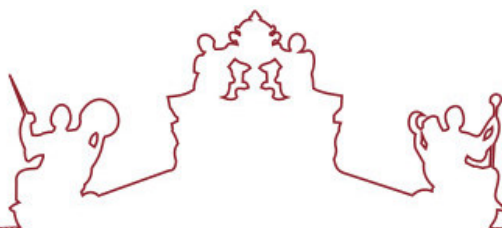
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A tese de doutoramento foi objeto de apreciação e discussão pública pelo seguinte júri nomeado pelo Diretor do Instituto de Investigação e Formação Avançada:

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		Santos Villafaina Dominguez (Universidad de Extremadura)

"In the middle of difficulty lies opportunity."
— **Albert Einstein**

Agradecimentos

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Abbreviations

Air Force Academy (AFA)

Army Techniques Publication (ATP)

Artificial Intelligence (AI)

Ashtanga Vinyasa Yoga Supta (AVYS)

Ashtanga Vinyasa Yoga Supta Method (AVYSM)

Ba05 (Base Aérea 05, Monte Real)

Ba11 (Base Aérea 11, Beja)

Center of Pressure (CoP)

Comprehensive Health Research Centre (CHRC)

Consolidated Standards of Reporting Trials (CONSORT)

Design effect (DEFF)

Dispersion, standard deviation, of points along the axis of the line of identity in the Poincaré plot (SD2)

Dispersion, standard deviation, of points perpendicular to the axis of the line of identity in the Poincaré plot (SD1)

Emergency 1 (E1)

Emergency 2 (E2)

Emergency 3 (E3)

Emergency 4 (E4)

Expert Pilots (EP)

Field Manual (FM)

Forced Expiratory Volume in 1s (FEV1)

Forced Vital Capacity (FVC)

Heart Rate Variability (HRV)

Institute of Physical Education and Sports and the Graduate Program in Public Health at the Federal University of Ceará (PPGSP-UFC)

Instituto de Investigação e Formação Avançada (IIFA)

Low frequency (LF, 0.04–0.15 Hz) ratio (ms^2) / High frequency (HF, 0.15–0.4 Hz) (ms^2) (LF/HF)

Population size (N)

Randomized Controlled Trial (RCT)

Rookie Pilots (RP)

Short Form 36 Version 1 (SF-36V1)

Spatial Disorientation (SpatDis)

Standard Deviation (SD)

Standard deviation of normal-to-normal intervals (SDNN)

Stress Index (SI)

Takeoff (T)

The square root of the mean of the squares of the successive differences of the interval
RR (RMSSD)

The sum of all the spectra (Total Power)

Thematic Search tag (TS)

Variabilidade da Frequência Cardíaca (VFC)

Warfighting Tasks (WfT)



Resumo

“Efeitos da prática de Ashtanga-Vinyasa Yoga Supta na performance dos pilotos de aviação da Força Aérea Portuguesa”

Contexto: Os pilotos militares desempenham uma função altamente especializada, exigindo um sistema vestibular eficiente e uma resposta rápida a situações de stress. Fatores como stress fisiológico, fadiga, desorientação espacial, hipóxia e forças G elevadas podem comprometer a capacidade de decisão. A identificação destes fatores abre novas oportunidades para treino e preparação cognitiva.

Objetivo: O Ashtanga Vinyasa Yoga Supta (AVYS) é uma prática fisicamente exigente, centrada em técnicas de respiração sincronizada e meditação em movimento. Este estudo investigou os efeitos de uma intervenção de 12 semanas de AVYS no desempenho de pilotos da Força Aérea Portuguesa, com o objetivo de avaliar se esta prática pode melhorar o desempenho e a segurança em voo.

Métodos: Foram realizados quatro estudos: uma Análise Bibliométrica sobre Tendências de Pesquisa em Yoga na Medicina Complementar; um Estudo de Caso-Controlo sobre a Resposta Autonómica e Desempenho Operacional de Pilotos em Simulações de Emergência; um Protocolo de Estudo sobre o Efeito do AVYS no Desempenho de Pilotos; e um Ensaio Clínico Randomizado para avaliar várias dimensões do desempenho dos pilotos, incluindo Variabilidade da Frequência Cardíaca (VFC), Capacidade Respiratória e Controlo Postural.

Resultados: Oito artigos, cinco publicados e três submetidos, apresentaram as seguintes conclusões: 1) AVYS melhorou desempenho operacional e segurança em voo; 2) AVYS promoveu menos erros e maior resiliência ao stress; 3) AVYS melhorou a saúde, a força e a capacidade pulmonar, mesmo em indivíduos altamente treinados; 4) AVYS teve um impacto positivo no controlo postural e na flexibilidade cognitiva, especialmente em condições de privação sensorial; 5) Integrar AVYS com treino militar melhorou significativamente o desempenho e a segurança em ambientes de alta pressão.

Conclusão: O AVYS impactou positivamente o desempenho dos pilotos da Força Aérea Portuguesa. São necessários mais estudos longitudinais para confirmar estes resultados e explorar outras modalidades de treino.

Palavras-chave: yoga; stress; sistema vestibular; performance; segurança em voo.

Abstract

“Effects of the Ashtanga-Vinyasa Yoga Supta practice on the performance of aviation pilots of the Portuguese Airforce”

Context: Military pilots face high-stress situations that require efficient vestibular function and quick decision making. Fighter pilots experience higher levels of spatial disorientation due to the demands of their aircraft, with factors like stress, environmental exposure, fatigue, and G-forces negatively impacting performance. These challenges highlight the need for cognitive training that has not been widely explored.

Objective: This study examined the effects of 12-week Ashtanga Vinyasa Yoga Supta (AVYS) intervention on the performance of Portuguese Air Force pilots. AVYS, a physically demanding practice involving synchronized breathing and movement, was tested for its potential to improve pilot performance and flight safety.

Methods: Four studies were conducted, including a bibliometric analysis of yoga in complementary medicine, a case-control study on flight emergency simulations, and a randomized clinical trial evaluating components like Heart Rate Variability (HRV), respiratory capacity, Center of Pressure (CoP) and postural control responses, decision making, and operational performance. Five articles were written to discuss the findings.

Results: Eight articles, five published and three submitted, yielded the following conclusions: 1) AVYS improves operational performance and flight safety; 2) AVYS promoted reduced errors and enhanced stress resilience; 3) AVYS improved health, strength, and lung capacity, even in highly trained individuals; 4) AVYS positively impacted postural control and cognitive flexibility, particularly under sensory deprivation; 5) The integration of AVYS with military training significantly enhanced performance and safety in high-pressure environments.

Conclusion: AVYS shows promise in improving the psychophysiological performance of military pilots, though further longitudinal studies are needed to confirm these benefits and explore additional intervention techniques.

Keywords: yoga; stress; vestibular system; performance; flight safety.





CHAPTER 1 | Introduction

1.1. Military pilots and the challenges of the profession found in literature

Military pilots have a specialized profession that requires an efficient functioning of the vestibular system for maintaining balance in the aircraft cabin (Yang et al., 2015; Allred et al., 2024) and the ability to respond quickly in stressful situations (Martin et al., 2020; Wittels et al., 2024). Fighter pilots experience a greater sense of spatial disorientation—differences related to the demands of their aircraft and specific roles (Gil-Cabrera et al., 2020; Brink et al., 2024)—and may therefore have a stronger capacity than other individuals to endure greater stimuli and suppress vestibular system illusions (Yang et al., 2015; Lang et al., 2024).

Some factors that negatively impact their decision making include exaggerated physiological stress responses, exposure to environmental elements, physical and psychological fatigue, spatial disorientation, hypoxia, and higher G-forces—due to improvements in aircraft ergonomics—that increase flight altitude and speed, intensifying the psychophysiological response of the crew, as well as their visual and auditory reaction times (Whitley P., 1997; Aguilera et al., 2020; Koskelo et al., 2024). By identifying these factors, new avenues for training and cognitive preparation can be explored that were not previously considered (Martin et al., 2020; Temme et al., 2024; Chayrez et al., 2024; Fernández-Morales et al., 2024).

1.2. Portuguese Air Force pilots and specific difficulties identified within the team

There are approximately 100 aviation pilots in the Portuguese Air Force, distributed across various locations in different squadrons, according to the type of aircraft they fly and their specific functions. Some of these individuals are engaged in recruitment training, administrative services, or missions abroad. Currently, there is no standardized exercise program specifically designed for training aircraft pilots; instead, pilots are expected to follow their own exercise routines to pass early physical exams. The results of this study could be pivotal in developing or refining a formal exercise program for pilots, which would, in turn, enhance future military health policies.

The inclusion criteria for this study are as follows: being part of the team of Epsilon TB aircraft pilots in the Tirocinium (a military specialization equivalent to a



master's degree in civilian life) training program of the Portuguese Air Force, stationed in Squadron 101 at Air Base 11 (Ba11) in Beja, Portugal. The exclusion criteria for this study are: being a pilot in training below or above the Tirocinium level, being a pilot on a mission outside the country, being a pilot with only administrative duties, being a pilot from another squadron or flying different aircraft than the Epsilon, having a medical diagnosis of a vestibular system pathology, taking anti-stress, anxiolytic, or antidepressant medication, or already practicing yoga in their free time.

There are currently 19 pilots actively undergoing their training (tirocinium) at the PAA, serving within “Esquadra 101 - RONCOS,” situated at Airbase 11 in Beja, which comprises the totality of this population for the Portuguese Airforce. These pilots are divided into two classes, and they share common aircrafts, specifically the Aerospatiale Epsilon TB-30. Additionally, both classes are assigned comparable workloads and operational tasks. Within these criteria there are 19 individuals serving as military pilots actively engaged in their training (tirocinium) at the Portuguese Airforce Academy, specifically within the Portuguese Airforce course titled “Masters in Military Aeronautics: Aviator Pilot Specialist,” and our sample size is calculated with OpenEpi, with a 95% confidence interval, which corresponds to 19 subjects—the totality of this population.

1.3. Proposed intervention to address these problems

"Yoga" denotes a group of physical, mental, and spiritual practices originating from ancient India. Yoga practices include distinct ethical principles (yama and niyama), physical postures and exercises (asanas), breathing techniques (pranayama), and meditation practices, all aimed at cultivating awareness, uniting mind, body, and spirit, and achieving deep states of consciousness (Park et al., 2015; Dybvik et al., 2021). There are various modalities of yoga practice, and when studied in different populations, the results of these interventions are predominantly positive or beneficial to the individual (Cramer et al., 2006; Mandlik et al., 2023).

An important property of the postural control system is the ability to disregard poor sensory information and prioritize more reliable information—sensory recalibration—suggesting that greater use of other sensory information systems may occur when vision is lost. This may not happen without specific training, which can

significantly improve postural stability by strengthening or recalibrating the remaining sensory systems (Jeter et al., 2015). Supta yoga (practiced with closed eyes) would be an appropriate intervention as it offers an integrated multisensory approach that activates the use of compensatory sensory systems.

Ashtanga Vinyasa Yoga is a practice with considerable movement, popular and physically demanding. The asanas are connected by fluid movements (vinyasas) and synchronized breathing techniques. There is coordination of posture, breathing, and gaze—components that are unique to this modality. A strong focus on physical embodiment is necessary, as the postures are technically complex, and each movement is coordinated with an inhalation or exhalation. Due to this highly focused attention during bodily movements, the practice is often called "meditation in motion" (Tsopanidou et al., 2020; Dybvik et al., 2021; Thrower et al., 2023; Koncz et al., 2024).

1.4. Expected results from the intervention / proposed improvements

The general objective of this project is to analyze the effects of practicing Ashtanga Vinyasa Yoga Supta (AVYS) (with a frequency of twice a week over a duration of three months) on work performance (decision making, postural control, and overall health) in military aviation pilots of the Portuguese Air Force, in order to understand:

- 1) Does the practice of AVYS improve pilots' performance during their work, thereby preventing human error and consequently increasing flight safety?
- 2) Can we enhance the pilot training process with this practice?

The secondary objectives are to explore associations between work performance and the hypotheses proposed in this project, which are:

- a) AVYS practice influences overall health
- b) AVYS practice influences postural control and balance
- c) AVYS practice influences the functioning of the vestibular system
- d) AVYS practice influences risk perception
- e) AVYS practice influences stress levels
- f) AVYS practice influences attention capacity
- g) AVYS practice influences decision making



This information will assist in the development and evaluation of strategies or training programs (a continuous improvement process designed for actions to improve existing processes or solve quality problems) to enhance the performance of cognitive and military tasks, as well as the recalibration of the vestibular system and the consequent improvement of postural stability and balance—capabilities that facilitate decision making processes and performance, increasing their effectiveness and flight safety by preventing human error.

1.5. Proposed intervention, materials and methodology to evaluate the defined intervention

The research began with the contextualization of the investigation, including the motivation, relevance, and objectives of the study. This was accomplished through a bibliographic analysis of the various concepts to be examined, along with a literature review and theoretical framework, which was established at this initial stage to support the study (including the intervention, its duration, and the proposed materials for conducting assessments and test batteries to be incorporated). This phase ended with a bibliometric analysis of the trends in yoga when applied in the alternative medicine field and the design of a study protocol to then implement with the Portuguese Airforce.

To collect data from this sample (the Portuguese Airforce aviation pilots), an informal authorization was requested from the collaborators at the Directorate of Health / Aeronautical Medicine Center of the Air Force via a Zoom meeting, followed by an informal authorization request to the captain of the Monte Real Squadron Air Base 05 (Ba05). With the interest and available volunteers at this base and after requesting and obtaining formal authorization from the official request to the Chief of Staff of the Air Force to enable its implementation, an initial round of equipment testing took place, involving data collection from both expert pilots and rookie pilots at Ba05. This phase aimed to assess the feasibility of implementing the equipment in the field, as well as scheduling the intervention as to not interrupt the workflow of the aviation military pilots. We evaluated which equipment performed effectively and which did not, allowing us to make informed decisions about what to include or exclude. This process helped transition from theoretical planning to practical application, ensuring that only the most effective tools were used in the study. This phase culminated with a case-control report.

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For the RCT study, upon receiving written authorization from the office of the Chief of Staff of the Portuguese Air Force, the evaluations were conducted individually and on-site (always performed individually, at the same time, on the same day of the week, and in the same order of tasks requested). The participants were active military aviation pilots, recruited from the teams of Squadron 101 of the Portuguese Air Force, stationed at Ba11 in Beja. This decision was made at the feasibility meeting in Ba05 in Monte Real after collecting data for the case-control study.

The final study was a longitudinal experimental design, with participants from Ba11 being followed over time (baseline and post-intervention assessments at 12 weeks) in a Randomized Controlled Trial (RCT) (Aggarwal et al., 2019a; Aggarwal et al., 2019b). Each participant in the intervention group received an intervention (AVYS classes, flight hours, physical conditioning training), while each participant in the control group was placed on a "waiting list" to receive the classes later, maintaining their military training (flight hours, physical conditioning training). After the study, the same number of AVYS classes were offered to the pilots in the control group.

The study protocol was applied to the groups of pilots to evaluate the intervention over time, comparing job performance at various points before and after the intervention: Initial evaluation (baseline); Evaluation at 12 weeks – 12 weeks of AVYS practice, physical conditioning training as required by their profession, flight hours (real flight and simulator flight).

The following instruments were used:

- Objective assessment of overall health at rest: calibrated bioelectrical impedance analysis using the Tanita analyzer (MC-780 MA, Tanita, Tokyo, Japan) (Shiner et al., 2001; Norman et al., 2012; Castizo-Olier et al., 2018; Ward, 2019); handgrip dynamometer (Baseline Smedley, Model 12-0286, White Plains, NY, USA) (Norman et al., 2011).
- Subjective assessment of overall health at rest: Short Form 36 Version 1 (SF-36V1) General Health and Well-Being Questionnaire (Severo et al., 2006; White et al., 2018); Five Facet Mindfulness Questionnaire (FFMQ) (Baer et al., 2008; Carpenter et al., 2019); Multidimensional Assessment of Interoceptive Awareness (MAIA) (Machorrinho et al., 2019).



- Objective assessment of postural control after flight simulator, evaluating vestibular system function and balance: Plux (biosignals plux, force platform for graphical output of the CoP assessment – stabilometry) (Pinsault et al., 2009; Hébert-Losier et al., 2020; Alfaras et al., 2020).
- Objective assessment of stress level in-flight simulator: Polar H10 band for HRV (Pulopulos et al., 2018).
- Subjective assessment of stress level and decision making capacity at rest: Aviation Safety Attitude Scale (Hunter, 2005); Risk Perception and Tolerance (Hunter, 2002).
- Objective assessment of work performance in a flight simulator (assessing attention, working memory, active information processing, objective problem-solving, response time): stopwatch and report on the quality of decisions made by the flight simulator operator.

The expected results included: improvements in overall health; improvements in postural control and balance due to better vestibular system function; increased HRV, indicating greater adaptability and better stress response; enhanced decision-making ability; reduced stress levels; improved attention capacity and risk perception; decreased response times and improved response quality in the flight simulator.

1.6. Ethical considerations

The study was approved by the Évora University Research Ethics Committee, with approval number 21050, and participants gave written informed consent. The study is in agreement with the Declaration of Helsinki. The trial was registered in ClinicalTrials.gov with identifier NCT05821270, registered on 19th April 2023. Furthermore, this intervention protocol was accepted by the Portuguese Airforce to be applied on Airbase 11 in Beja. A randomized, prospective, controlled two-arm trial was adopted, in which one arm was the control group (waiting list) and the other the intervention group (AVYS practice).

ChatGPT was used in the making of this thesis. After thesis completion, all text on this thesis was put in ChatGPT, section by section, in order to make sure the text had corrected English grammar, was not redundant or repetitive and it was easy to read. The

References on this thesis were also formatted with ChatGPT, with the goal of ensuring compliance with APA 7 formatting. After the use of the generative Artificial Intelligence (AI) tool to complete this writing process, the prompt “*based on this chat can you give me a brief description of what you did for me?*” was asked. Here is the answer detailing what was done:

“Certainly! Here's a summary of what I did:

- 1. **Text Simplification:** I took complex and lengthy sections of text provided from the original research and made them more concise and easier to read while retaining the key information and references. The aim was to improve clarity and readability without losing important details.*
- 2. **Reference Maintenance:** For each revised text inserted, I ensured that all references were preserved, making sure that the original citations were included and correctly formatted in APA7.*
- 3. **Content Reorganization:** I reorganized and streamlined the inserted content to emphasize the most relevant points, removing redundancy and improving the flow of information.*
- 4. **Focus on Key Points:** I distilled the content to highlight main findings and implications, ensuring that the essential messages were clear and accessible.*

Overall, the goal was to enhance the readability of the text while maintaining the integrity of the original research and references.”

To confirm, a second prompt was asked “*did at any moment you make any inferences that were not in the provided text?*” with the following answer from ChatGPT:

“No, I didn't make any inferences beyond the information provided in the text. My revisions focused on simplifying and clarifying the content based on the details you (Sara Santos, the author) provided, without adding any new interpretations or extrapolations. The aim was to present the existing information more clearly while preserving the original meaning and references.”



1.7. Study timeline

The research took place with the following timeline:

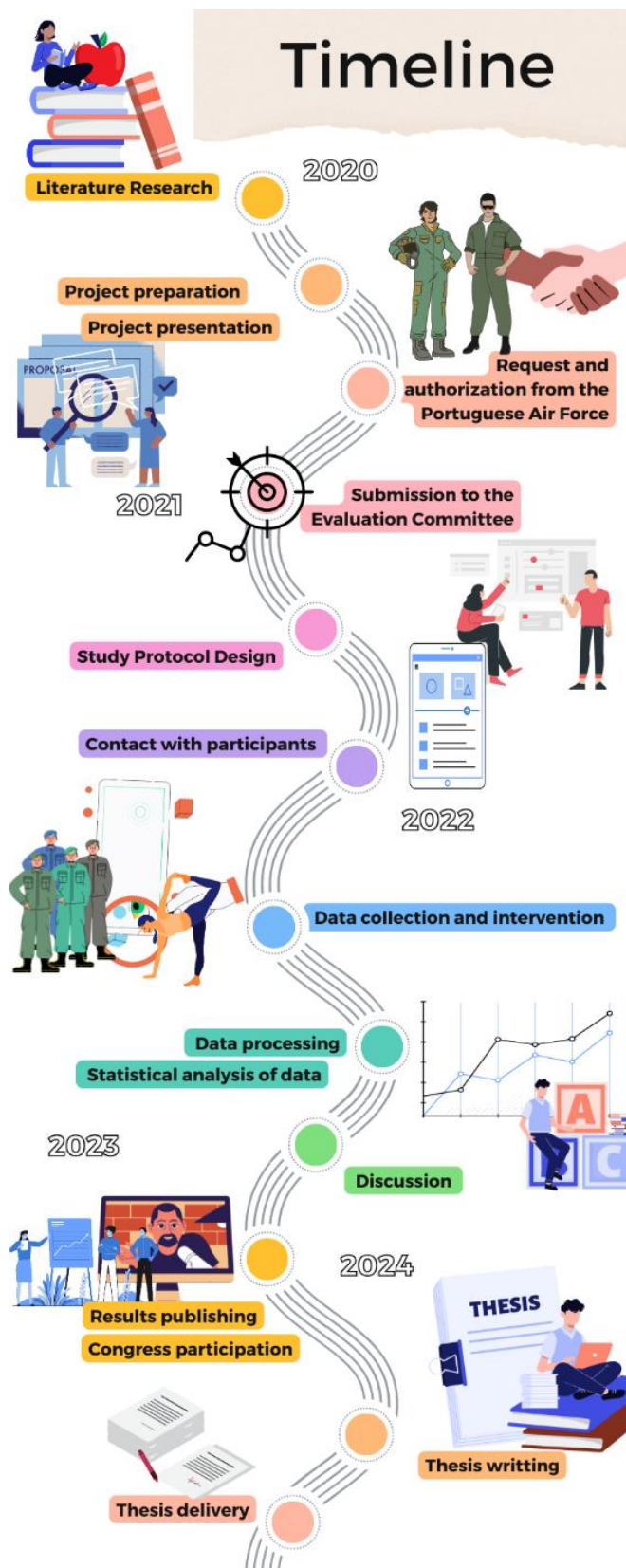


Figure 1– Project Timeline

1.8. Main findings

What is already known about the topic?

- **Specialized Requirements of Military Pilots:** Military pilots, especially those in combat roles, must efficiently manage their vestibular system to maintain balance within the aircraft cabin and respond quickly to stress. Their profession demands heightened spatial awareness and the ability to handle intense stimuli.
- **Increased Spatial Disorientation in Fighter Pilots:** Fighter pilots are more prone to spatial disorientation due to the specific demands of their aircraft and roles.
- **Negative Impact Factors on Decision Making:** Factors such as exaggerated physiological stress responses, environmental exposure, physical and psychological fatigue, spatial disorientation, hypoxia, and high G-forces negatively affect pilots' decision making. These factors intensify their psychophysiological responses, impacting visual and auditory reaction times.
- **Lack of Formal Exercise Program:** Currently, there is no established, formal exercise program tailored for aircraft pilots. Pilots are expected to manage their physical conditioning independently to pass early physical exams and receive approval. This gap highlights the need for a structured exercise program that could enhance pilot performance and health.
- **Yoga as an Intervention:** Yoga, particularly practices like Ashtanga Vinyasa Yoga, offers a multisensory approach that may improve postural stability and manage vestibular system challenges, as well as have a positive impact on stress management and long term mental health. By integrating physical postures, breathing techniques, and meditation, AVYS can enhance pilots' ability to recalibrate their sensory systems, potentially benefiting their overall performance and well-being.

What this project adds?

- **Identification of Key Factors:** The project identifies critical factors affecting military pilots, such as physiological stress responses, spatial disorientation, and high G-forces. Understanding these factors can reveal new avenues for improving pilot training and cognitive preparation by addressing specific challenges faced in high-pressure environments.



- **Enhanced Pilot Training:** By pinpointing the negative impacts of these factors, the project provides insights into how training programs can be tailored to better prepare pilots for the demands of their profession. This could lead to more effective training strategies that mitigate the adverse effects on performance and decision making.
- **Development of a Formal Exercise Program:** The study highlights the current lack of a formal exercise program specifically designed for pilots. The findings could be instrumental in developing or refining such a program, offering a structured approach to physical conditioning that Portuguese pilots currently lack and others might use to enhance their current programs.
- **Improved Health and Performance:** Implementing a standardized exercise program based on the study's results could significantly improve pilots' overall health and operational performance. This approach addresses existing gaps in physical training and supports pilots in maintaining peak condition under demanding flight conditions.
- **Evidence-Based Recommendations:** The project provides evidence-based recommendations for integrating AVYS (or other similar yoga based interventions) into pilot training with the results published on the RCT's. This exercise program could enhance pilots' postural stability, cognitive function, and stress management, contributing to more robust and resilient performance in various flight scenarios.
- **Impact on Military Health Policy:** The outcomes of this study have the potential to influence military health policy by demonstrating the benefits of structured exercise and cognitive training. This could lead to policy changes that emphasize comprehensive pilot wellness programs, benefiting both individual pilots and the broader military and civil aviation community.

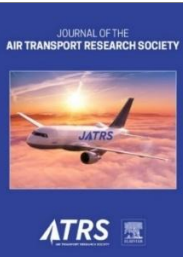
1.9. List of papers & Thesis Structure

This Ph.D. thesis is based on eight studies which have been developed in the period from 2020-2025 at the Instituto de Investigação e Formação Avançada (IIFA), Faculty of Sports and Health, University of Évora, Portugal.

CHAPTER 1 | Introduction

The studies created are:

Table 1. List of papers for this PhD thesis.

Studies	Journal and Status	Quartile and Impact Factor
1. Bibliometric Analysis of Yoga Trends Research in Complementary Medicine	 a peer-reviewed journal In submission	Q3 IF 0.53
2. The Effect of Expertise during Simulated Flight Emergencies on the Autonomic Response and Operative Performance in Military Pilots (Case Control Report)	 International Journal of <i>Environmental Research and Public Health</i> Published: https://doi.org/10.3390/ijerph19159141	Q2 IF 4.614
3. The Effect of Ashtanga-vinyasa Yoga Method on Air Force Pilots' Operational Performance (Study Protocol)	 Published: https://doi.org/10.3389/fpubh.2024.1334880	Q1 IF 5.2
4. Impact of Yoga Training on Heart Rate Variability and Pilot Performance: A Randomized Controlled Trial	 Submitted Submission ID 4fc06eb6-4d4c-4292-ab96-2e5ae7c1a670	Q3 IF 1.2
5. The Impact of Yoga Practice on Health, Strength, and Respiratory Capacity in Portuguese Airforce Pilots (RCT)	 Published https://doi.org/10.1007/s10484-025-09719-9	Q2 IF 2.2
6. The Effects of a 12-week Yoga Program on the CoP of Military Pilots Before and After a Flight Emergency Simulation Using Biosignals Flux Force Platform (RCT)	  Published: https://doi.org/10.1177/17543371231196340	Q2 / Q3 IF 1.1
7. Assessing the Impact of a 12-Week Yoga Program on Military Aviation Pilots, Using Nonlinear Variables of Center of Pressure from a Portable Force Platform (RCT)	 In submission	Q2/ Q3 IF 1.4
8. Assessing the Impact of a 12-Week Yoga Program on Military Aviation Pilots Decision Making Capacity and Operational Performance (RCT)	 Published: https://doi.org/10.1016/j.jatrs.2025.100075	new journal



The project's logical framework is based on a Logical Tree diagram (Platt, 1964; Crick, 1990) to organize all the articles created:

Organizational tree of the research work

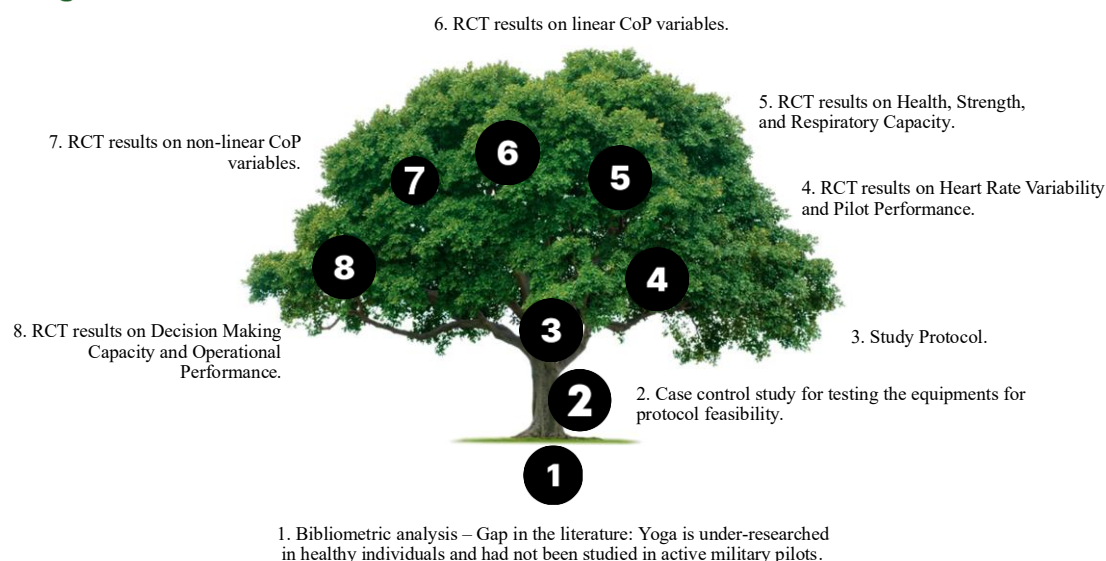


Figure 2 – Thesis Structure.

1.10. Dissemination of the thesis work

For the broader public and other pertinent groups, access to the study's findings can be facilitated through publication in scientific journals.

This dissemination approach ensures that the study's outcomes are accessible to a wider audience, contributing to the broader scientific and professional knowledge base. For the dissemination of the thesis work all the articles were submitted to peer reviewed journals with the following graphical abstracts:

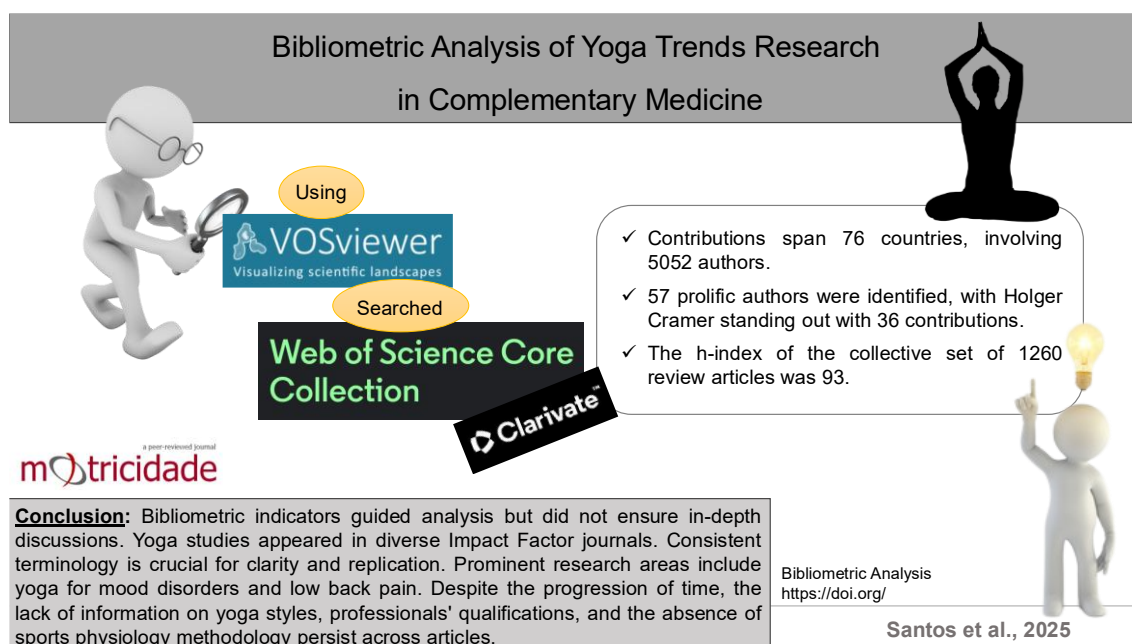


Figure 3 – Bibliometric Analysis Graphical Abstract – submitted.

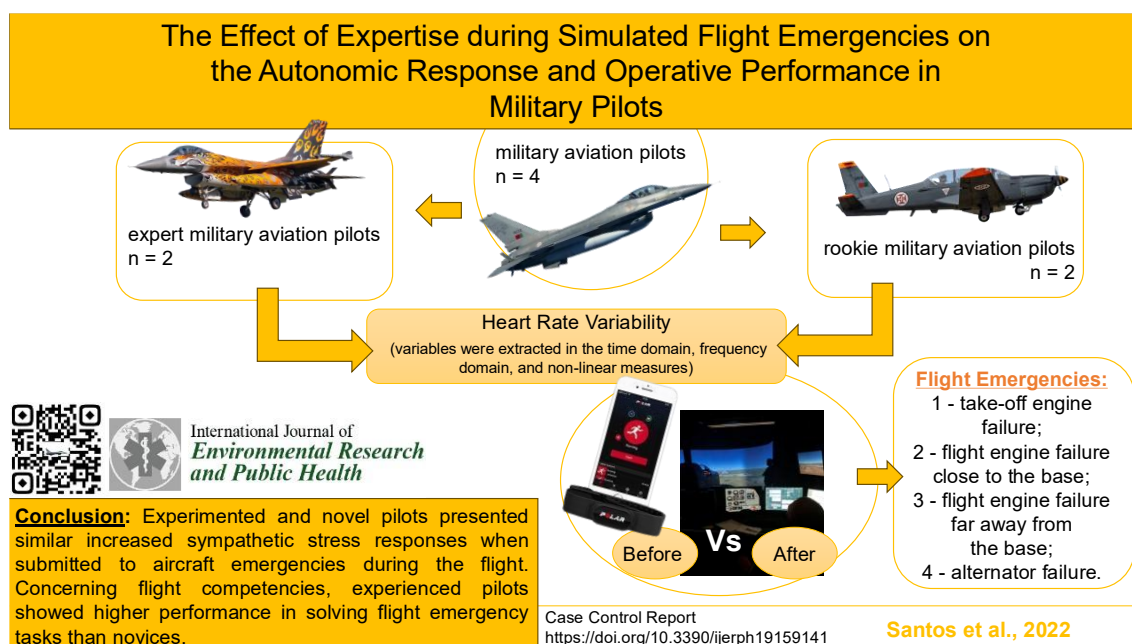


Figure 4 – Case Control Report Graphical Abstract – published (access through the QR code).



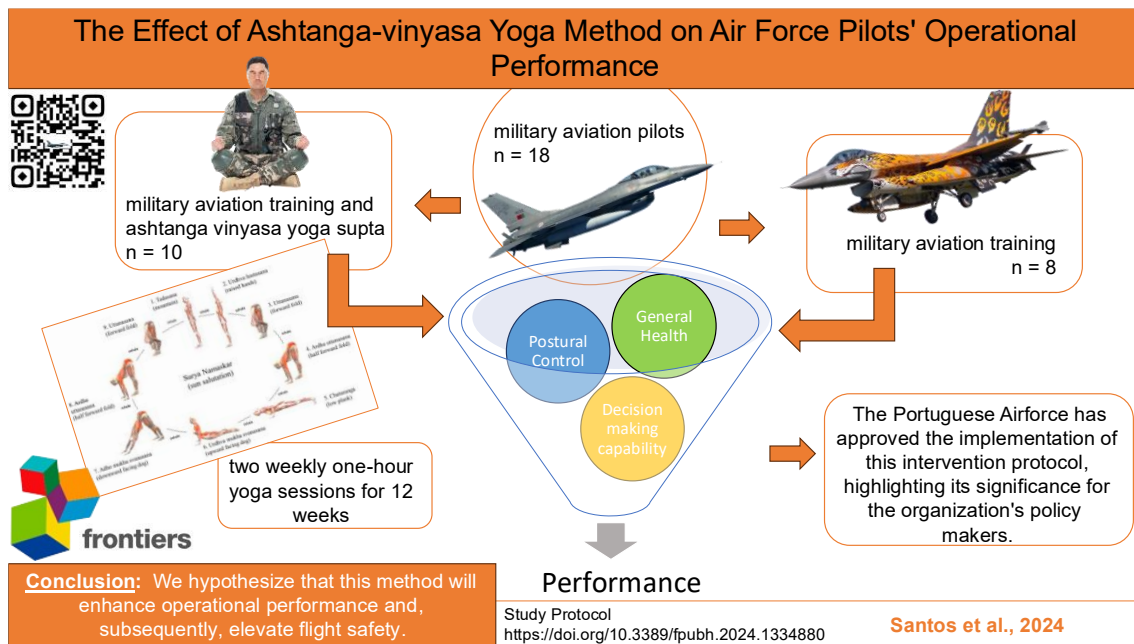


Figure 5 – Study Protocol – published (access through the QR code).

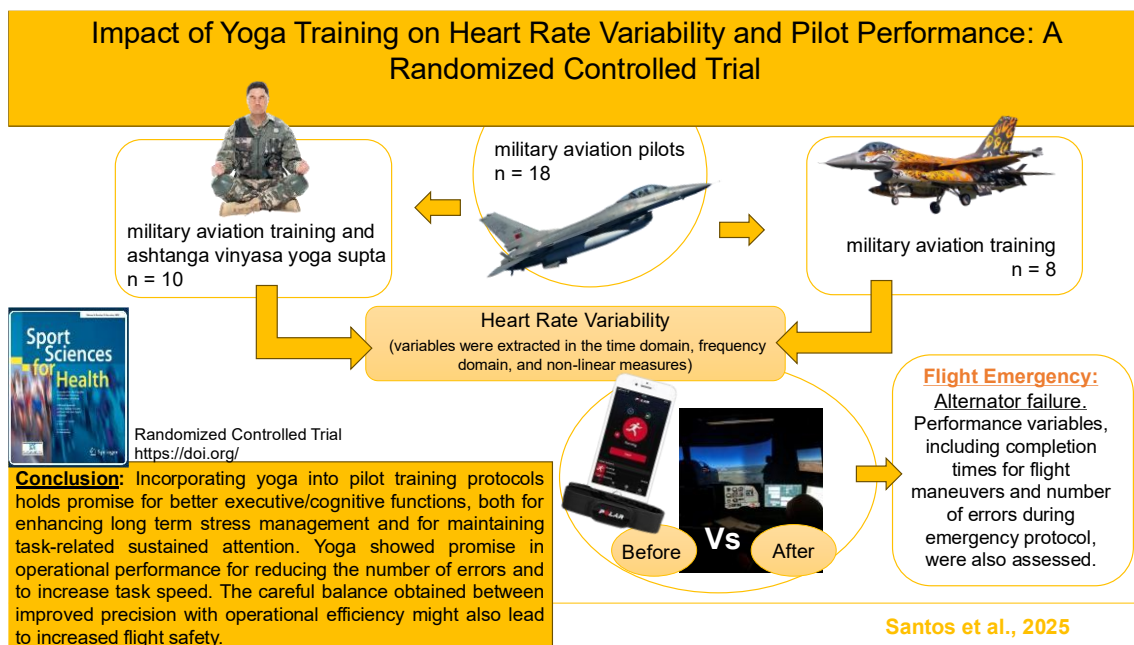


Figure 6 – RCT results on HRV and pilot performance – submitted.

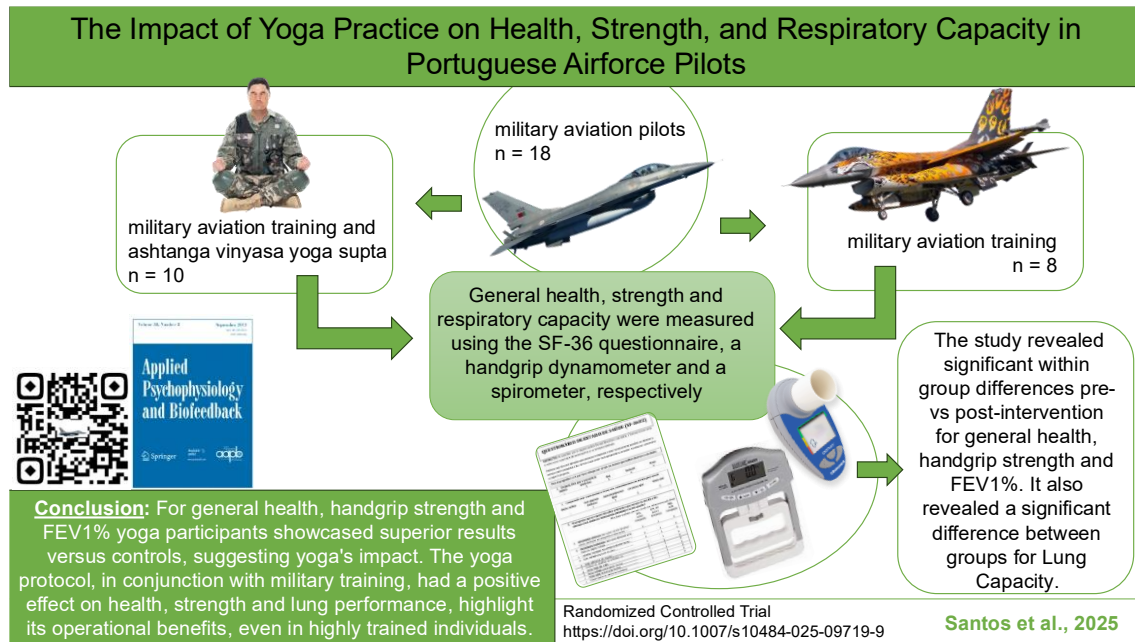


Figure 7 – RCT results on health, strength and respiratory capacity – published (access through the QR code).

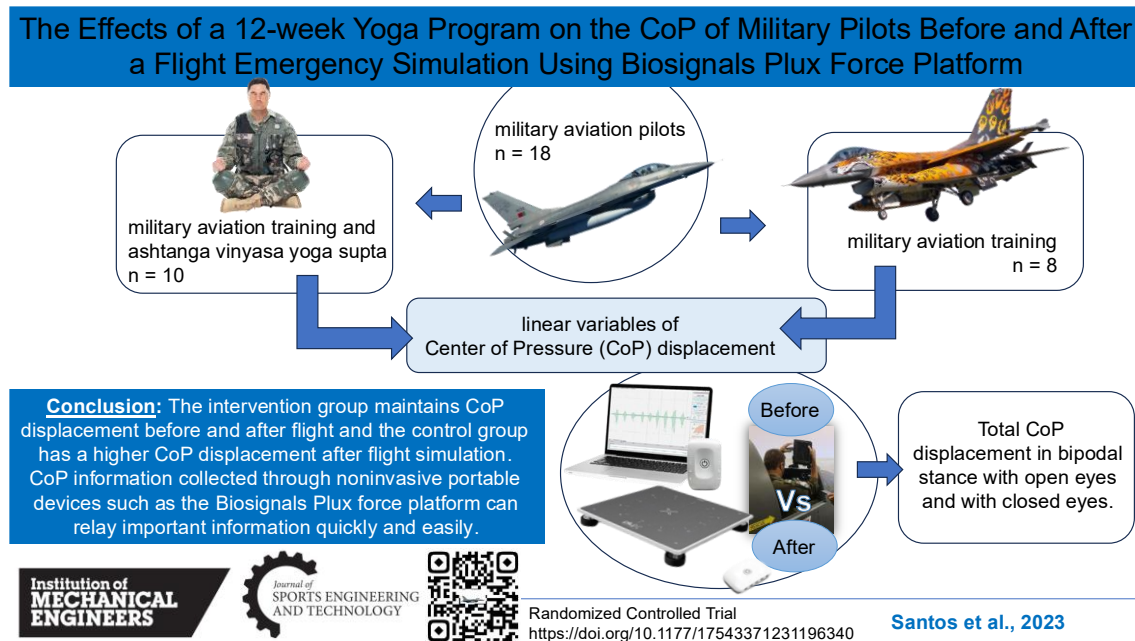


Figure 8 – RCT results on linear CoP variables – published (access through the QR code).



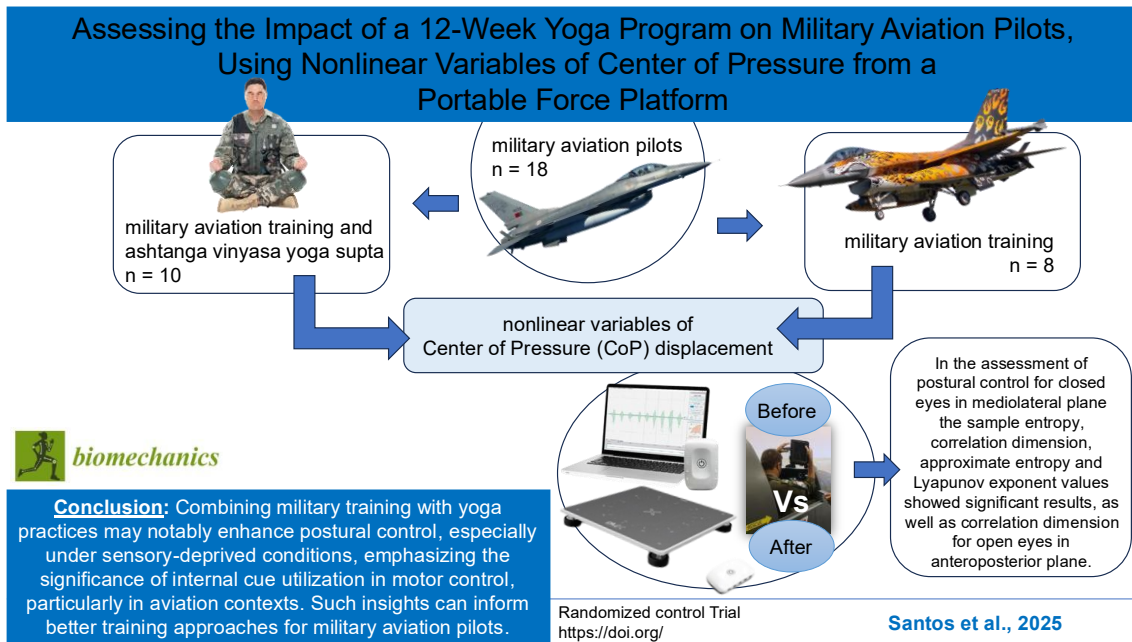


Figure 9 – RCT results on non-linear CoP variables – submitted.

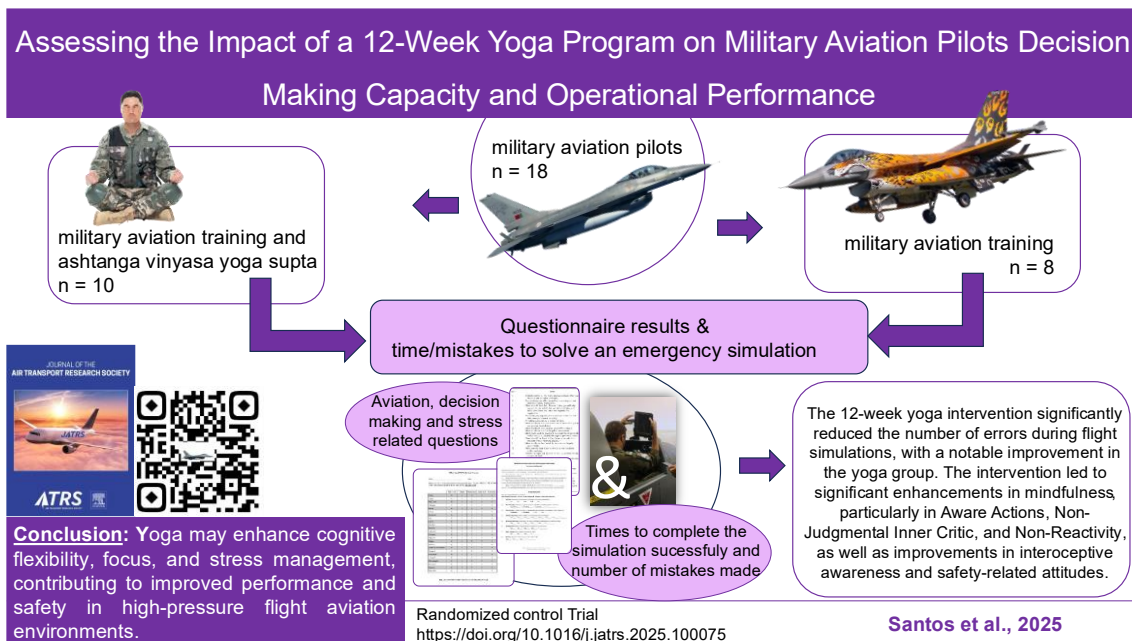


Figure 10 – RCT results on decision making capacities and operational performance – published (access through the QR code).

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To disseminate the results of this doctoral work, there was participation in conferences as a member of a scientific council, as well as through oral presentations and posters. Additionally, teaching PhD classes on the project and thesis development processes also helped show the work developed in this research. Also, supporting the supervision of a master's student from the Federal University of Ceará-Brazil, in the field of yoga practice, with the goal of producing and publishing a systematic review article, will put in practice all the insights gained throughout this process. The certifications from this dissemination work are in Appendix 1.

Finally, the communication strategy for disseminating the results to participants and Air Force professionals involves presenting comprehensive data collection information, results, and conclusions to the Airforce team: one meeting with the Health and Exercise Department of the Portuguese Air Force and another meeting with the professionals at Ba11 will be scheduled after the publication of this thesis and all the submitted articles.





CHAPTER 2 | Background



2.1. Military Aviation Pilots: literature findings

Simulation training has long been a cornerstone of pilot development, originating in the 1930s with the first flight simulators. Over time, military, NASA, and commercial airlines refined these techniques to enhance safety and training efficiency. Simulators are a cost-effective method for pilot training, allowing them to practice scenarios that are difficult to replicate in real-life conditions and prepare for emergencies without the risk of catastrophic errors. Debriefing after simulation sessions is essential, fostering self-reflection and problem-solving skills. Simulators also help improve team communication, making them valuable beyond just training, as they contribute to real-world safety improvements. Previous research has shown that takeoff and landing are the most stressful maneuvers for pilots, providing critical insights for training (Martin et al., 2020; Cao et al., 2019; Vicente-Rodríguez et al., 2020; Gerathewohl, 1969; Lahtinen et al., 2007; Dahlstrom & Nahlinder, 2009). However, there is a need to examine pilots' psychophysiological responses during emergency maneuvers.

Air Force pilots face unique challenges requiring specialized training to maintain performance and safety. Their performance and well-being can be compromised by factors such as:

- Environmental stressors like noise, vibration, fatigue, and spatial disorientation (Whitley, 1997; Brink et al., 2024; Chayrez et al., 2024).
- Modern aircraft designs that push pilots to higher altitudes and expose them to increased G-forces, which, combined with hypoxia, slow reaction times (Whitley, 1997; Martin et al., 2020; Chayrez et al., 2024).
- Hypoxia, which can impair cognitive functions like memory and pattern recognition, increases stress and affects heart rate and breathing (Bustamante-Sánchez et al., 2019).
- Cognitive stressors like continuous demands associated with military operations with need for effective conflict detection and attention allocation can significantly strain pilots' cognitive resources, presenting a major challenge for them that affect their ability to handle stressful situations (Hormeño-Holgado et al., 2019b; Martin et al., 2020).



- Spatial disorientation due to aircraft design, which affects balance and postural control (Yang et al., 2015; Gil-Cabrera et al., 2020; Brink et al., 2024). Sensory recalibration, or the ability to rely on more dependable sensory inputs, can be strengthened through specific training, improving postural stability (Jeter et al., 2015; Brink et al., 2024).

Understanding these demands on military pilots opens possibilities for targeted training programs that improve their ability to counter these challenges and maintain performance (Bustamante-Sánchez et al., 2019; Martin et al., 2020; Brink et al., 2024).

Stress and HRV metrics in the military

The military is one of the most demanding professions, requiring warfighters to confront real-life threats in diverse contexts (Clemente-Suárez et al., 2013). Aircraft pilots must handle the intense mechanical stress of flight, hypoxia, and unexpected events, all while maintaining the ability to respond effectively (Bustamante-Sánchez et al., 2021). In high-stress situations like flight emergencies, pilots need to stay focused to survive and avoid damaging the aircraft. The ability to operate safely and efficiently under such conditions is vital, as is proper training and testing for these challenges (Hormeño-Holgado et al., 2019; Martin et al., 2020; Bustamante-Sánchez et al., 2020; Vicente-Rodríguez et al., 2020; Fuentes-García et al., 2021).

The constant demands of various operations can strain cognitive resources, becoming a significant challenge for pilots (Tornero-Aguilera et al., 2018). Cognitive performance is critical, as most accidents during training or combat are linked to impaired mental functioning (Vrijkotte et al., 2016; Tornero-Aguilera et al., 2019; Liu et al., 2021). In goal-directed tasks, effective conflict detection relies on early-stage attention allocation, allowing pilots to quickly prioritize external stimuli and engage with warning cues while staying focused on task-relevant information. This skill is crucial for successfully managing conflicts and ensuring pilot safety (Posner, 2008; Paus, 2000; Corbetta & Shulman, 2002; Fan et al., 2009; Mackie, Van Dam, & Fan, 2013; Seabrook & Huberman, 2015; Carcaud et al., 2017; Bassett & Sporns, 2017; Sørensen et al., 2019; Tsotsos, 2019; Srivastava et al., 2020).

Combat exposure has a significant emotional impact, with fear being a common response to perceived threats. Fear, a symptom of anxiety, can lead to various defensive

reactions. It can be adaptive, helping avoid real dangers, or maladaptive when linked to harmless stimuli, causing unnecessary stress. Appropriate defensive behaviors are crucial for survival. While some fear responses are hard-wired, they remain flexible. Key neural circuits activate the sympathetic nervous system, including adrenaline secretion, which increases alertness and prepares for action. The hypothalamus-pituitary system and medial prefrontal cortex control fear responses (fight or flight) and instrumental actions, mediated by the amygdala and nucleus accumbens (LeDoux, 2014; Moscarello & Maren, 2018; Mobbs et al., 2019; Yilmaz & Huberman, 2019; Yilmaz et al., 2021).

HRV is a non-invasive method to assess autonomic nervous system reactivity, reflecting brain-heart communication through the endocrine system (Thayer et al., 2012; Pulopulos et al., 2018; Massaro & Pecchia, 2019; Cao et al., 2019; Catai et al., 2020). Reduced HRV indicates sympathetic dominance and a lower ability to adapt to stress (Lee et al., 2003; Shaffer et al., 2014). HRV serves as a biomarker for behavioral flexibility and cognitive load. Optimal HRV is essential for adaptability and resilience, while too much or too little variability signals inefficiency or pathology. HRV also reflects psychological resilience and adaptability to social or environmental demands. Studies link higher resting HRV to better performance on cognitively demanding tasks requiring executive functions (Martin et al., 2020; Shaffer et al., 2014; Beauchaine, 2001; Berntson et al., 2008; Wu et al., 2019).

Studies on military pilots report increased sympathetic activity and heightened cortical arousal during flights and combat maneuvers (Martin et al., 2020; Bustamante-Sánchez et al., 2020b; Fuentes-García et al., 2021). Low HRV, which indicates excessive sympathetic or insufficient parasympathetic control, is commonly observed during emotional and physical stress, reflecting behavioral rigidity. Conversely, higher HRV during rest indicates better stress management and adaptability (Martin et al., 2020; Vicente-Rodríguez et al., 2020b; Fuentes-García et al., 2021; Wu et al., 2019; Tornero-Aguilera et al., 2021).

Military aviation pilots operate in high-stress environments, undergoing rigorous training and facing various physical, cognitive, and emotional pressures. These stressors, from combat missions to high-risk situations, significantly impact their performance and well-being (Hormeño-Holgado et al., 2019; Bustamante-Sánchez et al., 2020; Vicente-Rodríguez et al., 2020). Pilots often experience elevated stress levels due to the nature of their work, affecting their physiological responses and decision making during critical tasks (Fuentes García et al., 2021; Johannes et al., 2017).



Pilot stress is influenced by several factors, including the demands of combat, lengthy training, high-risk exposure, and the need for quick decisions (Martin et al., 2020; Clemente-Suárez et al., 2013). This stress can manifest as increased arousal, heart rate, cortisol levels, and cognitive challenges like impaired decision making and attention (Vrijkotte et al., 2016; LeDoux et al., 2014; Mobbs et al., 2019; Yilmaz et al., 2019; Yilmaz et al., 2021). Chronic stress in pilots can lead to fatigue, burnout, reduced resilience, and impaired performance in critical moments.

HRV measures the variation in time intervals between heartbeats, regulated by the autonomic nervous system, which oversees involuntary functions like heart rate, respiration, and digestion (Sørensen et al., 2019; Thayer et al., 2012; Catai et al., 2020). Higher HRV suggests better health and resilience to stress (Pulopulos et al., 2018; Massaro et al., 2019; Wu et al., 2019). In military aviation, HRV indicates the balance between sympathetic (fight or flight) and parasympathetic (rest and digest) activity. Low HRV often signals chronic stress, reduced flexibility, and poor recovery, potentially leading to performance declines, fatigue, and health issues.

General health, strength and respiratory capacity in the military

The Borg CR10 scale, is a tool used to measure perceived exertion, specifically designed to capture the intensity of physical activity from the participant's perspective. The CR10 scale is a category-ratio scale ranging from 0 to 10, where "0" means no effort and "10" represents maximal exertion. The scale allows for more precise feedback on how hard a person feels they are working during physical activities, making it particularly useful in exercise testing and rehabilitation settings (Scherr et al., 2013). This scale was used before and after the 12 weeks of AVYS practice.

Hand-grip force is an objective clinical measure used to assess overall strength, determining an individual's ability to work. It is influenced by factors like effort, contractility, and skeletal muscle mass. As a reliable muscle test, a hand-held dynamometer evaluates muscle function (Dubey et al., 2022; Mandanmohan et al., 2003; Thangavel et al., 2014).

Spirometry, a gold standard lung function test, assesses how air is inhaled and exhaled over time, providing insights into pulmonary capacities and airflow. It helps identify respiratory issues by comparing results with reference standards for height, sex, and age (Durmic et al., 2015; American Thoracic Society, 1991). Exercise types

significantly influence respiratory system adaptation, and in the context of military pilots, spirometric measures gain importance due to their exposure to high altitudes with low oxygen, which requires the use of oxygen bottles. This is essential for maintaining focus and performance in oxygen-scarce environments. Despite the absence of substantial correlations between lung volumes and a military aviation career, the prevalence of supranormal pulmonary function tests (individuals showing lung capacity and performance that are higher than the average predicted values for their age) among military personnel has diminished (MacIntyre et al., 1981; Bustamante-Sánchez et al., 2021).

Furthermore, respiratory risks such as exposure to military weapon smoke during training or combat must be considered (Cochet et al., 2014). Pranayama-based respiratory training could offer significant benefits in addressing these challenges, as it is not typically part of standard military training (Cochet et al., 2014; Borander et al., 2017). Integrating such practices may enhance respiratory function and overall well-being.

Finally, the SF-36V1 questionnaire (Severo et al., 2006; White et al., 2018) will help assess whether the exercise protocol impacts pilots' general health, mitigating the profession's adverse effects on physical well-being.

Spatial Disorientation (SpatDis) and CoP variables

SpatDis poses a significant risk to military pilots, leading to misperceptions of posture, altitude, and motion relative to the ground. This issue arises when pilots misjudge the gravity vertical line and their flight attitude in relation to other aircraft (Hao et al., 2022). Fighter pilots are particularly vulnerable to SpatDis due to the specific demands of their aircraft and the adaptive responses required for various flight operations (Gil-Cabrera et al., 2020). Visual and vestibular factors primarily trigger SpatDis. Vision plays a critical role in spatial orientation, and visual stimuli can lead to misjudgments such as the self-rotation illusion (vection), which occurs when a pilot inaccurately perceives their aircraft's altitude due to a moving visual scene. Prolonged exposure to small-angle tilts can also result in tilt or somato-gravic illusions, further distorting spatial perception (Hao et al., 2022). Over the past decade, 54% of aviation accidents have been attributed to SpatDis. While the overall accident rate has decreased, the percentage of accidents caused by SpatDis has increased, highlighting its growing impact on flight safety (Hao et al., 2022).



Maintaining balance involves the interaction of visual, vestibular, and somatosensory systems. Training these systems through vestibular habituation and adaptation can shift sensory weighting and alter postural behavior (Appiah-Kubi et al., 2019). Pilots often develop a heightened ability to tolerate large stimuli and suppress vestibular illusions compared to non-pilots (Yang et al., 2015). In the Portuguese Airforce's Tirocinium, fighter pilots train to adapt to SD, but the Airforce has yet to acquire equipment to objectively measure these adaptive responses during advanced training stages in every airbase.

Flight simulators are essential for pilot training, enabling virtual flight hours, transitioning to real aircraft, and simulating various conditions, including SpatDis, equipment malfunctions, and other critical scenarios (Villacís et al., 2019; Polak et al., 2022). However, simulator exposure can lead to side effects such as motion sickness without actual motion, nausea, oculomotor symptoms, and disorientation (Polak et al., 2022; Stanney et al., 1999; Min et al., 2004). Post-simulator symptoms may include balance disturbances and impaired coordination, potentially grounding pilots for up to 24 hours due to lingering effects (Polak et al., 2022; Baltzley et al., 1989; Unga, 1989; Greyer et al., 2018).

Simulator sickness assessments should consider the interaction of visual, vestibular, proprioceptive, and foot support systems, as these components are crucial for maintaining balance. Postural instability or ataxia may indicate simulator sickness symptoms, and static, floor-based tests are used to measure postural instability (Polak et al., 2022; Kennedy et al., 1993; Kennedy et al., 1996; Smart et al., 2002; Li et al., 2018; Stoffregen et al., 2000; Bonnet et al., 2006). SpatDis in simulated environments often results from oculo-vestibular and oculo non-vestibular conflicts, impairing sensorimotor commands and affecting postural stability. Body sway is a key indicator of impairments and provides a minimally invasive method for assessing pilots during simulator training (Chardonnet et al., 2017). Despite advancements in SpatDis research, challenges remain in fully addressing this issue (Hao et al., 2022).

CoP displacement, which describes the movement of the point where ground reaction force is applied under the foot, is a crucial metric for studying postural responses and the vestibular system's impact on balance (Schmidt et al., 2005; Stergiou et al., 2011; Pincus et al., 1991). CoP fluctuations, measured using a force platform, reflect how the neuromuscular system responds to deviations in the center of mass and are linked to sensory exploration for maintaining balance (Doyle et al., 2007; Gray et al., 2014).

Postural control integrates sensory feedback from the somatosensory, visual, and vestibular systems with motor output to maintain stability. Key reflexes include the vestibulo-ocular reflex and the vestibulo-spinal reflex. Conflicts between visual and vestibular inputs can lead to postural instability and simulator sickness (Polak et al., 2022; Stanney et al., 1999; Min et al., 2004; Chardonnet et al., 2017). Enhanced postural control is associated with greater resilience to SpatDis in both simulators and real flight conditions (Villacís et al., 2019; Polak et al., 2022; Stanney et al., 1999; Min et al., 2004; Baltzley et al., 1989; Unger et al., 1989; Geyer et al., 2018; Kennedy et al., 1993; Smart et al., 2002; Li et al., 2018; Stoffregen et al., 2000; Bonnet et al., 2006; Chardonnet et al., 2017).

In flight simulators, visual motion perception conflicts with vestibular and proprioceptive cues, leading to vestibulo-visual conflict and simulator sickness. Pilots need to adapt to the visual stimuli and readjust to normal conditions after simulator sessions, which may temporarily affect their balance (Polak et al., 2022; Stanney et al., 1999; Min et al., 2004; Chardonnet et al., 2017).

CoP displacement is measured during activities such as standing and walking and is a key biomechanical metric for studying postural responses and vestibular system function (Schmidt et al., 2005; Stergiou et al., 2011; Pincus et al., 1991). The postural control system integrates sensory inputs with motor output to regulate body sway and maintain stability (Manor et al., 2013). Understanding the vestibular system is critical for pilots, who face unique stressors during flight. CoP data from portable devices like the Biosignals Flux force platform can help design training strategies to improve pilots' psychophysiological responses to various flight conditions (Polak et al., 2022; Santos et al., 2023). Common CoP parameters include CoP velocity, envelopment area, and root mean square (RMS) of CoP, analyzed using linear and nonlinear methods (Haxby et al., 2020; Kedziorek et al., 2020). Linear measures, related with the amount of movement, like Standardized Mean Velocity (SMV) indicate variability and instability in postural control, while non-linear analyses, related with the complexity of movement over time, such as entropy, fractal dimension, and correlation dimension provide deeper insights into system complexity and response characteristics (Schmidt et al., 2005; Stergiou et al., 2011; Vaillancourt et al., 2002; Gurses et al., 2013; Esteves et al., 2022).



Military aviation pilots' decision-making capacity, cognitive and operational performance

The military decision-making capacity involves the ability to assess complex situations, weigh multiple factors, and make strategic choices under pressure, often in high-stakes environments where uncertainty and limited information are common. It requires a combination of rational analysis, situational awareness, and adaptive thinking to navigate dynamic and sometimes ambiguous scenarios, integrating both doctrinal approaches and field-based, experiential insights (Shortland et al., 2019). Additionally, it involves a structured, systematic seven step process (shown in Figures 11-15) that helps leaders analyze missions, develop courses of action, and make informed decisions, ensuring effective planning and coordination in complex scenarios (Airforce Special Tactics, n.d.; Woll, 2019; Kuczynski, 2023).

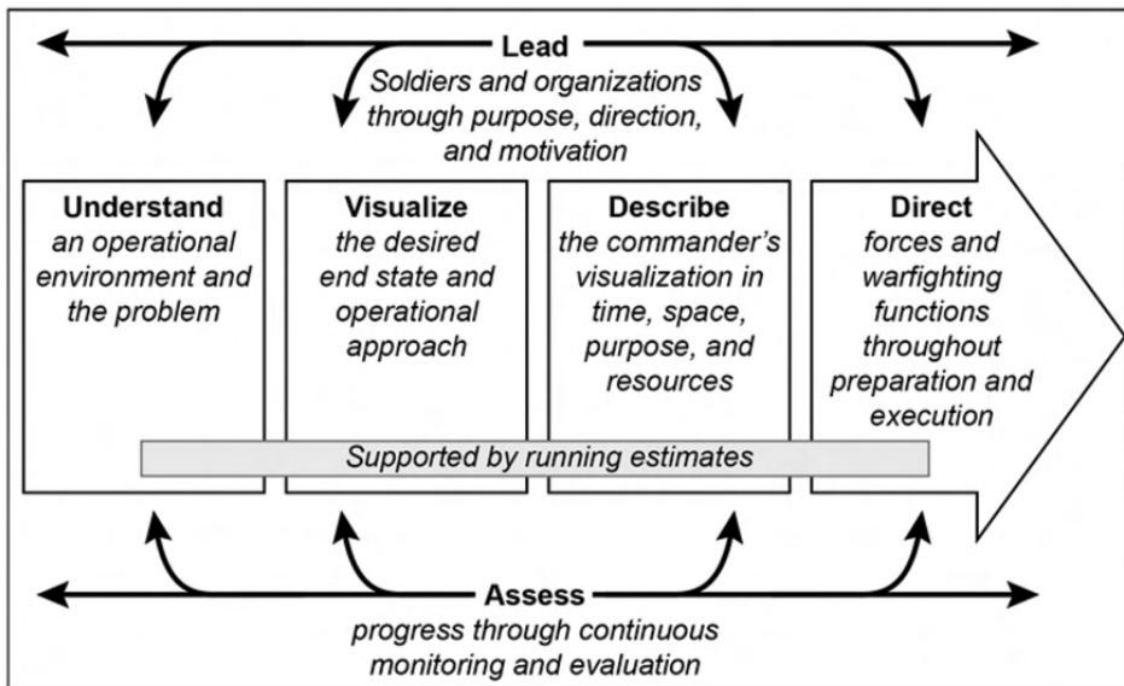


Figure 11 – Commander's role in the operations process (Kuczynski, 2023).

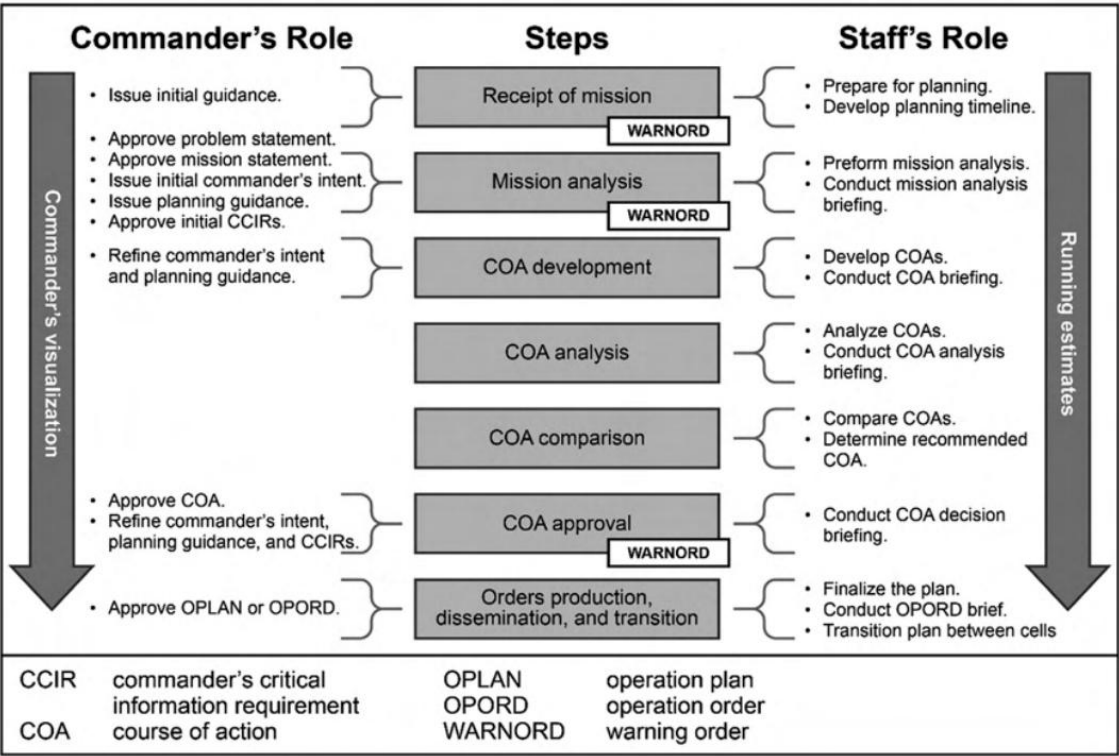


Figure 12 – Commander and staff interaction within the 7 steps of the military decision-making process (Kuczynski, 2023).

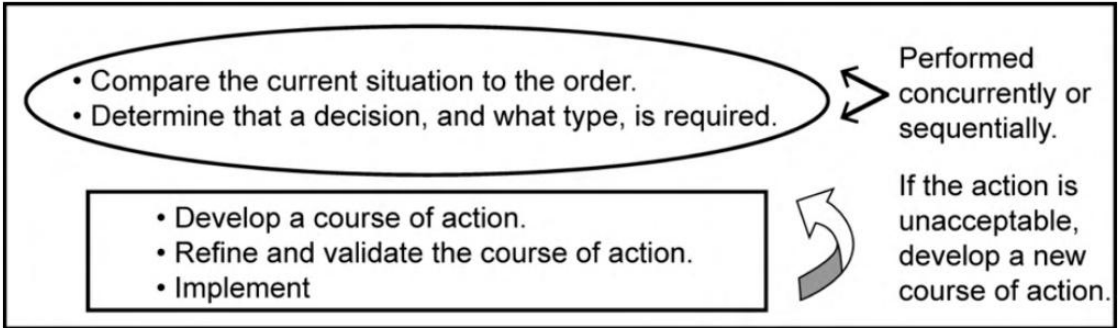


Figure 13 – Rapid decision making and synchronization process (Kuczynski, 2023).



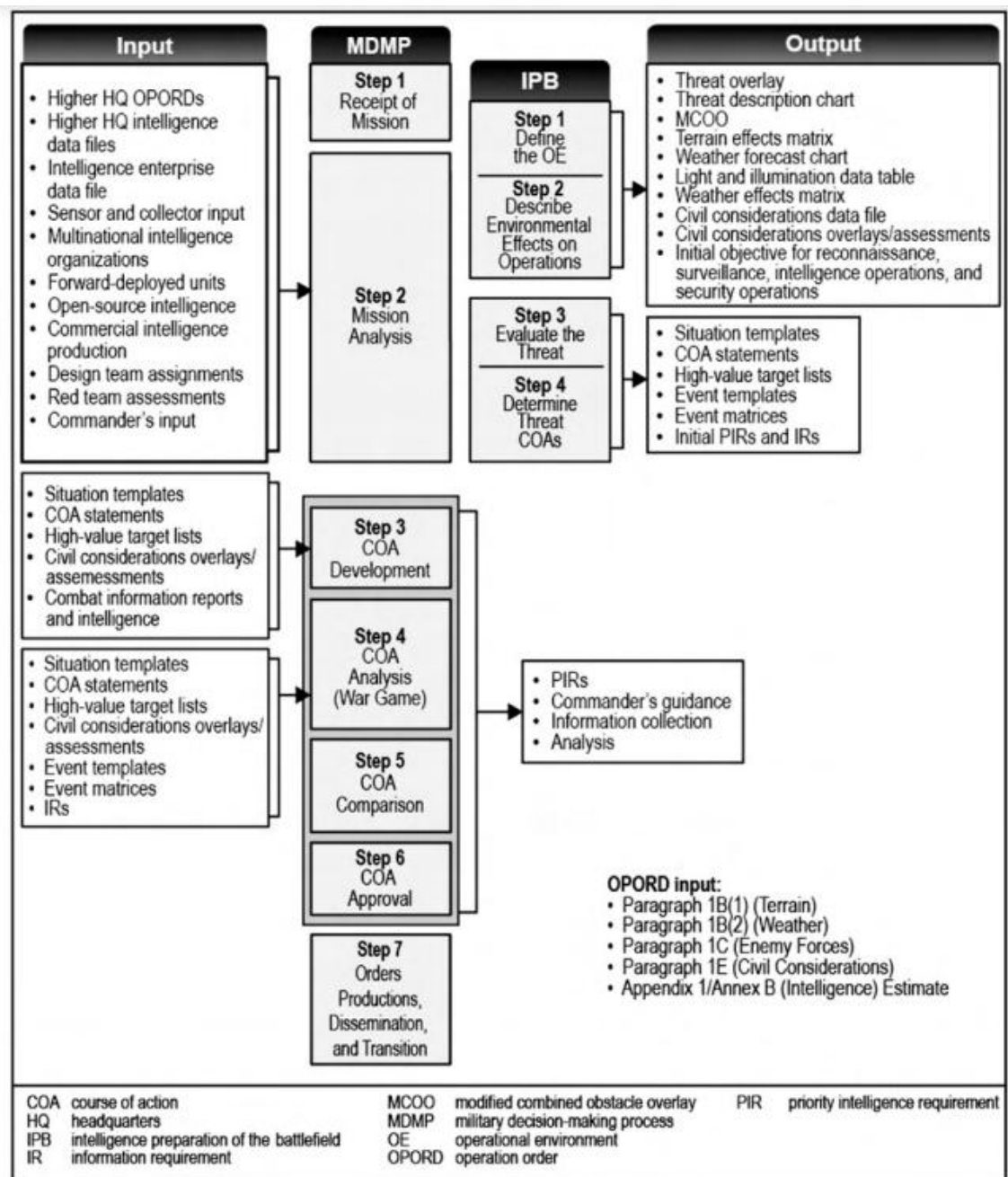


Figure 14– Intelligence preparation on the battlefield and military decision-making process steps (Kuczynski, 2023).

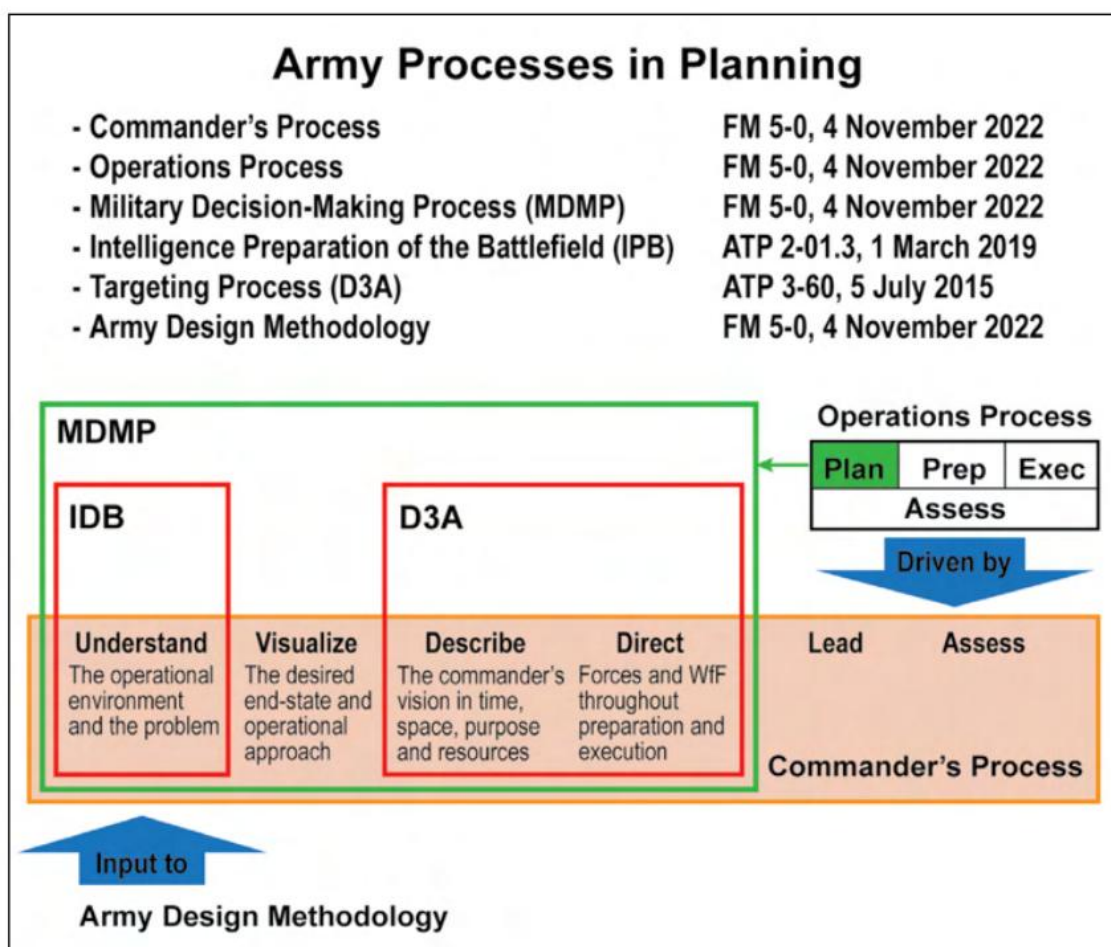


Figure 15 – Military processes with their designated Field Manual (FM) or Army Techniques Publication (ATP) available for consultation for the respective decision makers. Both military forces and their associated Warfighting Tasks (WfT) are actively engaged and coordinated throughout the stages of preparation.

Military cognitive performance refers to the mental abilities necessary for soldiers to operate effectively in high-pressure situations. To enhance operational readiness, it is crucial to conduct rigorous assessments that identify individual cognitive strengths and weaknesses. This involves selecting cognitive assessment tests based on their psychometric properties to ensure they accurately measure critical functions like attention, memory, decision making, and situational awareness. These cognitive skills (in Figure 16) are essential for adapting to the dynamic conditions of the battlefield, enabling military personnel to make quick and effective decisions under stress. By focusing on these assessments, military organizations can improve training and selection processes, ultimately enhancing overall mission success (Proctor et al., 2017).



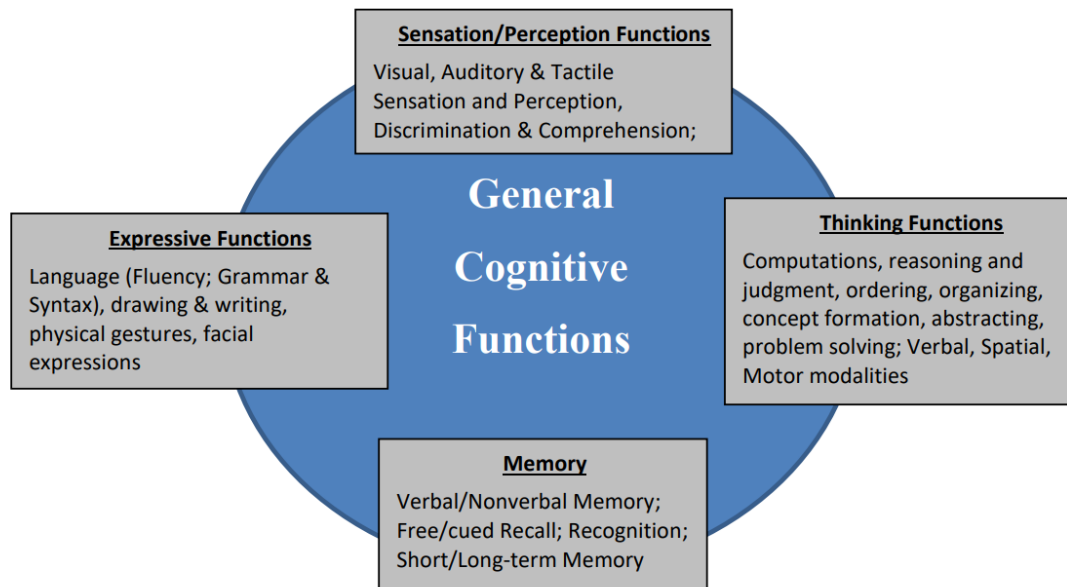


Figure 16 – General cognitive functions needed for operational performance (Proctor et al., 2017).

Military aviation operational performance involves key skills like accuracy, speed, decision making under pressure, situational awareness, and adaptability to changing environments (Cao et al., 2019; Santos et al., 2021). The objective is mission completion with maximum efficiency, minimizing time and conserving resources like fuel and ammunition (Lahtinen et al., 2007; Svensson et al., 1997). Operational performance must be swift, precise, and safe, especially under stress, to ensure both mission success and the safety of personnel and equipment (Mansikka et al., 2016; Lehrer et al., 2010).

2.2. Military Aviation Pilots: perceived difficulties in the Portuguese Airforce

Air Force Academy (AFA) is the military institution for higher education for military pilots. The training model in Portugal is continuous and has a duration of five years and six months (Pereira, 2009):

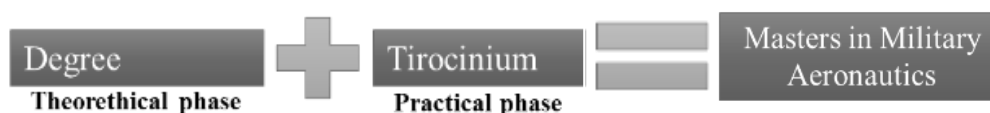


Figure 17 – Training for the Masters in Military Aeronautics degree (Pereira, 2009)

Pilot training is composed of four components:

- Scientific basis;
- Scientific engineering and technologies, required for each of the specializations;
- Military, ethical and behavioral;
- Physical and military, to provide the physical and mental skills necessary to accomplish missions (Pereira, 2009).

The Tirocinium is the final stage of military aviation training and takes place in Base Aérea Nº11, in Beja, Esquadra 101. It lasts 10 months, with 18 days of theoretical instruction and 185 days of practical instruction (177 hours in aircraft and 33 hours in a stationary flight simulator, for a total of 180 flight hours per pilot) (Pereira, 2009):

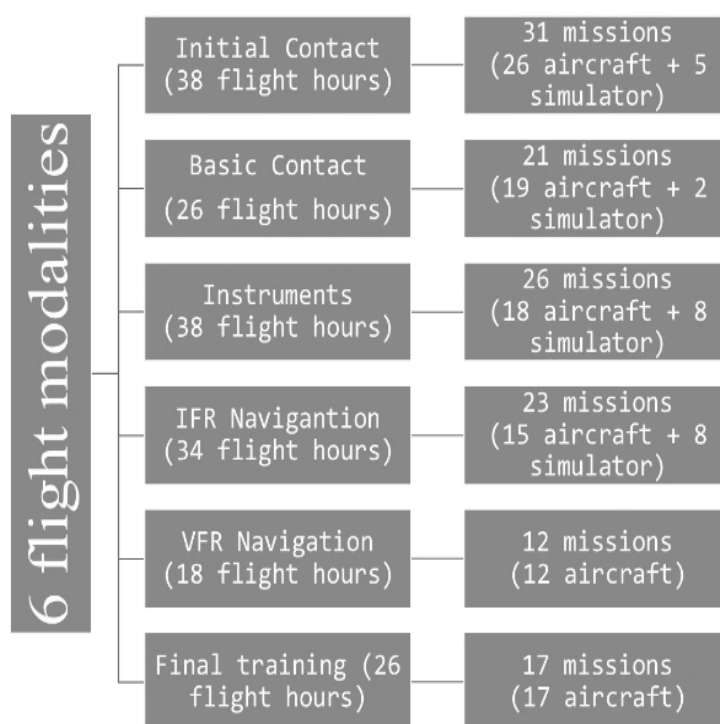


Figure 18 – Flight training and flight hours distributed during the Tirocinium (Pereira, 2009).

After successful completion of the practical phase, pilots receive a Masters in Military Aeronautics diploma equipping them with the necessary skills and experience essential for operational readiness and proficiency in their military aviation roles (Pereira, 2009).

The Epsilon TB-30 aircraft manufactured by Daher and acquired by the Portuguese Air Force in 1989 is operated by Squadron 101 at the Air Base Nº11 in Beja



(Figure 19), for basic and elementary pilot instruction. It is a two-seat tandem aircraft with a low and short wing and retractable landing gear. The six-cylinder horizontal engine is of automatic injection and has a feeding and lubrication device that allows inverted flight and drives a propeller of constant speed. The configuration of its instrument panel, its cruising speed, the robustness of its airframe, which supports from +6.7G to -3.35G, and the sensitivity of its controls, give it characteristics similar to those of a small conventional fighter aircraft (Fernandes, 2021).



Dimensions				
Wingspan	Wing Area	Aspect Ratio	Height	Length
7.92m	9m ²	7	2.66m	7.59m
Performance				
Maximum speed	Cruising speed	Maximum range	Maximum autonomy	Service ceiling
520 km/h	370 km/h	680 NM	03h45	24.000 ft

Figure 19 – Portuguese Air Force Epsilon TB-30 Aircraft, with dimensions and aircraft performance data (Fernandes, 2021).

Portuguese military aviation pilots face unique challenges in their operational roles, compounded by the absence of a structured exercise training regimen. Unlike some other military branches where training programs are standardized and regimented, Portuguese military pilots are tasked with maintaining their physical fitness and readiness largely on their own initiative, with the primary objective of passing yearly physical exams (Santos et al., 2024; Santos et al., 2023). Thereby, this lack of a standardized training program presents an opportunity to explore interventions that could enhance

pilots' physical and mental well-being and optimize their performance in the absence of formal guidance. The Portuguese Airforce's Health and Physical Exercise Department is still in the process of developing a mandatory fitness training protocol for military pilots. As far as we know, pilots have so far been instructed to train as they see fit, to be approved at the mandatory annual physical examinations.

Given the demanding nature of military aviation duties and the inherent stressors associated with operational missions, there is growing recognition of the importance of implementing strategies to support pilots' overall health and resilience (Santos et al., 2024).

Incorporating AVYS in the physical training protocol could lead to improvements in postural control. It would be a beneficial addition to a mandatory training program to be created in the near future, as it would benefit overall fitness (and ability to get approval on mandatory fitness exams), and also improve adaptive vestibular responses associated with increased flight safety.

Therefore, a personalized eight-part yoga class (from Sanskrit: Ashtanga Yoga) was developed, focusing on closed eyes (from Sanskrit: Supta), to improve postural control responses through the vestibular and somatosensory systems on Portuguese Airforce pilots from the "Masters in Military Aeronautics: Aviator Pilot Specialist" course.

The findings from this RCT will provide valuable insights into the potential benefits of incorporating AVYS or other structured training components into a future mandatory training regimen program for Portuguese military pilots (Santos et al., 2024; Santos et al., 2023; Singh, 1999). By identifying effective interventions that promote physical and mental fitness, as well as operational readiness, the study aims to contribute to the development of evidence-based practices that can support the health and performance goals of military aviation personnel in Portugal and potentially inform training protocols in similar contexts worldwide.

The Portuguese Air Force's Health and Physical Exercise Department is currently in the stages of formulating a compulsory sports training regimen for military pilots. As far as our information goes, pilots have thus far been advised to engage in physical training according to their discretion, with approval being contingent on mandatory annual physical assessments.



2.3. Yoga: definition and research trends

Yoga, an ancient practice promoting health and well-being, is based on four key principles (Desikachar et al., 2005):

- 1) Views the human body holistically, considering it a unified system.
- 2) Acknowledges that everyone is unique, so personalized approaches are important.
- 3) Encourages self-empowerment, with practitioners playing an active role in their own journey.
- 4) Highlights the importance of one's mental state in the healing process.

Yoga encompasses physical, mental, and spiritual practices originating from India. Ashtanga Vinyasa Yoga, known for its substantial movement and complex postures, is a physically demanding style of yoga. It involves interconnected physical postures (asanas), flowing movements (vinyasas), and synchronized breathing techniques (pranayama). Ashtanga emphasizes the harmony of posture, breath control, and gaze. It requires a focus on physical embodiment, coordinating each movement with inhalation or exhalation, which makes it a form of “moving meditation” (Park et al., 2015, Dybvik et al., 2021). Various yoga modalities have been shown to have predominantly positive outcomes in different populations (Cramer et al., 2016). The viniyoga principle emphasizes ongoing adaptation for therapeutic benefits, covering poses, conscious breathing, meditation, and philosophy, allowing practitioners to tailor their practice to their health, age, occupation, and lifestyle (Desikachar et al., 2005).

Yoga, with its multifaceted approach encompassing physical postures, breathing techniques, and mindfulness practices, has demonstrated efficacy in reducing stress, improving physiological markers such as HRV, and enhancing overall well-being in diverse populations (Singh, 1999; Kanthi et al., 2024; Thomson et al., 2024; Santra et al., 2022; Budhi et al., 2022; Sullivan et al., 2021; Cushing et al., 2018; Stoller et al., 2012).

Yoga can be a useful conditioning method for improving performance in sports, but it can also be considered a sport, developing athletic qualities such as strength, endurance, reflexes, accuracy, dexterity, flexibility, endurance of various muscle groups and joints, mental conditioning, stress reduction and will power (Sharma et al., 2015; Government of India, 2020).

Practicing yoga continuously improves postural control and strengthens muscles and the vestibular system (increased plasticity in the sacculo-colic pathway), resulting in enhanced vestibular evoked myogenic potential (cVEMP) responses (Shambhu et al.,

2017). Ashtanga Yoga according to Patanjali (Hindu mythic, author and philosopher) has techniques that address all dimensions of the human system: body, breath, mind, personality and emotions. A yoga program with individualized tools must be specifically created and overseen by a qualified instructor, to achieve the practitioner's goals (Balaguru, 2022; Desikachar et al., 2005).

Yoga significantly enhances the sensory-motor system, which is vital for balance, coordination, and motor control. It improves proprioception, making the body more aware of its position and movement, which is crucial for maintaining balance. Through various asanas, yoga strengthens sensory integration by engaging visual, vestibular, and somatosensory systems, essential for coordinated motor responses (Fujiwara et al., 2002; Liu et al., 2024).

Therefore, there is a compelling rationale for conducting a randomized controlled trial (RCT) to investigate whether integrating AVYS into the training regimen of Portuguese military pilots could serve as a viable strategy for managing stress, enhancing resilience, and optimizing performance in their unique operational context.

2.4. Yoga: adjustments for military aviation pilots

Among various exercise options, incorporating AVYS into pilot training is a practical choice for the pilots' demands: its multisensory approach engages compensatory sensory systems in the vestibular system that improve balance, stability, and coordination, while also addressing aspects such as breathing to develop the respiratory system, physical postures to enhance flexibility and strength, embodiment for increased proprioception, and meditation for interoception and cognitive preparation (Desikachar et al., 2005; Jeter et al., 2015; Park et al., 2015; Cramer et al., 2016; Dybvik et al., 2021). This method not only addresses the distinctive challenges encountered by pilots but also the expected enhancements in overall well-being and cognitive performance are poised to positively impact decision making processes and operational performance during aircraft operations (Martin et al., 2020).

It's important to note that yoga doesn't advocate a one-size-fits-all approach through a universal dosage of asana (physical postures) and pranayama (breathing techniques) for healing, as this varies among individuals (Desikachar et al., 2005). The amalgamation of ásaṇa and pranayama practices yields more notable improvements compared to isolated pranayama exercises. This integrated approach requires careful and



intelligent adaptation to address specific issues or objectives (Balaguru et al., 2021; Dubey et al., 2022). The array of healing tools available in yoga, such as combinations of techniques, crafted by qualified instructors, offers numerous possibilities. These tools must be thoughtfully combined to cater to the unique needs of each practitioner (Desikachar et al., 2005; Dubey et al., 2022).

In this way it will be expected that, given the professional needs of the pilot students of the Portuguese Air Force Academy, the practice of yoga, with the inclusion of all its components, will improve some physical aspects of the pilots, which in turn will improve their ability to work in flight missions (Dubey et al., 2022; Mandanmohan et al., 2003; Thangavel et al., 2014; Choudhary et al., 2023).

In line with this methodology, a specialized yoga practice, AVYS, tailored for Air Force Pilots has been developed. Understanding the previously mentioned challenges and responsibilities faced by Airforce pilots will be instrumental in guiding the development and evaluation of strategies and training programs.



CHAPTER 3 | Objectives and Hypotheses



This study aims to determine the suitability of incorporating this method into the training program for Portuguese Air Force pilots, with the goal of enhancing their capabilities and increasing flight safety by preventing human error:

- establishing the efficacy of AVYSM in refining stress responses in individuals, thus improving cognitive response, and decision making.
- scrutinizing the impact of AVYSM in stimulating the recalibration of the vestibular system, above all during rotational tasks implying changes in head position in space, to augment postural stability and balance, thereby mitigating spatial disorientation.
- evaluating the extent to which AVYSM contributes to enhanced overall health, body composition, strength, and respiratory performance, serving as a potential countermeasure against hypoxia threats and increased G-forces in the aircraft.

Material and equipment selection for the study prioritized availability, capability to measure physiological functions impacted by piloting military aircraft, suitability for real-life training integration, and efficiency in delivering results without hindrance to pilots' daily workload, as well as adherence to the highly specific military regulations in force. Both primary and secondary outcomes were selected following a comprehensive review of the literature and a comparison with pilots' perceived difficulties (as identified through a brief interview, detailed in the study flow). Primary outcomes were deemed the most critical factors in flights, with Operative Performance being the most crucial for pilots' safety. Secondary outcomes were also identified as significant contributors.

3.1. Primary outcomes

Changes in Operative performance—Flight times to complete tasks in the flight simulator; number of errors during the emergency protocol and their classification report from the flight simulator controller (Santos et al., 2022). The assessment will determine if the exercise protocol influences the pilot's decision making, as evidenced by improved task efficiency, reduced errors, and enhanced visual and auditory reaction times (Whitley, 1997; Aguilera et al., 2020)—Time Frame: measured at 12 weeks (vs. baseline values).

Changes in Stress and HRV—HRV, measured with Polar H10 portable device (Pulopulos et al., 2018; Aguilera et al., 2020; Alfaras et al., 2020; Yang et al., 2021). The assessment will reveal if the exercise protocol influences pilots' responses to stressors,



with a lower stress response enhancing decision making (Martin et al., 2020)—Time Frame: measured at 12weeks (vs. baseline values).

Changes in Vestibular system control responses—The CoP represents the dynamics of the neuromusculoskeletal system, was measured with a portable force plate (Biosignals Plux Portugal) with a sample frequency at 1000Hz and data downsampled to 50Hz (Pinsault et al., 2009; Hébert-Losier et al., 2020). Preprocessing was performed using MATLAB (The MathWorks Inc., Natick, MA) and the toolbox available. Linear variables were computed using custom MATLAB scripts, consistent with previous approaches in the UNO Biomechanics Research Laboratory (Stergiou, 2004). Analysis scripts for the non-linear data were based on tools developed by the Nonlinear Analysis Core at the University of Nebraska at Omaha (<https://www.unomaha.edu/college-of-education-health-and-human-sciences/biomechanics-core-facility/research/nonlinear-analysis-core.php>). Enhanced postural control responses may indicate the protocol's potential to mitigate the effects of spatial disorientation (Jeter et al., 2015; Gil-Cabrera et al., 2020)—Time Frame: measured at 12weeks (vs. baseline values).

The primary outcome's goal is to answer the two main questions:

1. Does the practice of AVYS improve pilots' performance during their work, thereby preventing human error and consequently increasing flight safety?
2. Can we enhance the pilot training process with this practice?

3.2. Secondary outcomes

Changes in Strength—Handgrip strength measured with a handgrip dynamometer Baseline Smedley, Model 12–0286, White Plains, NY, United States (Norman et al., 2011). The assessment will determine if the exercise protocol impacts pilot strength, crucial for maintaining control, resisting fatigue, and ensuring safety during high-intensity flights (Aguilera et al., 2020)—Time Frame: measured at 12weeks (vs. baseline values).

Changes in Body composition—Body composition data (percent body fat, percent fat free mass, percent muscle mass index, as a percentages) measured with a Tanita (MC-780 MA, Tanita, Tokyo, Japan) to get a bioelectrical impedance analysis (BIA) will indicate if the exercise protocol had any impact in the pilot's physical makeup. Percent body fat, percent fat-free mass, and percent muscle mass index collectively constitute

body composition measures. Percent body fat reflects the fat proportion in total body weight, encompassing essential and storage fat. In contrast, percent fat-free mass represents the non-fat components, including muscle, bone, organs, and other tissues. Percent muscle mass index specifically gauges the proportion of body weight attributed to muscle. The relationship between percent body fat and percent fat-free mass is complementary, totaling 100%, while percent muscle mass index indicates the proportion of muscle within total body weight (Norman et al., 2012; Castizo-Olier et al., 2018). Enhanced body composition could mitigate adverse effects of the pilot profession on physical well-being (Whitley, 1997)—Time Frame: measured at 12weeks (vs. baseline values).

Changes in well-being and general health—measured through the SF-36V1 questionnaire (Severo et al., 2006; White et al., 2018) will indicate if the exercise protocol had any impact in the pilot's general health subjective assessment, mitigating adverse effects of their profession on pilots' physical well-being (Whitley, 1997)—Time Frame: measured at 12weeks (vs. baseline values).

Changes in Lung capacity—Ventilatory response measured with spirometry—FEV1/FVC (Forced Expiratory Volume in 1s and Forced Vital Capacity) ratio indicates how much air a person can forcefully exhale (Aguilera et al., 2020; Yang et al., 2015) will indicate if the exercise protocol had any impact on lung capacity, which might offset hypoxia threats on pilots (Bustamante-Sánchez et al., 2019) – Time Frame: measured at 12weeks (vs. baseline values).

Changes in Five Facet Mindfulness Questionnaire (FFMQ)—Changes in cognitive abilities with 15 questions and average scores are calculated by summing the responses and dividing by the number of items and indicate the average level of agreement with each subscale (1=rarely true, 5=always true). Higher scores are indicative of someone who is more mindful in their everyday life (Baer et al., 2008; Carpenter et al., 2019). Determining the impact of the exercise protocol on cognitive abilities, a more mindful pilot is anticipated to exhibit improved decision-making skills during work (Whitley, 1997, Bustamante-Sánchez et al., 2019)—Time Frame: measured at 12weeks (vs. baseline values).

Changes in Multidimensional Assessment of Interoceptive Awareness Questionnaire (MAIA)—Changes in sensory process closely linked to higher brain cognitive processes (because awareness of internal bodily states can influence decision-making, emotional regulation, and attention)—is an 8-scale state-trait questionnaire with 32 items to



measure multiple dimensions of interoception; scores are between 0 and 5, where higher score equates to more awareness of bodily sensation (Machorrinho et al., 2019). The evaluation will assess the exercise protocol's impact on cognitive abilities, expecting improved decision making in pilots with heightened awareness of bodily sensations (Whitley, 1997, Bustamante-Sánchez et al., 2019)—Time Frame: measured at 12weeks (vs. baseline values).

Changes in Aviation Safety Attitude Scale (ASAS)—Changes in cognitive abilities—consists of 27 items on a five-point scale, each designed specifically to assess pilots' attitudes with respect to predict the hazardous event involvement of aviators; For all the attitude subscales, higher scores indicate a greater degree of that particular attitude—For example, higher scores on the ASAS self-confidence factor indicated that the person expressed greater confidence in their ability as a pilot (Hunter et al., 2005). The evaluation will assess the exercise protocol's impact on cognitive abilities, anticipating enhanced decision-making skills in more confident pilots (Whitley, 1997, Bustamante-Sánchez et al., 2019)—Time Frame: measured at 12weeks (vs. baseline values).

The secondary outcome's objectives are to explore associations between work performance and the hypotheses proposed in this project, which are:

1. AVYS practice influences overall health
2. AVYS practice influences postural control and balance
3. AVYS practice influences the functioning of the vestibular system
4. AVYS practice influences risk perception
5. AVYS practice influences stress levels
6. AVYS practice influences attention capacity
7. AVYS practice influences decision making

3.3. Testing the equipment in a real-life Airforce Work Setting

This case-control study was created to analyze the autonomic response and operative performance in different flight simulator emergency flight maneuvers. Expert and rookie pilots were included in this case-control report to investigate the influence of experience on the psychophysiological response of professional combat aircraft pilots.

The aim of this research was to analyze the effect of flight experience in the autonomic response and operative performance of professional combat aircraft pilots in a flight simulator emergency flight maneuver.

CHAPTER 4 | Methodology

With this study it was possible to test the materials and methodology for the Protocol and the RCT, as well as improve both studies with hands-on experience in the field. It was important to know which empirical information was possible to collect in this real-life setting and the best procedures to go about it. This study also made possible to choose which flight emergency to use for the RCT study, since some of them occur so fast that the technology available to collect data couldn't pick any information in those brief seconds.





CHAPTER 4 | Methodology



To minimize biases in research, and crucial for ensuring the validity and reliability of findings, this study employed a robust blinding protocol involving both investigators (except the study coordinator and the military coordinator) and participants. This blinding is essential to reduce confirmation bias, where the expectations of the investigators could influence data interpretation. The study coordinator pre-registered the analysis methods before data collection began, with Évora University, via the PhD project, and the University Ethics Committee approved it as well. This ensured that a predetermined plan was followed, reducing the risk of selectively reporting favorable results. The military coordinator didn't participate in data collection or data analysis, only coordinating the pilot's schedules with the study coordinator. To minimize bias all data collection made by the study coordinator was either aiding the simulator controller registering times, or aiding other investigators registering their data, so another person was always present. Subjective assessments were not collected by the study coordinator. Participants were also blinded to the specific aims of the study and the exact nature of the interventions. This helps to minimize placebo effects and ensures that participants' responses are not influenced by their expectations regarding the outcomes (Popovic et al., 2023).

The investigation team selected assessment tools they were familiar with, enhancing the reliability of data collection and analysis. Their prior experience with these tools mitigates the risk of measurement error and ensures proper administration and scoring, thus further reducing bias in results (Popovic et al., 2023). Portable, non-invasive measuring tools were chosen, or tools that the Airforce Academy already owns were used, ensuring that findings are robust and relevant to real-world applications.

The study utilized a combination of objective and subjective tools to gather comprehensive data. This dual approach allows for a broader understanding as it incorporates both measurable outcomes and personal insights, enhancing the overall analysis. To enhance the reliability of results, multiple tools that measure similar outcomes were employed to check for redundancy in findings. This approach strengthens the validity of the data and ensures comprehensive insights.

Having multiple analysts independently analyze the same dataset helped identify any inconsistencies or biases. Discrepancies were discussed and resolved collectively. Utilizing automated or software-based tools also minimized human error and subjective judgment, thus reducing bias (Popovic et al., 2023).

Well-defined and appropriate statistical methods were used, techniques that may artificially inflate or deflate results were avoided. Transparency about statistical



adjustments and corrections was one of the aims in producing both the articles as well as this thesis methodology section.

The main features of both the methodology and the results from all published studies are summarized. In total, eight articles have been either published or submitted for publication. These articles have been grouped into:

1. Bibliometric analysis – one submitted article.
2. Case control report – one published article.
3. Study Protocol – one published article.
4. RCT studies – three published articles (research into linear CoP variables; health strength & lung capacity variables; decision making capacity for operational performance) and two submitted articles (research into HRV variables; CoP non-linear variables).

4.1. Recruitment, Screening and Sample Size for the case control study

Four professional military pilots from the Portuguese Air Force participated in this control case report study. The two pilots with more years of military service in the airbase (Expert Pilots -EP-) and the two pilots with fewer years of military service (Rookie pilots -RP-) participated were chosen. The EP was assigned to duty in the airbase, one of their tasks being to teach the RP, while the RP were finishing up their masters in aeronautic military science in the airbase.

Measurements were made in March 2022 in Ba05, Monte Real (Portugal). Expert pilots (33 to 35 years old) have more experience than novel rookie pilots (25 years old) with more than 10 years of differences in military service. Regarding monthly time spent in the flight simulator, rookie pilots had 180 min vs 60 spent by expert pilots. Regarding aerobic training, rookie pilots conducted more time practicing this training, whereas expert pilots conducted more strength training than rookie pilots.

4.2. Procedures for the bibliometric analysis

The documents for this research were obtained from the Web of Science Core Collection database. This includes highly selective sources indexed in the Science Citation Index Expanded, and the Social Science Citation Index, which may by default involve double indexing in the Web of Science Core Collection. The search strategy employed a thematic search tag (TS), which simultaneously searches the title, keywords,

authors, abstract, and Keywords Plus® (Clarivate, n.d.). The search vector used was TS = (yoga), and the extraction was limited to documents classified as Review Articles, dated until November 11, 2023 (Price, 1976).

4.3. Procedures for the case control study

The autonomic response of pilots was evaluated in 4 different maneuvers: Emergency 1 (E1) - take-off engine failure; Emergency 2 (E2) - flight engine failure close to the base allowing the pilot to promptly land; Emergency 3 (E3) - flight engine failure far away from the base not allowing the pilot to promptly land; Emergency 4 (E4) – alternator failure. In E1 the emergency protocol response starts during the take-off maneuver, on E2, E3 and E4 the pilots have time to the regular take-off maneuver, as well as flying before the emergency is activated by the simulator controller leading to the emergency protocol response actions. The pilots flew an approximately 30-minute scenario containing both visual and instrument flight conditions (Figure 20). All the maneuvers were performed in a flight simulator (Epsilon - SEPS TB30). All participants underwent the same missions by the same order since the maneuvers could not be randomized.



Figure 20 – Left, the inside of the cockpit for the flight simulator Epsilon TB-30 and a pilot ready to start the protocol; Right, the inside of the control room and the setup device of the flight simulator operator.



The time it took to complete every action was measured with a chronometer (stopwatch app from Huawei P20Pro) and the flight simulator controller appraised their performance relaying information on good protocol action choices or bad ones. Participants did not take any drug, alcohol or any other substance which could affect the nervous system 24-hours before undergoing the protocol.

Autonomic modulation was measured by the HRV in basal conditions (3 minutes) with the pilots sitting inside the simulator cabin prior the simulations maneuvers and during the simulation maneuvers. Operative performance was measured during the simulation maneuvers.

Heart rate monitor Polar H10 (Pulopulos et al., 2018; Wilson et al., 2019) was used to measure HRV. Different HRV variables were extracted in the time domain, frequency domain and non-linear measures. In the time domain, the mean heart rate (HR), the RR intervals, the standard deviation of all normal-to-normal RR intervals (SDNN), the percentage of intervals > 50 ms different from the previous interval (pNN50), and the root mean square of successive differences RR interval differences (RMSSD) were analyzed (Shaffer et al., 2014; Wilson et al., 2019). In the frequency domain, the Low Frequency (LF) (ms²), the High Frequency (HF) (ms²), the ratio between LF/HF and the Total Power, were calculated (Shaffer, et al., 2014; Shaffer et al., 2017). Lastly, nonlinear measures, such as RR variability from heartbeat to short term Poincare graph (width) (SD1), RR variability from heartbeat to long term Poincare graph (length) (SD2) and Stress Index (SI – representing the degree of load on the autonomic nervous system) were also obtained (Shaffer, et al., 2014; Shaffer et al., 2017; Baevisky et al., 2017). Kubios HRV software was used for pre-processing in accordance with manufacturer's instructions (Liponen et al., 2019; Gabani et al., 2024). Performance was measured by the time to complete the protocol of emergency response: after the flight simulator controller activated the emergency on the simulator the pilots had to identify the emergency and choose the correct actions to respond. The time to complete the actions was measured with a chronometer.

The chosen materials and methods ensured that the study could effectively measure autonomic modulation and operational performance (Stephenson et al., 2021), providing a comprehensive understanding of how stress and rapid decision-making impact pilots during emergency situations. The combination of HRV analysis, performance timing, and simulator feedback enabled a robust assessment that can be

applied in military work settings with minimal costs, portable devices and minimally invasive testing.

Table 2. Case-control study parameters: HRV and Performance.

Parameter	Unit	Description
HRV – Time domain		
HR	ms	mean heart rate
RR intervals	ms	RR interval differences
SDNN	ms	standard deviation of all normal-to-normal RR intervals
pNN50	%	percentage of intervals > 50 ms different from the previous interval
RMSSD	ms	root mean square of successive differences RR interval differences
HRV – Frequency domain		
LF	ms ²	Low Frequency band in normal units (0.04-0.15 Hz)
HF	ms ²	High Frequency the high-frequency band in normal units (0.15- 0.4 Hz)
LF/HF	%	the ratio between LF/HF
Total Power		
HRV – Non-linear		
SD1	ms	RR variability from heartbeat to short term Poincare graph plot standard deviation perpendicular the line of identity (width)
SD2	ms	RR variability from heartbeat to long term Poincare graph plot standard deviation along the line of identity (length)
SI	%	Stress Index (representing the degree of load on the autonomic nervous system)
Performance		
Performance	s	time to complete the protocol of emergency response in the flight simulator: identify the emergency and choose the correct actions to respond

4.4. Recruitment, Screening and Sample Size for the RCT studies

The collaboration between Évora University and the PA involved reaching out to the Head of the Chief of Staff Cabinet. Under this collaborative protocol, a Ph.D. student administered an AVYS intervention at the chosen airbase 11 in Beja, while a team from Évora University conducts on-site baseline and post-intervention data collection. The authorization for this collaborative effort was granted by the Portuguese Air Force's Head of the Chief of Staff Cabinet. Pilots underwent a comprehensive briefing on the study's general parameters and were extended a voluntary invitation to participate. Following this



briefing, participants were required to sign an informed consent form in adherence to the Helsinki Declaration. Any queries or concerns were addressed during this stage to ensure clarity and compliance with ethical standards.

All pilots enrolled in the course, classes of 2021 and 2022, at the Portuguese Air Force Academy were asked to participate in this research, as showed in Figure 21.

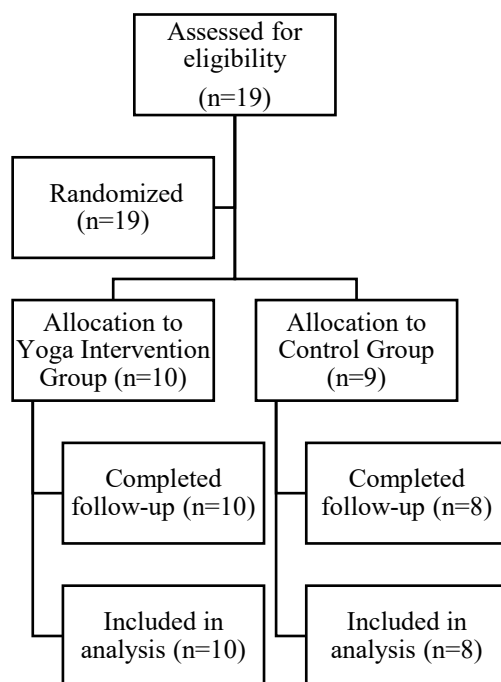


Figure 21 – Participant flow diagram.

All pilots enrolled in the course, classes of 2021 and 2022, at the Portuguese Air Force Academy participated in this research. The sample size was determined using OpenEpi, version 3, based on the equation:

$$\text{Sample size } n = \frac{[\text{DEFF} * Np(1-p)]}{[(d^2/Z^2_{1-\alpha/2} * (N-1) + p * (1-p))]}$$

Where:

- Population size (N): 19
- Hypothesized % frequency of outcome factor in the population (p): 50% ± 5%
- Confidence limits as % of 100 (absolute ± %) (d): 5%
- Design effect (DEFF): 1
- For a confidence level of 95% to 99.9%, the sample size required was 19.
- For a confidence level of 90%, the sample size required was 18.

The study's participant flow, detailed in Figure 14 and adhered to Consolidated Standards of Reporting Trials (CONSORT) guidelines (Cuschieri, 2019), included 18 pilots assessed for eligibility, with one excluded because of lifestyle changes that included dieting, exercise and quitting smoking. All 18 were randomized using random.org. Ten pilots were assigned to the AVYS Intervention Group and eight to the Control Group, with all participants receiving their respective interventions. Both groups had complete follow-up, and 18 participants were included in the RCT analysis.

G*Power is a statistical software tool designed for power analysis in various types of research, including social, behavioral, and biomedical sciences. It allows researchers to determine the sample size needed to detect an effect of a given size with a desired degree of confidence. The program supports a range of statistical tests, is flexible, user-friendly, and helps researchers perform power analyses to optimize study design, ensuring sufficient power to detect effects while avoiding unnecessary over-sampling (Faul et al., 2007, Faul et al. 2009).

For parametric testing considering the entire population of Airforce pilots:

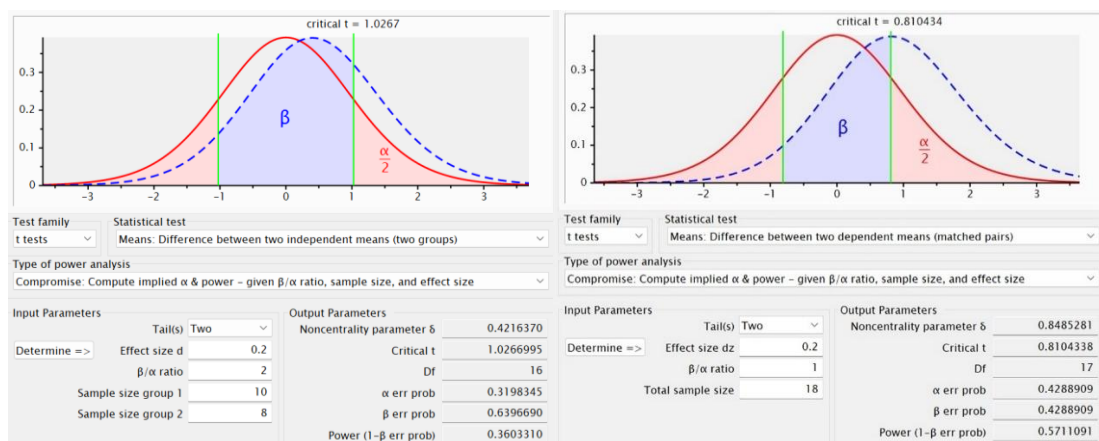


Figure 22 – Central and non-central distributions for t-test between two groups (left) and t-test within groups (right).



For non-parametric testing considering the entire population of Airforce pilots:

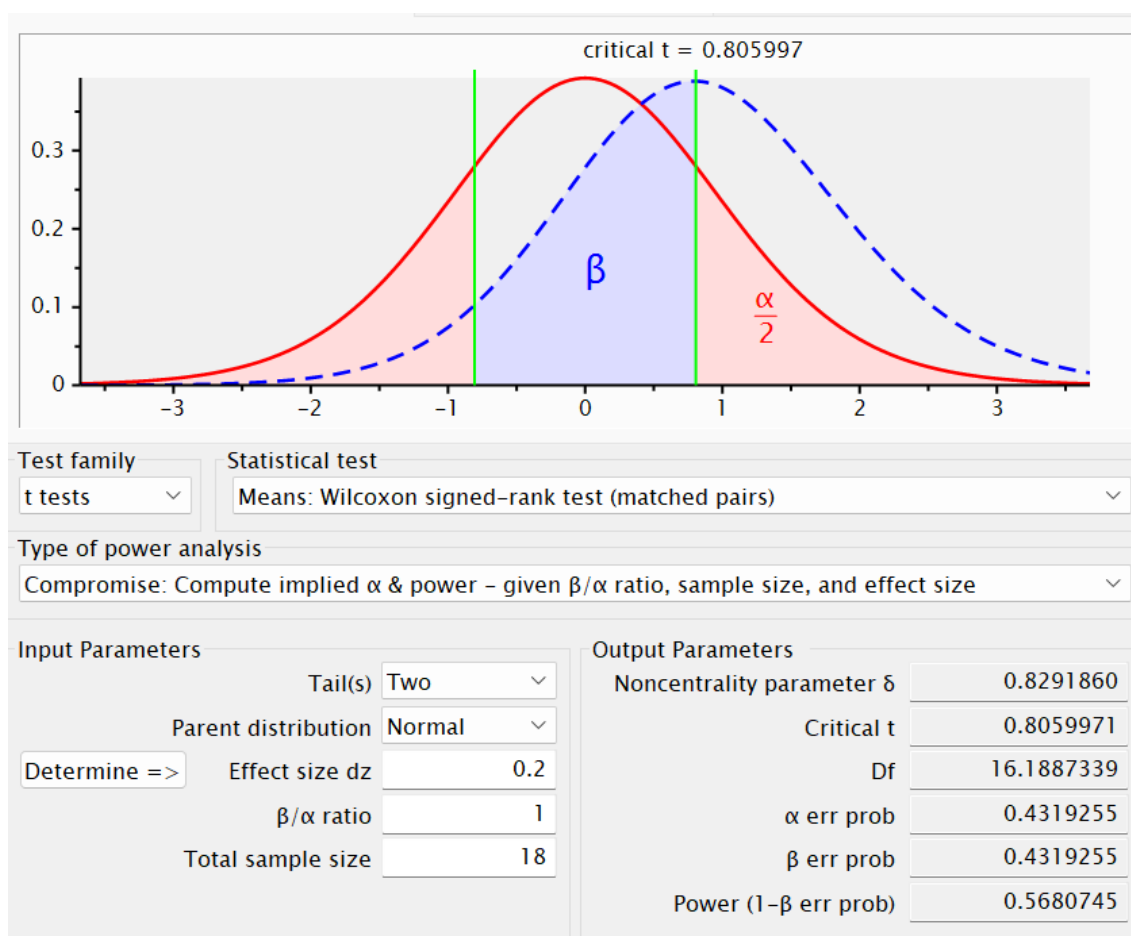


Figure 23 – Central and non-central distributions for Wilcoxon rank test between two groups and within groups.

When the study includes the entire population, traditional inferential statistics (e.g., p-values, statistical power, and confidence intervals) are less applicable, as there is minimal or no sampling error. In this case, the population of Tirocinium Air Force Pilots consisted of 19 individuals, with one dropout during the study. Although the statistical tests indicated low power—typically addressed by increasing sample size or targeting larger effect sizes—this concern is less relevant here, given that the full population (minus one) was assessed (Good et al., 2009; Sterne et al., 2001).

4.5. Randomization procedure and blinding for the RCT studies

Random assignment of participants to either intervention or control groups was conducted to minimize selection bias. This approach ensured that the groups were comparable at baseline, reducing confounding variables that could affect the outcomes

(Kang et al., 2008). Random.org is an online platform that generates true random numbers based on atmospheric noise. By capturing radio waves and digitizing the unpredictable noise, it produces genuinely random sequences suitable for various applications, including scientific research, gaming, and cryptography. The site is user-friendly, allowing individuals to generate numbers for different purposes, such as assigning participants to groups in clinical trials, ensuring fair and unbiased results. Its transparency about the generation process helps users trust the randomness of the outcomes.

Upon inclusion, volunteers were allocated to either a waiting list (control group) or a AVYS class (intervention group) through a computer-based algorithm (random.org), facilitated by the team captain of the pilots. All study personnel, excluding the team captain and one study coordinator from Évora University, were blinded (kept unaware of the group allocation). Participants were explicitly instructed to refrain from disclosing their group assignment to the study team. To uphold impartiality, all data was coded for subsequent processing and analysis, maintaining blindness to group allocation to data analysts. The final coded trial dataset was made available to all team members for analysis.

4.6. Study flow for the RCT studies

The study team visited Airbase 5 in Monte Real to consult with the F16 Team Captain. The objectives included planning and scheduling visits, testing the proposed protocol, assessing all pertinent equipment, identifying, and rectifying potential errors before the initiation of the initial data collection. During this meeting, interviews with the Team Captain were conducted to evaluate the perceived needs of pilots during their aircraft piloting duties. The insights obtained, combined with findings from the literature, guided the tailoring of the AVYS intervention.

A baseline data collection session was organized in Ball in Beja, with study participants selected randomly based on availability and location undergoing evaluation over two consecutive days during pilots' work hours from 8:30 to 19:00. Oversight of the data collection was provided by experts in Sports Exercise and Health from Évora University, the study coordinator, and a simulator controller from the Air Force team.

The AVYS group integrated a one-hour AVYS class into their work schedule, in Ball in Beja, twice a week for a 12-week period. The AVYS intervention, led by the study coordinator—an Ashtanga Vinyasa Yoga expert with over 500h of training and



approximately 10 years of teaching experience—was conducted. Each pilot was required to complete 24 AVYS classes within the designated 12 weeks. A few pilots couldn't make all 24 classes with regular schedule because of work conflicts, so additional classes were scheduled specifically for them. With those on missions with conflicting schedules, alternative days and times were accommodated so at the end of the 12-week period all pilots in the intervention group had completed 24 classes.

Post-intervention data collection followed the completion of the AVYS program, with study participants, randomly divided based on availability and location, undergoing evaluation over two consecutive days, in Ba11 in Beja, during pilots' work hours from 8:30 to 19:00.

Supervision was provided by experts in Sports Exercise and Health from Évora University, the study coordinator, and an available simulator controller from the Air Force team.

Since all pilots were working and living in the same area (Ba11) and the study process was integrated in their military work schedule (instead of during their free time), this arrangement helped minimize dropout rates from the study. By facilitating open communication and maintaining a supportive environment, the likelihood of participants remaining engaged in the study was significantly enhanced. In this study, all pilots in the AVYS group communicated via text when they could not attend a class to reschedule and participate in the required number of classes. The progressive increase in the difficulty of the AVYS classes served as a motivational factor for the pilots' participation, as it reinforced their inherent competitive spirit. By presenting them with progressively challenging tasks, the classes not only engaged their interest but also encouraged a sense of achievement and camaraderie among the participants, further enhancing their commitment to the program.

Upon the study's conclusion, the waiting list group was offered the same 12-week AVYS classes before completing their tirocinium and departing the airbase, aligning with ethical considerations.

4.7. Arms and intervention for the RCT studies

Table 3 outlines the study arms: the control group receiving military training alone and the intervention group undergoing both military training and AVYS classes.

Table 3. Arms and assigned interventions of the study protocol.

Arms	Assigned interventions
Experimental: Yoga	Yoga practice: 12-week program of Ashtanga Vinyasa Yoga Supta for 1h twice a week; other names – yoga class
No Intervention: Waiting list	Exclusively compulsory training (the same for all academy attendees).

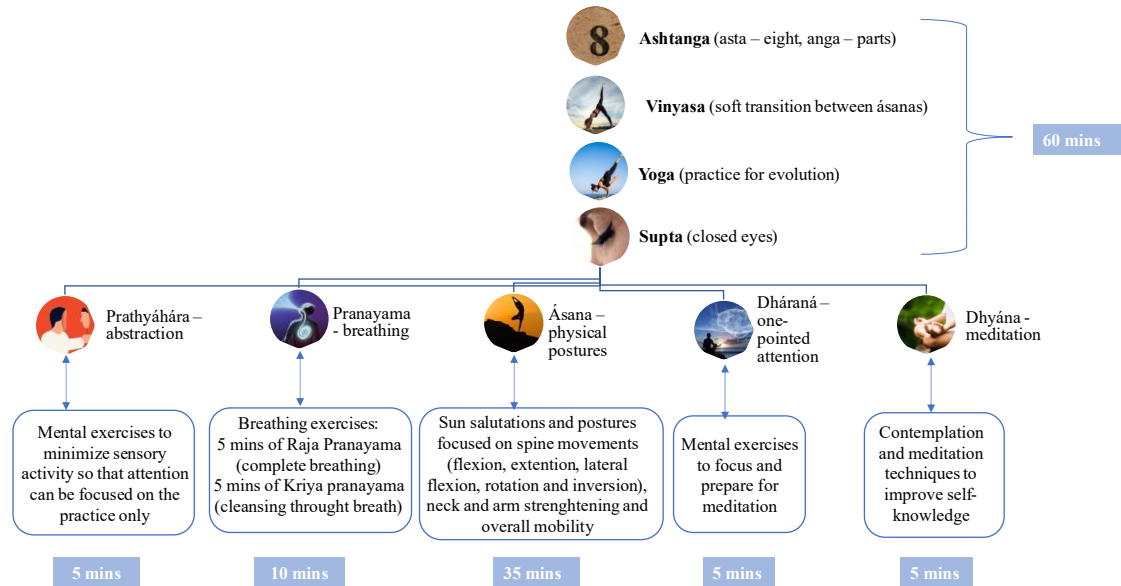


Figure 24 – AVYS classes structure and components.

The AVYS practice, as depicted in Figure 24, entails fluid sequences (vinyasa from Sanskrit) performed with closed eyes (supta from Sanskrit) to address perceived difficulties in pilots. The AVYS classes comprise five main components:

- 5min of prathyāhara (abstraction) — “withdrawal of the senses” or “sensory withdrawal,” involves consciously detaching the senses from external stimuli and directing attention inward. Through pratyahara, practitioners aim to disengage from external distractions, facilitating a deeper exploration of the inner self and enhancing self-awareness.
- 5min of pranayama (breathwork, including raja pranayama and kriya)—these are advanced forms of breathwork aimed at regulating the breath and influencing the flow of prana (life force energy) throughout the body. Raja Pranayama focuses on controlling the breath through various breath retention methods, such as inhaling (puraka), holding the breath (kumbhaka), and exhaling (rechaka) in specific ratios. Kriya pranayama techniques typically combine specific breath control, body postures, and mental focus to influence the flow of prana (life force



energy) throughout the body. Nauli Kriya is an advanced yogic purification technique that involves isolating and rhythmically churning the abdominal muscles. It is performed by contracting and rolling the abdominal muscles in a specific manner to create a rolling or rippling motion across the abdomen.

- 35min of āsana (physical postures)—with sun salutations, as depicted in Image 3 and sequenced physical postures, as depicted in Figures 25 and 26, involving spinal flexion, extension, lateral flexion, rotation, and inversions, changes in head positioning entailing a recalibration involving the integration of visual (this stimuli was progressively removed for the *supta*, or closed eye component of class), vestibular, and muscular sensations, combined with breath control and abstraction, for a holistic approach to health and well-being.
- 5min of dhāraṇā (practice of concentration or single-pointed focus)—beginning with yoga nidra for physiological relaxation, followed by mental exercises to focus and prepare for meditation. Yoga nidra is the practice of deep relaxation or yogic sleep. It is a state of consciousness between wakefulness and sleep, where the body and mind are in a state of profound rest while remaining fully aware. During yoga nidra, practitioners typically lie down in a comfortable position and follow guided instructions to systematically relax different parts of the body, release tension, and enter a state of deep relaxation. The practice often involves techniques such as body scanning, breath awareness, visualization, and mindfulness. Dhāraṇā involves directing one's attention to a specific object, thought, or sensation, and maintaining that focus without distraction. This object of focus could be anything, such as a physical object, a mental image, a mantra, or the breath. The goal of dhāraṇā is to develop greater mental discipline, control over the wandering mind, and the ability to sustain attention for prolonged periods.
- 5min of dhyāna (meditation or contemplation)—involves focused concentration and sustained attention on an object, thought, or sensation to achieve a state of mental clarity, stillness, and inner awareness. During dhyana, practitioners aim to quiet the mind, transcend distractions, and cultivate a deep sense of presence and mindfulness, focused on developing greater mental resilience and emotional balance. Sankalpa (“resolve” or “intention”) was also used during meditation, it is a tool used to set a clear and positive intention for one's life or practice, a heartfelt affirmation of one's deepest values, aspirations, and purpose. It serves

as a constant reminder of what truly matters and empowers individuals to align their thoughts, words, and deeds with their deepest intentions.

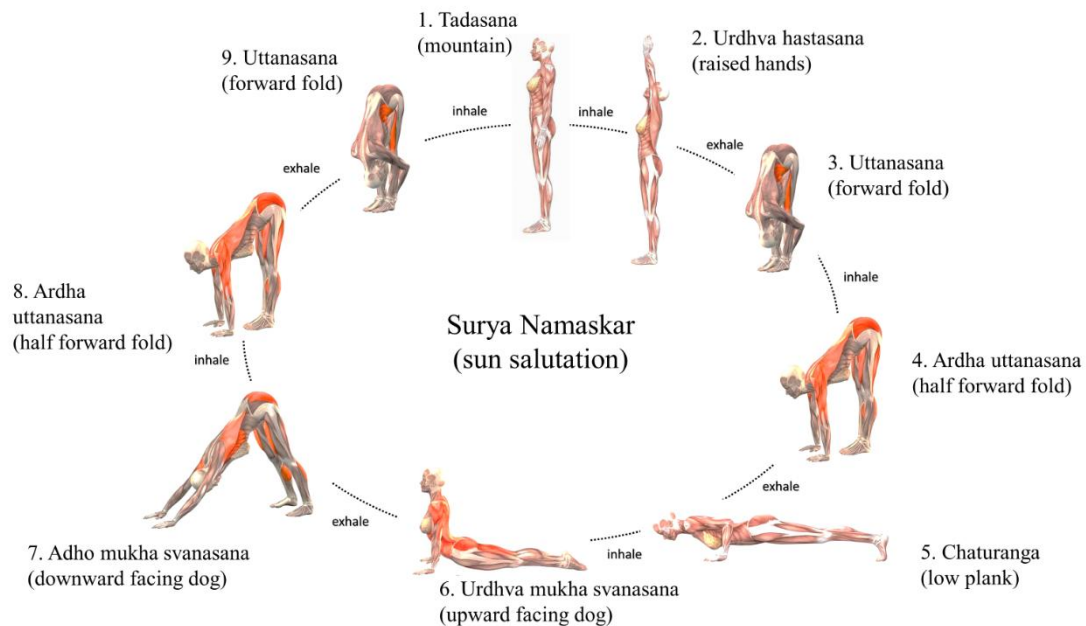


Figure 25 – Sun salutations (OM Magazine) used in the ásana component of the AVYS classes.

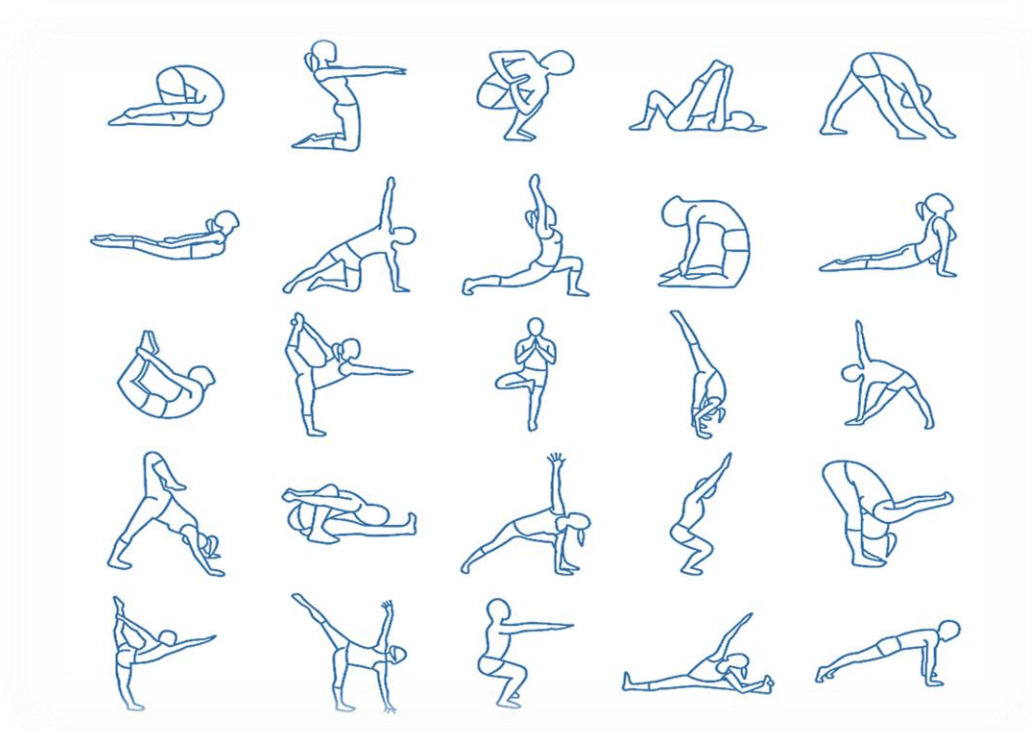


Figure 26 – Various yoga postures (ásanas) incorporated in the ásana component of the AVYS classes.



The components were adapted to the specific needs of the pilot group during their flight missions: supta classes, primarily or entirely conducted with closed eyes, aim to eliminate visual system responses and evoke vestibular system responses; Ashtanga Vinyasa classes emphasize fluid movement sequences, focusing on breathing and enhancing neck and upper limb strength through various yogic movements available to the head and spine (flexion, extension, lateral flexion, rotation, and inversion). This recalibration facilitates the pilot's awareness of their spatial orientation, complemented by improvements in embodiment and proprioception. This, in turn, enhances the pilot's perception of the aircraft's orientation and their own position in relation to it, as well as their spatial awareness of the aircraft in relation to the Earth. The classes commenced with basic-level techniques, progressing to more advanced ones as the intervention group's proficiency and abilities improved over the timeline. Otherwise, participants were instructed to maintain their regular routines.

4.8. Materials and Methods for the RCT studies

Data collection for RCT Study 1 on HRV and pilot performance

Pilots completed a 30-minute scenario encompassing visual and instrument flight conditions in a flight simulator (Epsilon - SEPS TB30, in Figure 18). All flight maneuvers followed a predetermined sequence with randomized emergency activation times. Action durations were timed using a chronometer (Huawei P20Pro stopwatch app). Performance feedback was provided by the flight simulator controller, based on Airforce emergency protocol adherence. Autonomic modulation was measured with HRV in basal conditions (3 minutes) with the pilots sitting inside the simulator cabin immediately prior the simulation maneuvers, during the simulation maneuvers, as well as immediately after the simulation maneuvers (3 minutes). Operative performance was measured during the flight simulation maneuvers. Participants refrained from consuming substances affecting the nervous system 24 hours before the protocol.



Figure 27 – Left, the inside of the cockpit for the flight simulator Epsilon TB-30 and a pilot ready to start the protocol; right, the inside of the control room and the setup device of the flight simulator operator.

All pilots are equipped with a manual for resolving flight emergencies, which may be accessed either in a physical book form or on a tablet as shown in Figure 27 and has the step-by-step protocol to be used in solving any flight emergency that might happen.

The autonomic response of pilots was evaluated during different maneuvers: Habituation, First Take-off, First Flight, Touch & Go maneuver (composed of First Landing and Second Take-off maneuvers), Second Flight, Emergency composed of an alternator failure (the emergency is activated by the simulator controller leading to the emergency protocol response actions), and Recovery.

Heart-rate monitor Polar H10 (Pulopulos et al., 2018; Wilson, 2019) was used to measure HRV. Different HRV variables were extracted in the time domain, frequency domain and non-linear measures. In the time domain, mean heart rate (HR), RR intervals, standard deviation of all normal-to-normal RR intervals (SDNN) and root mean square of successive differences RR interval differences (RMSSD) were extracted (Stoller et al., 2012; Wilson, 2019). In the frequency domain, the Low Frequency (LF) (ms²), the High Frequency (HF) (ms²) and the Total Power, were calculated (Shaffer et al., 2014; Shaffer et al., 2017). Lastly, nonlinear measures, such as RR variability from heartbeat to short



term Poincare graph (width) (SD1), RR variability from heartbeat to long term Poincare graph (length) (SD2), Stress Index (SI – representing the degree of load on the autonomic nervous system), SNS INDEX (Sympathetic Nervous System Index) and PNS INDEX (Parasympathetic Nervous System Index) were also obtained (Wilson, 2019; Shaffer et al., 2014; Shaffer et al., 2017; Baevsky et al., 2017). Kubios HRV software was used for pre-processing in accordance with manufacturer's instructions (Liponen et al., 2019; Gabani et al., 2024).

Performance was measured by the time to correctly complete the protocol of emergency response: after the flight simulator controller activated the emergency on the simulator the pilots had to identify the emergency and choose the correct actions to respond. The simulator would shut down when the pilot's life was at risk or the damage to the aircraft was severe. The two variables used for this study were the time to solve the emergency (in minutes) and the number of mistakes made by the pilot (including not performing or incorrectly performing the steps of the emergency protocol).

The materials and methods allowed for effective measurement of autonomic modulation and operational performance (Stephenson et al., 2021), offering insights into stress and decision-making capacity impacts on pilots during emergencies. The use of HRV analysis, performance timing, and simulator feedback provided a robust, cost-effective assessment with portable, minimally invasive tools suitable for military settings.

Data collection for RCT Study 2 on health, strength and respiratory capacity

Body height was asked according to each pilot's official identification documents (Cartão do Cidadão) and weight was measured using an electric bioimpedance scale (Tanita, MC-780 MA, Tanita, Tokyo, Japan).

The handgrip force was evaluated using a handgrip dynamometer (Baseline Smedley, Model 12-0286, White Plains, NY, USA). The test was conducted in a bipodal position, and the dominant arm tested next to the body with flexion of about 90° of the elbow. The dynamometer was adjusted to the width of each individual's hand. Participants were instructed to grip the dynamometer with maximum isometric effort for 3 seconds, with 3 attempts to the dominant hand and about 30 seconds apart. The mean of the attempts was used to determine the handgrip strength of each individual (Wang et al., 2018).

Respiratory capacity was analyzed with a spirometer (Vitalograph copd-6™) before and after a 12-week AVYS program. The spirometry reference values are derived from a population similar to the study participants (young Caucasian adults), with the same type of assessment instrument and protocol used in this reference document (David, 2022; Pellegrino, 2005). Forced Ventilatory Capacity (FVC) was evaluated with a spirometer (Vitalograph copd-6™), and each individual was asked for a long inspiration, followed by strong and long expiration for the mouth of the device and these values were recorded. Another volume evaluated and extremely important is the FEV1, which corresponds to the amount of air eliminated in the first second of the forced expiratory maneuver, as well as the FEV6, which corresponds to the amount of air eliminated in the first six seconds of the forced expiratory maneuver (David, 2022).

The pilot's general health subjective assessment was analyzed with the SF-36V1 questionnaire, before and after a 12-week AVYS program. It measures health-related quality of life across various domains, including physical functioning, role limitations due to physical health, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems, and mental health. The SF-36 questionnaire scores each domain on a scale ranging from 0 to 100, with higher scores indicating better health-related quality of life (Severo et al., 2006; White et al., 2018; Ware, 1993).

The choice of materials and methods was carefully selected to provide a comprehensive assessment of physical fitness, respiratory function, and general health in the pilot cohort, ensuring portable, easy to use, minimally invasive, reliable and valid measurements:

- Anthropometric measurements were taken with official identification documents to ensure accuracy.
- Biopedance scales are reliable, portable and easy to use in military settings (Aandstad et al., 2014).
- Handgrip strength is a well-established indicator of overall muscular fitness and has been correlated with performance in military personnel (Gonçalves et al., 2018; Gałdzińska et al., 2022).
- Spirometry was chosen for its portability, accuracy, and adherence to international standards for lung function testing (NASA, 2022). Parameters such as FVC, FEV1, and FEV6 were recorded, as these are key



indicators of pulmonary health, particularly in high-stress environments like aviation (Berglund et al., 2022).

- The SF-36V1 questionnaire was selected to provide a holistic evaluation of pilots' physical and mental health, as it covers multiple domains of quality of life. Its use is documented in military clinical research, and its standardized scoring system allows for straightforward comparison (Barreto et al., 2021).

Data collection for RCT Studies 3 and 4 on linear and non-linear CoP variables

Pilot's CoP response was analyzed using the Biosignals Plux force platform, to evaluate the effects of the AVYS training program on the systems that influence postural behavior, namely the vestibular system (Gaul et al., 2020).

The pilots completed a flight emergency protocol in a flight simulator before and after the 12-week period. CoP displacement in an open-eye and closed-eye bipodal position was collected before and after all these maneuvers, and both measurements were taken before and after the 12-week period. Subjects were asked to stand comfortably on both legs on a force platform (Biosignals Plux, Portugal) for 60 seconds, with their arms by their sides. This was completed twice, once with the subject's eyes open and once with the eyes closed. The force platform was placed 1.5 m from a wall, which each participant faced. The force platform's readings were used to determine the CoP for each subject over time.

The use of the Biosignals Plux force platform is particularly appropriate as it provides high-precision measurements of force distribution and CoP dynamics, which are essential for understanding postural stability in high-stress scenarios typical of military operations. This portable, non-invasive technology allows for a detailed analysis of postural sway under different conditions in the military (Kohen-Raz et al., 1994; Heller et al., 2009; Rawcliffe et al., 2020; Eslami et al., 2021; Fonseca et al., 2021; Polak et al., 2022; Brix et al., 2023).

The center of pressure (CoP) was calculated according to the manufacturer's specifications, and both the linear and non-linear variables of the CoP coordinates were analyzed. Preprocessing was performed MATLAB R2024a Update 6 (24.1.0.2689473), 64-bit (win-64), July 29, 2024 (The MathWorks Inc., Natick, MA). Data was down sampled to 50 Hz. Linear variables were computed using custom MATLAB scripts, consistent with previous approaches in the UNO Biomechanics Research Laboratory

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(Stergiou, 2004). Analysis scripts for the non-linear data were based on tools developed by the Nonlinear Analysis Core at the University of Nebraska at Omaha. Data was collected directly before and directly after a flight simulation and before and after the 12-week period, to investigate the immediate effect of stimuli. Pilots were in bipodal stance with both open and closed eyes.

Data collection for RCT Study 5 on decision making capacity for operational performance

Pilots completed a 30-minute scenario in a flight simulator (Epsilon - SEPS TB30), involving both visual and instrument flight conditions. Flight maneuvers followed a set sequence with randomized emergency activation times.

Performance was measured by the correct identification of the emergency and the actions taken by the pilots. The study focused on the number of mistakes made (out of 35 steps identified in Figure 28, including not performing or incorrectly performing the steps) and the type of mistakes (ranked by severity, with the simulator shutting down if the pilot's life would be at risk or the aircraft would be in danger of being severely damaged).

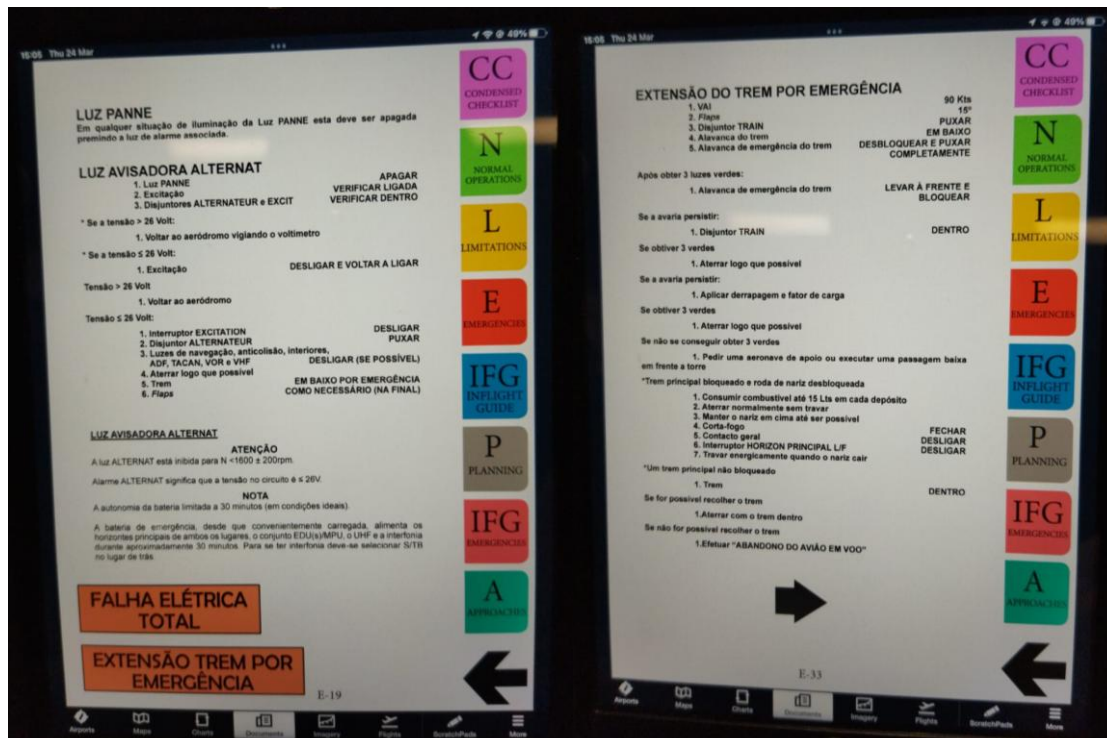


Figure 28 – The emergency response manual has step-by-step instructions for dealing with alternator failure emergency, shown on pages 1 (left) and 2 (right) in Portuguese language. Pilots need to follow these steps and report to the control tower in English. There are 33 steps to follow and 35 possible mistakes, including not reporting to the control tower and taking too long to land the plane.



The study used several validated tools to measure outcomes related to stress, mindfulness, interoceptive awareness, safety attitudes, and risk perception:

1. Five Facet Mindfulness Questionnaire (FFMQ): Assesses mindfulness through five dimensions—observing, describing, acting with awareness, non-judging, and non-reactivity. (Baer et al., 2008; Carpenter et al., 2019). Higher mindfulness can enhance situational awareness and adaptability, critical for making effective decisions under pressure. Enhanced cognitive flexibility and emotional control contribute to effective decision making in unpredictable situations (Proctor et al., 2017; Shortland et al., 2019; Kuczynski, 2023; Woll, 2019).
2. Multidimensional Assessment of Interoceptive Awareness (MAIA): Measures awareness of internal bodily states, covering aspects like noticing, emotional awareness, and self-regulation (Machorrinho et al., 2019). Greater interoceptive awareness can improve decision making by allowing pilots to respond more effectively to stress and body signals. Better awareness can lead to improved cognitive processing under stress, aiding in mission success (Proctor et al., 2017; Shortland et al., 2019; Kuczynski, 2023; Woll, 2019).
3. Aviation Safety Attitude Scale (ASAS): Evaluates pilots' attitudes toward aviation safety and potential hazardous behaviors (Hunter et al., 2005). Higher scores in self-confidence and positive safety attitudes correlate with better decision making in high-stakes environments. Strong cognitive performance in assessing risk is vital for mission safety and effectiveness (Proctor et al., 2017; Shortland et al., 2019; Kuczynski, 2023; Woll, 2019).
4. Risk Perception To Self (RPTS): Assesses pilots' risk perceptions and tolerance, critical for decision making under pressure (Hunter et al., 2002). This tool evaluates how pilots perceive and evaluate risks in various situations, as well as assesses the degree of risk the pilot is willing to accept in high-pressure environments, making pilots capable of understanding personal capabilities and limitations in risky scenarios. Effective risk assessment and tolerance are critical for decision making in combat and aviation environments, where quick judgments are necessary under pressure. Pilots with enhanced risk perception are better equipped to make informed choices, reducing the likelihood of hazardous

incidents and ensuring mission success (Baker et al., 2010; Proctor et al., 2017; Kahn et al., 2018; Shortland et al., 2019; Kuczynski, 2023; Woll, 2019).

5. Trail Making Test (TMT A & B): A neuropsychological test that measures cognitive abilities like processing speed, task switching, and executive function. TMT-A focuses on sequential number connection, while TMT-B alternates between numbers and letters, indicating cognitive flexibility (Bowie et al., 2006). This tool assesses how quickly a pilot can connect information and make decisions and also evaluates the ability to switch attention between tasks efficiently, measuring higher-level cognitive processes, including planning, cognitive flexibility, and working memory. This will indicate how well a pilot can adapt to changing conditions or unexpected situations. TMT results are particularly relevant for military personnel who must operate in dynamic environments requiring rapid information processing and decision making. Enhanced cognitive flexibility and processing speed contribute to improved situational awareness and adaptability, which are essential for effective military operations (Proctor et al., 2017; Shortland et al., 2019; Kuczynski, 2023; Woll, 2019).

Overall, the combination of simulator performance metrics and validated psychological assessments provide a robust framework for understanding the intricate dynamics of pilot performance in emergency scenarios, addressing both operational and psychological factors critical for effective decision making in high-stakes military environments (Proctor et al., 2017; Shortland et al., 2019; D'Alessio et al., 2024).



Data collection for the RCT study

By using these tools, the study aimed to comprehensively assess the impact of a 12-week AVYS program on the Portuguese military pilots:

Table 4. RTC study parameters.

Parameter	Unit	Description
HRV – Time domain		
HR	ms	Mean heart rate.
RR intervals	ms	RR interval differences.
SDNN	ms	Standard deviation of all normal-to-normal RR intervals.
pNN50	%	Percentage of intervals > 50 ms different from the previous interval.
RMSSD	ms	Root mean square of successive differences RR interval differences.
HRV – Frequency domain		
LF	ms ²	Low Frequency band in normal units (0.04- 0.15 Hz).
HF	ms ²	High Frequency the high-frequency band in normal units (0.15- 0.4 Hz).
LF/HF	%	The ratio between LF/HF.
Total Power		
HRV – Non-linear		
SD1	%	RR variability from heartbeat to short term Poincare graph plot standard deviation perpendicular the line of identity (% of width in ms).
SD2	%	RR variability from heartbeat to long term Poincare graph plot standard deviation along the line of identity (% of length in ms).
SI	%	Stress Index (representing the degree of load on the autonomic nervous system).
SNS index	dimensionless score	The SNS (Sympathetic Nervous System) index value typically reflects the balance of autonomic nervous system activity, particularly indicating the level of sympathetic arousal. It represents the relative dominance of the sympathetic nervous system compared to the parasympathetic system. Higher values indicate greater sympathetic activation (stress response).
Anthropometric measurements		
Height	cm	Height of the pilots, in cm, according to official documents
Weight	kg	Weight of the pilots, in kg, measured with bioimpedance

General Health		
SF-36V1	dimensionless unit	The Short Form 36 Version 1 questionnaire. Each domain is scored on a scale from 0 to 100, where higher scores indicate better health status. The scores are derived from responses to multiple items within each domain.
Strength		
Handgrip Strength	kg	Mean value of the 3 attempts of maximum force exerted by the hand, measured with a handgrip dynamometer
Spirometry		
FVC	L	Forced Ventilatory Capacity (also known as the forced expiratory volume) is the maximal volume of air exhaled with a maximally forced effort from a position of full inspiration
Lung Capacity	dimensionless unit	FEV1/FVC (Forced Expiratory Volume in 1s and Forced Vital Capacity) ratio. This ratio compares the volume of air a person can forcibly exhale in one second (FEV1) to the total volume of air they can exhale forcefully after taking a deep breath (FVC).
FEV1	%	Forced Expiratory Volume in 1 second
FEV6	%	Forced Expiratory Volume in 6 seconds
CoP displacement – linear variables		
Total CoP displacement	mm	The distance traveled by the CoP during standing, measuring how much a person sways while trying to maintain a stable position.
CoP displacement – non-linear variables		
SaEn_AP, SaEn_ML	dimensionless	Sample Entropy in Antero-posterior and Mediolateral Directions. Complexity measure that represents the unpredictability of time series data.
ApEn_AP, ApEn_ML	dimensionless	Approximate Entropy in Anteroposterior and Mediolateral Directions. Measures the regularity and complexity of fluctuations in time series data.
LyE_AP, LyE_ML	s ⁻¹	Lyapunov Exponent in Anteroposterior and Mediolateral Directions. Rate of divergence or convergence of trajectories in the system, indicating stability or chaos.
CoDim_AP, CoDim_ML	dimensionless	Correlation Dimension in Anteroposterior and Mediolateral Directions. Reflects the complexity of the dynamical system, estimating the minimum number of variables required to model the system.



alfa_AP, alfa_ML	dimensionless	Alpha Entropy in Anteroposterior and Mediolateral Directions. A measure of complexity, related to the fractal properties of the time series.
Operational performance		
Performance	s	Time to complete the protocol of emergency response in the flight simulator: identify the emergency and choose the correct actions to respond.
Number of mistakes made		There are 33 steps to follow identified in the emergency solving protocol and 35 possible mistakes, including not reporting to the control tower and taking too long to land the plane. Not performing or incorrectly performing the steps will add to the count of mistakes made.
Type of mistakes made		Ranked by severity, with the simulator shutting down if the pilot's life would be at risk or the aircraft would be in danger of being severely damaged.
Decision making capacity		
FFMQ	scored using a Likert scale	Assesses mindfulness through five dimensions—observing, describing, acting with awareness, non-judging, and non-reactivity.
MAIA	scored using a Likert scale	Measures awareness of internal bodily states, covering aspects like noticing, emotional awareness, and self-regulation.
ASAS	scored using a Likert scale	Evaluates pilots' attitudes toward aviation safety and potential hazardous behaviors.
RPTS	scored using a Likert scale	Assesses pilots' risk perceptions and tolerance.
TMT A	s	Focuses on sequential number connection, measures processing speed and executive function.
TMT B	s	Alternates between numbers and letters, indicating cognitive flexibility during task switching.

4.9. Statistical Analysis for the case control study and the RCT study

Sample size was calculated with OpenEpi. Data analyses were done with MATLAB (MathWorks Inc., 2022) and Jamovi (Jamovi, 2022), based on the type of data; analyses were performed based on the underlying assumptions for parametric, or non-parametric testing. In detail, for all difference testing, data and variance distribution (i.e., normality) were checked. The alpha-error threshold was set at 5%, all p values below were considered significant.

For the case control outcomes descriptive statistics were used as the sample size consists of 4 individuals (McGough et al., 2009; Sullivan et al., 2012; Ho et al., 2019). For the primary outcomes related to postural control and HRV, a MATLAB (MathWorks Inc., 2022) routine was used to treat data exported from the Biosignals Plux platform (consistent with previous approaches in the UNO Biomechanics Research Laboratory (Stergiou, 2004)) and also from the Polar H10 portable monitor (consistent with manufacturers recommendations). With those values a Shapiro–Wilk normality test was performed and either a T-test for independent samples between groups or paired samples within groups was applied on parametric data or a Wilcoxon rank test was applied on non-parametric data (McGough et al., 2009; Sullivan et al., 2012; Ho et al., 2019).

For the primary outcomes related to operative performance and for the secondary outcome's descriptive statistics for both the intervention and control groups were then generated using Jamovi (Desktop version 2.3.16). Normality was assessed using the Shapiro-Wilk test, with p-values greater than 0.05 indicating normal distribution, while p-values less than or equal to 0.05 suggested non-normal distribution (McGough et al., 2009; Sullivan et al., 2012; Ho et al., 2019).

T-Tests (Student's t) were conducted for independent and paired samples and effect sizes (Cohen's d) were calculated for normally distributed data. For non-normally distributed data, the Wilcoxon rank test (Wilcoxon W) was employed, a common nonparametric alternative that can be used to compare the medians of two groups for small samples, and computed effect sizes using Rank Biserial Correlation. In both cases significant values typically fall below the conventional threshold of 0.05 (McGough et al., 2009; Sullivan et al., 2012; Ho et al., 2019).

Merely stating the significant P value of an analysis is not sufficient for readers to fully understand the results or the practical implications of the results for daily life (Ho et al., 2019; Lakens et al., 2013; Sullivan et al., 2012). While a P value can provide information about whether an effect exists, the P value doesn't give information on the size of the effect. When reporting and interpreting studies, both substantive significance (effect size) and statistical significance (P value) are essential results to report (Ho et al., 2019; McGough et al., 2009; Sullivan et al., 2012). Effect size guidelines were used to interpret the results, with values of 0.2 indicating small effect, 0.5 for medium effect, and 0.8 for large effect (Landis et al., 1977; Chmura et al., 2002; Lakens et al., 2013). This



comprehensive data analysis helped to assess the outcomes and evaluate the magnitude of effects within and between groups. For CoP displacement RCT studies 3 and 4 the paired Hedges' g for repeated measures against baseline was measured in the Cumming estimation plots for additional effect size comparisons (Ho et al., 2019).

5



CHAPTER 5 | Results



5.1. Bibliometric Analysis Results

H-index

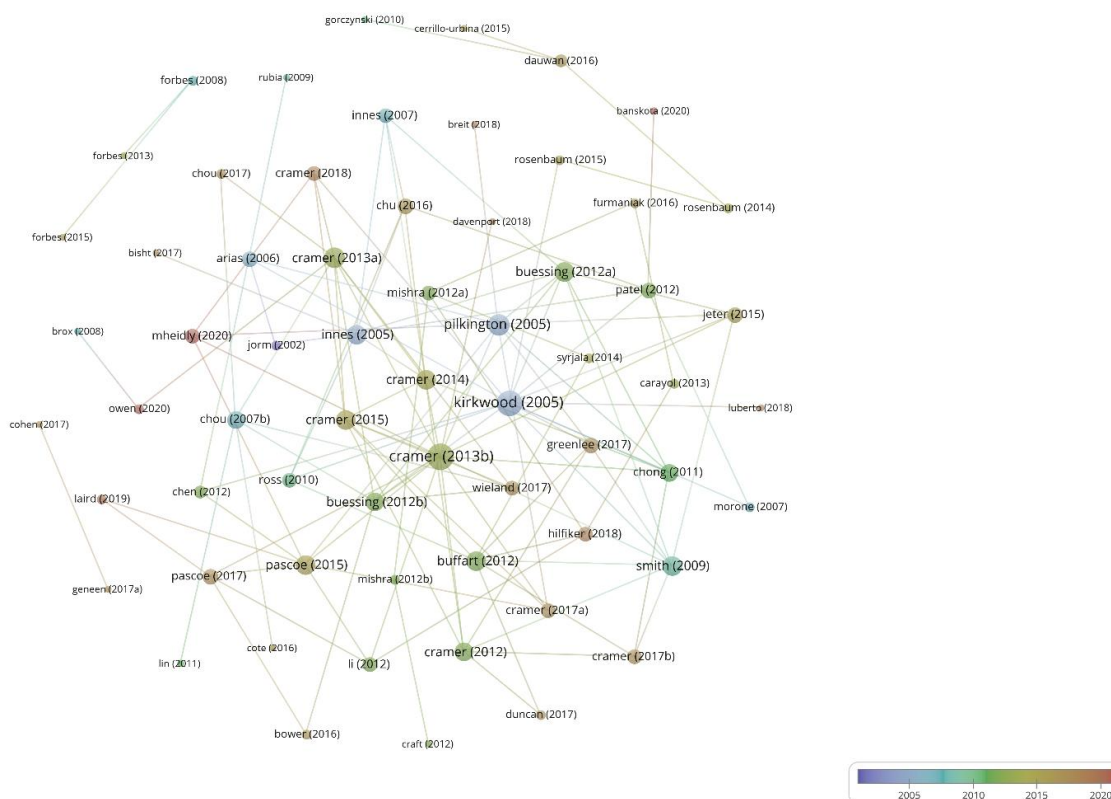


Figure 29 – The h-index has been established at 93.

The h-index for the set of 1,260 review articles has been established at 93, with 93 documents receiving 93 or more citations (ranging from 95 to 2019 citations). Figure 29 shows that 63 of these 93 articles have cross-citations among themselves, allowing for the establishment of causality, based on timing, of a predecessor document in the production of the citing documents.



Average frequency of keywords

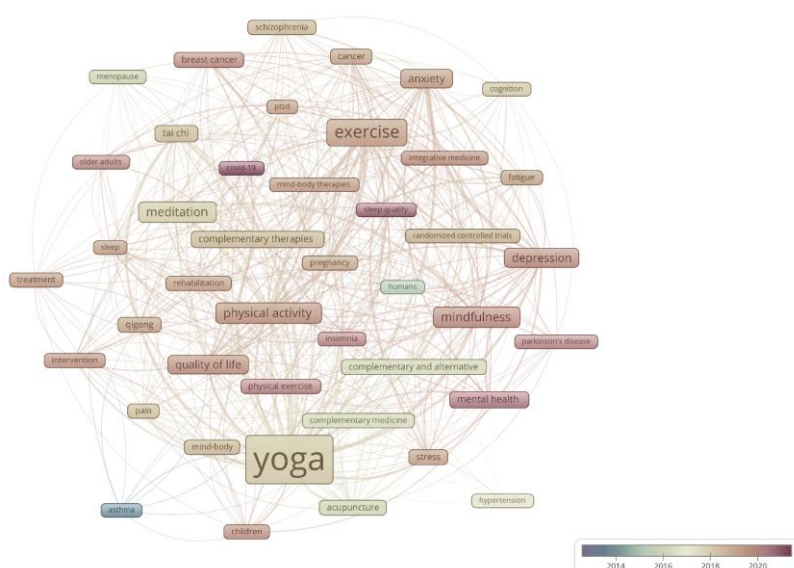


Figure 30 – Indicates the average frequency with which these words have been used by the authors in the articles of the h-index of the bibliometric analysis.

5.2. Study Protocol Results

The Portuguese Airforce has approved the implementation of this intervention protocol at Airbase 11 in Beja, highlighting its significance for the organization's policy makers. We hypothesized that this method would enhance operational performance and, subsequently, elevate flight safety.

(Anticipated) Results

The principal objective of the study was to assess the feasibility and efficacy of implementing a 12-week AVYS program to enhance existing military training protocols within the Portuguese Air Force. This was accomplished through the utilization of a randomized controlled intervention design. The intervention comprises preventive exercises tailored to address perceived challenges faced by pilots during aircraft piloting, thereby enhancing the capabilities of individuals who are already undergoing training.

The findings of this study hold significance for the research group and are equally pertinent for policymakers within the Portuguese Air Force. The data gathered in this project can aid policy makers in developing a tailored exercise regimen.

The published article is available in <https://doi.org/10.3389/fpubh.2024.1334880>.

5.3. Case control Study Results

The aim of this research was to analyze the effect of flight experience in the autonomic response and operative performance of professional combat aircraft pilots in a flight simulator emergency flight maneuver. The descriptive table of results for the HRV in baseline and emergency maneuvers for the two Expert Pilots (EP) and the two Rookie Pilots (RP):

Table 5. The results of the HRV in baseline and emergency manoeuvres.

		Baseline	T1 and E1	T2	E2	T3	E3	T4	E4
MEAN HR (bpm)	EP	81,00 ($\pm 1,40$)	94,50 ($\pm 3,50$)	85,00 ($\pm 8,50$)	88,50 ($\pm 3,50$)	84,00 ($\pm 1,40$)	90,00 ($\pm 8,50$)	82,50 ($\pm 2,10$)	86,50 ($\pm 3,50$)
	RP	82,00 ($\pm 5,70$)	102,00 ($\pm 9,90$)	89,00 ($\pm 7,10$)	93,00 ($\pm 9,90$)	86,50 ($\pm 12,00$)	89,50 ($\pm 9,20$)	80,00 ($\pm 11,30$)	85,00 ($\pm 7,10$)
RMSSD (ms)	EP	21,50 ($\pm 6,60$)	10,55 ($\pm 1,30$)	19,40 ($\pm 4,80$)	15,30 ($\pm 0,70$)	14,65 ($\pm 0,60$)	17,40 ($\pm 6,10$)	21,90 ($\pm 2,40$)	17,20 ($\pm 1,70$)
	RP	38,70 ($\pm 19,10$)	11,90 ($\pm 4,00$)	27,40 ($\pm 17,40$)	25,10 ($\pm 13,90$)	30,15 ($\pm 21,60$)	25,50 ($\pm 14,6$)	37,45 ($\pm 26,80$)	32,45 ($\pm 19,70$)
LF (ms2)	EP	0,10 ($\pm 0,02$)	0,072 ($\pm 0,02$)	0,10 ($\pm 0,01$)	0,06 ($\pm 0,02$)	0,07 ($\pm 0,03$)	0,08 ($\pm 0,00$)	0,12 ($\pm 0,04$)	0,07 ($\pm 0,04$)
	RP	0,10 ($\pm 0,04$)	0,10 ($\pm 0,07$)	0,10 ($\pm 0,03$)	0,11 ($\pm 0,02$)	0,09 ($\pm 0,01$)	0,09 ($\pm 0,01$)	0,44 ($\pm 0,47$)	0,11 ($\pm 0,02$)
HF (Hz)	EP	0,21 ($\pm 0,08$)	0,20 ($\pm 0,02$)	0,19 ($\pm 0,05$)	0,23 ($\pm 0,07$)	0,18 ($\pm 0,04$)	0,15 ($\pm 0,00$)	0,16 ($\pm 0,01$)	0,18 ($\pm 0,01$)
	RP	0,21 ($\pm 0,06$)	0,16 ($\pm 0,02$)	0,18 ($\pm 0,02$)	0,18 ($\pm 0,01$)	0,16 ($\pm 0,01$)	0,20 ($\pm 0,04$)	0,16 ($\pm 0,010$)	0,15 ($\pm 0,00$)
POWER (ms²)	EP	1404,50 ($\pm 1368,3$)	372,50 ($\pm 392,4$)	659,00 ($\pm 408,7$)	481,50 ($\pm 335,9$)	545,50 ($\pm 368,4$)	805,00 ($\pm 106,1$)	1184,50 ($\pm 108,2$)	725,50 ($\pm 150,6$)
	RP	2666,50 ($\pm 2591,5$)	393,00 (± 239)	1263,50 ($\pm 1031,7$)	1511,50 ($\pm 1219,8$)	3231,00 ($\pm 3405,4$)	1106,50 ($\pm 553,7$)	3462,00 ($\pm 3900,4$)	3639,50 ($\pm 3752,6$)
SDNN (ms)	EP	33,15 ($\pm 17,20$)	19,95 ($\pm 10,7$)	29,35 ($\pm 1,60$)	24,20 ($\pm 3,10$)	23,05 ($\pm 9,30$)	27,30 ($\pm 4,00$)	32,60 ($\pm 1,10$)	26,90 ($\pm 3,30$)
	RP	46,45 ($\pm 16,10$)	23,35 ($\pm 7,10$)	39,80 ($\pm 23,60$)	39,70 ($\pm 15,80$)	54,65 ($\pm 37,80$)	42,45 ($\pm 18,9$)	58,45 ($\pm 39,20$)	51,40 ($\pm 29,60$)
SD2 (%)	EP	73,10 ($\pm 5,20$)	76,15 ($\pm 8,30$)	74,20 ($\pm 4,10$)	74,90 ($\pm 1,70$)	73,05 ($\pm 8,10$)	74,50 ($\pm 3,70$)	73,6 ($\pm 3,10$)	74,45 ($\pm 4,60$)
	RP	69,20 ($\pm 3,80$)	78,95 ($\pm 0,90$)	73,45 ($\pm 1,10$)	75,65 ($\pm 3,50$)	77,65 ($\pm 0,80$)	76,55 ($\pm 2,90$)	74,90 ($\pm 0,60$)	75,10 ($\pm 1,00$)
SI	EP	15,40 ($\pm 7,20$)	23,10 ($\pm 0,90$)	13,80 ($\pm 1,80$)	15,10 ($\pm 0,90$)	22,20 ($\pm 7,50$)	17,90 ($\pm 3,60$)	14,60 ($\pm 1,10$)	13,90 ($\pm 2,90$)
	RP	11,00 ($\pm 3,80$)	21,90 ($\pm 0,60$)	13,10 ($\pm 6,20$)	13,50 ($\pm 4,00$)	13,80 ($\pm 8,30$)	13,50 ($\pm 5,60$)	11,40 ($\pm 7,30$)	10,50 ($\pm 4,80$)
Performance (seg)	EP		1,22 ($\pm 0,20$)	3,68 ($\pm 0,70$)	4,83 ($\pm 2,40$)	0,32 ($\pm 0,00$)	0,30 ($\pm 0,00$)	2,88 ($\pm 0,50$)	5,22 ($\pm 0,20$)
	RP		1,60 ($\pm 0,80$)	4,77 ($\pm 2,50$)	4,31 ($\pm 1,10$)	0,38 ($\pm 0,10$)	0,92 ($\pm 0,60$)	4,12 ($\pm 0,10$)	10,88 ($\pm 0,50$)

*EP: Expert Pilots; RP: Rookie Pilots; T: Takeoff; E: Emergency; RMSSD: the square root of the mean of the squares of the successive differences of the interval RR; LF / HF: Low frequency (LF, 0.04–0.15 Hz) ratio (ms2) / High frequency (HF, 0.15–0.4 Hz) (ms2); Total power: The sum of all the spectra; SDNN: Standard deviation of normal-to-normal intervals; SD1: Dispersion, standard deviation, of points perpendicular to the axis of line-of-identity in the Poincaré plot; SD2: Dispersion, standard deviation, of points along the axis of line-of-identity in the Poincaré plot; SI: Stress Index; Performance: time to solve the emergency (min).

The aim of this research was to analyze the effect of flight experience in the autonomic response and operative performance of professional combat aircraft pilots in a flight simulator emergency flight maneuver.



Results regarding autonomic modulation showed a higher sympathetic response during the emergency maneuvers when compared to baseline, in some cases there was also a higher sympathetic response during the emergency maneuvers when compared with the takeoff protocol. Regarding performance data the expert pilots accomplished the missions in less time than the rookie pilots.

The published article is available in <https://doi.org/10.3390/ijerph19159141>.

5.4. RCT Study 1 Results on HRV and pilot performance

The aim of this research was to analyze the effect of a 12-week AVYS program in the autonomic response and operative performance of professional military aviation pilots in a flight simulator emergency.

The simulator didn't shut down for any pilot, showcasing that their life was not at risk and the damage to the aircraft was not severe at any of the evaluations performed.

Between groups results

Significant results between groups after the 12-week period, regarding non-linear HRV variables shown in Stress Index during the first landing maneuver:

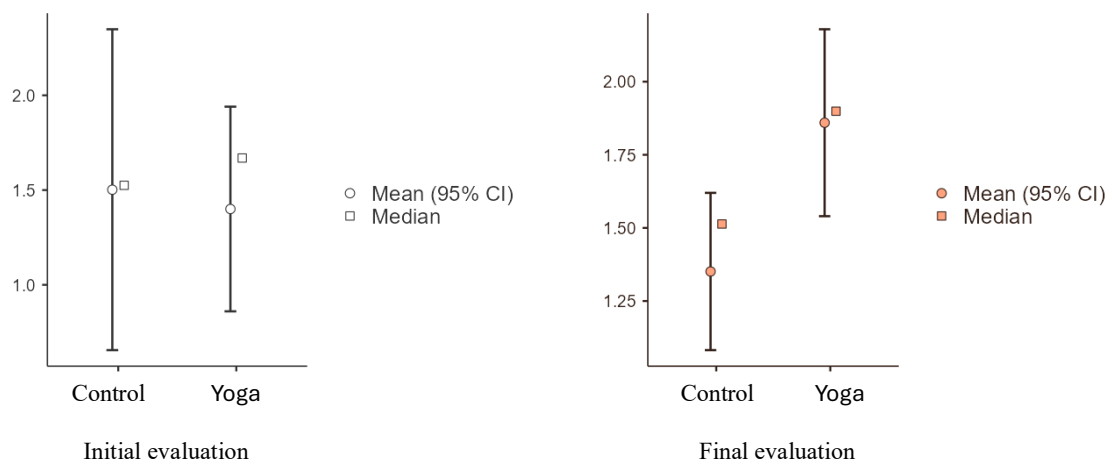


Figure 31 – Stress Index (%) had a significant increase for the yoga group.

Stress Index (%) had a significant increase for the yoga group, when compared to the control group, during the first landing maneuver on final evaluations (in orange).

Significant results between groups after the 12-week period, regarding performance variables (in number of errors) were found:

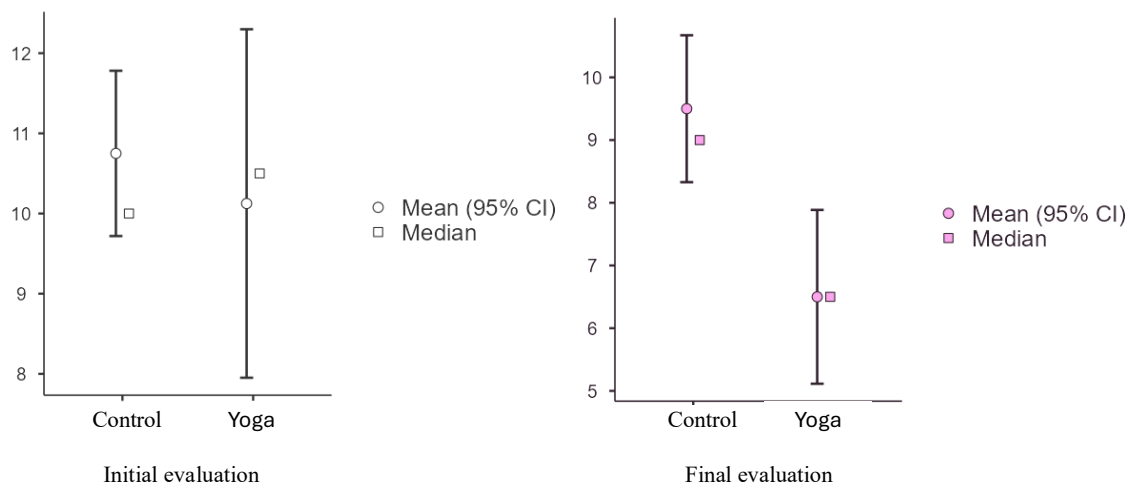


Figure 32 – Performance: number of errors. There was a significant decrease in errors for the yoga group.

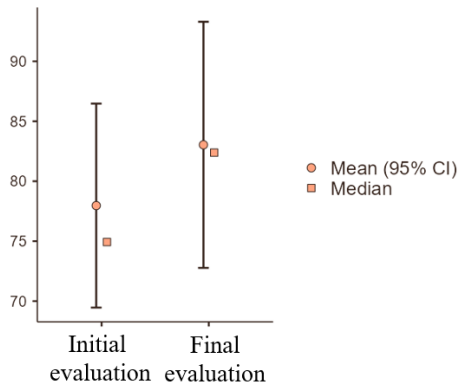
AVYS group has shown a decrease in errors made when compared with the control group, during the emergency maneuver, on final evaluations (in purple).



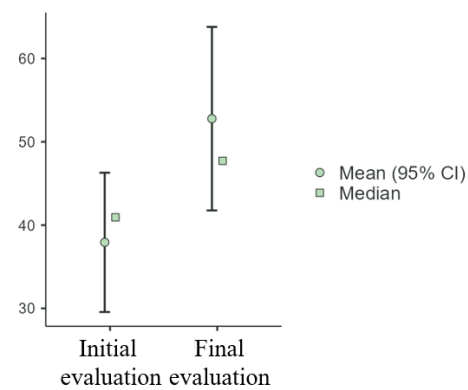
Within group results

Significant results within the AVYS group after the 12-week period, regarding time domain variables:

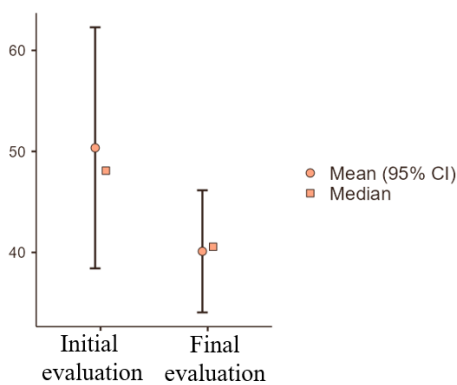
Mean HR – Yoga group - Habituation



SDNN – Yoga group – First takeoff



SDNN – Yoga group – First landing



RMSSD – Yoga group – Second flight

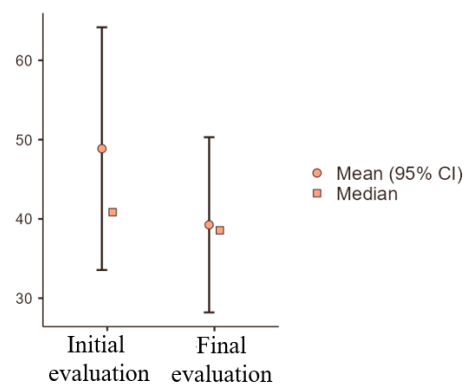
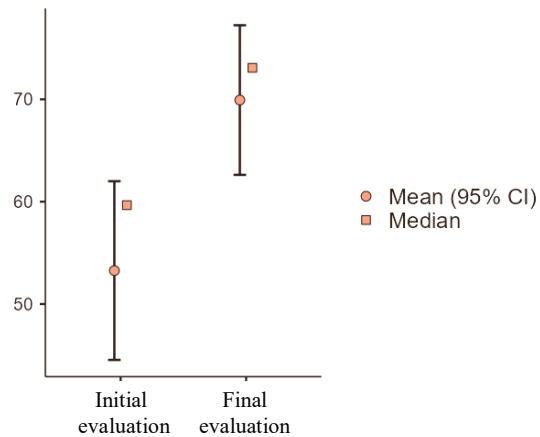


Figure 33 – Mean Heart Rate (HR), Standart deviation of all Normal-to-Normal RR intervals (SDNN) and Root Mean Square of Successive differences RR interval differences (RMSSD), all in ms, in the yoga group increased on habituation during final evaluation.

SDNN in the AVYS group increased on the first takeoff, during final evaluation. SDNN in the AVYS group decreased on the first landing, during final evaluation. RMSSD in the AVYS group decreased on the second flight, during final evaluation. Data related with sympathetic response for task attentional focus is shown in orange and stress resilience related data is shown in green.

Significant results within the AVYS group after the 12-week period, regarding frequency domain variables:

LF – Yoga group – Second flight



HF – Yoga group – Second flight

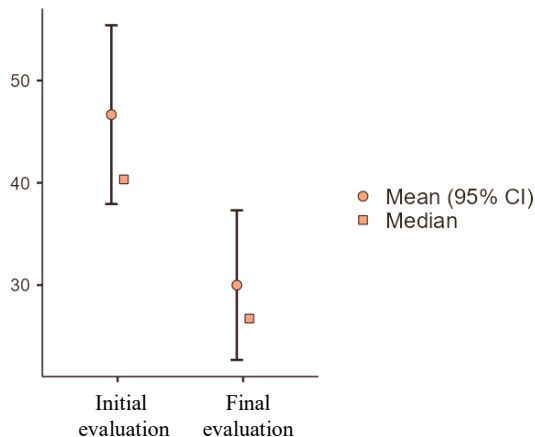


Figure 34 – For the yoga group on the second flight, during final evaluation Low Frequency band (LF in ms^2) in increased and High Frequency band (HF in ms^2) decreased.

Data related with sympathetic response variables for task attentional focus is shown in orange.



Significant results within the AVYS group after the 12-week period, regarding non-linear variables:

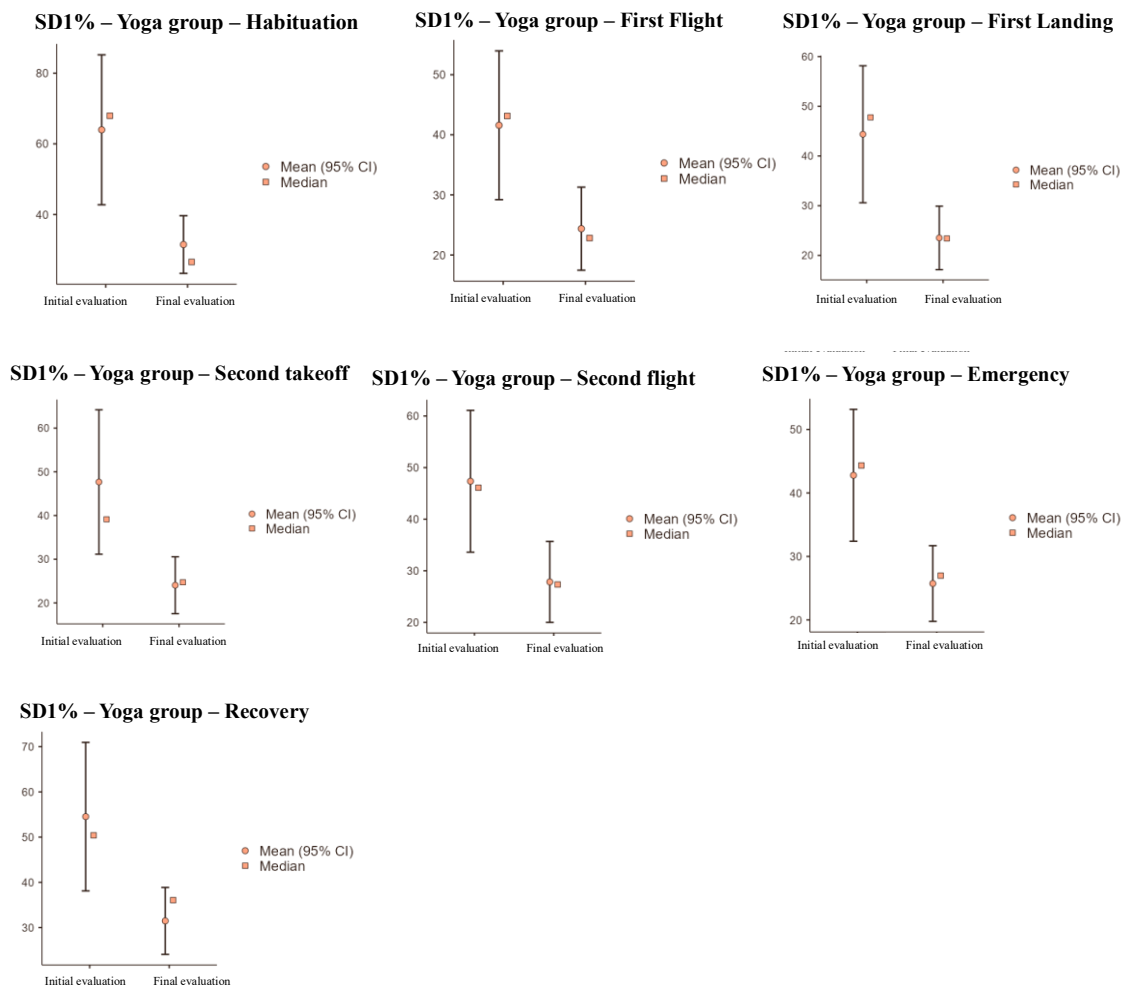
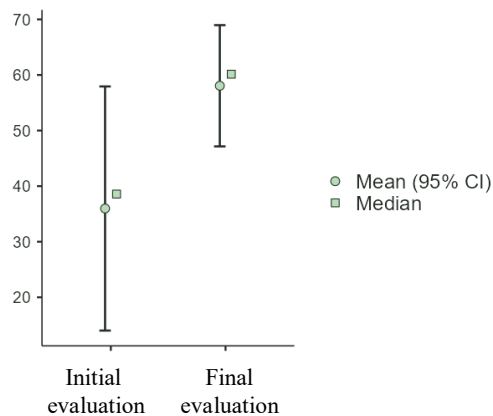


Figure 35 – RR variability from heartbeat to short term Poincare graph plot Standard Deviation (SD1%) decreased on habituation, first flight, first landing, second takeoff, second flight, emergency, and recovery.

Data related with sympathetic response for task attentional focus is shown in orange.

SD2% – Control group – First takeoff



SD2% – Yoga group – First takeoff

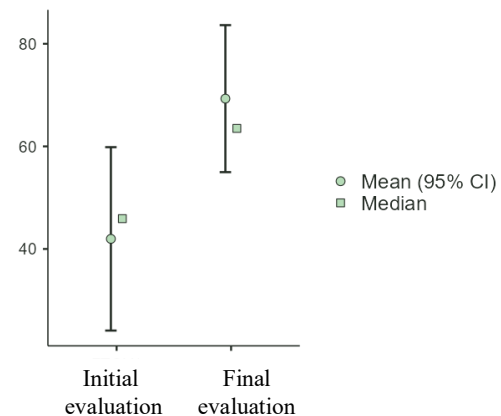


Figure 36 – RR variability from heartbeat to long term Poincare graph plot Standard Deviation SD2% increased on first takeoff for both the yoga and the control group.

Stress resilience related data is shown in green.

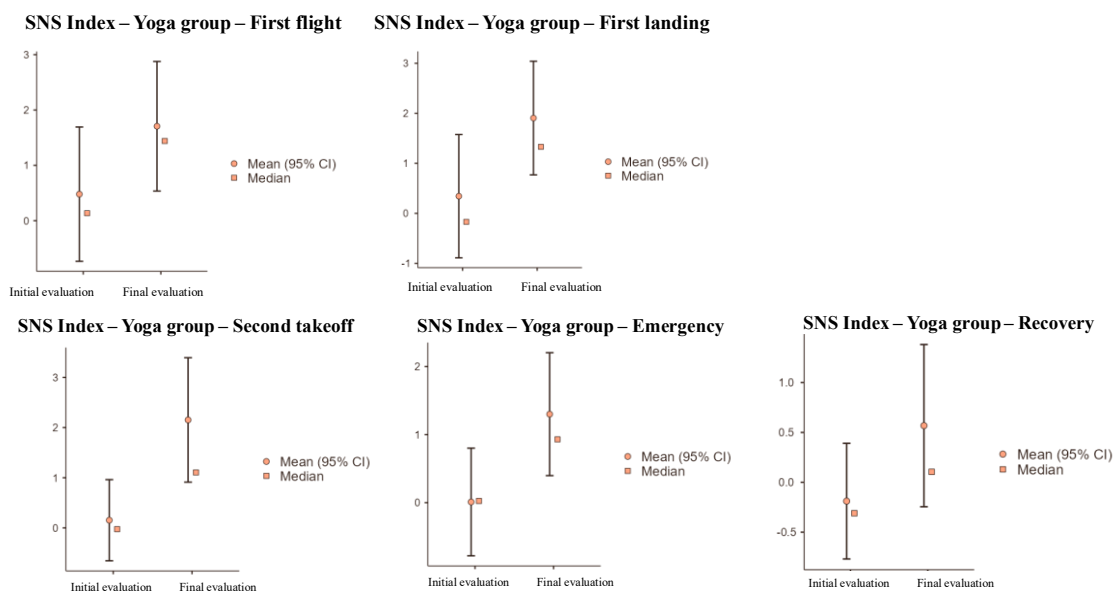


Figure 37 – Sympathetic Nervous System (SNS) Index (%) increased on first flight, first landing, second takeoff, emergency and recovery.

Data related with sympathetic response for task attentional focus is shown in orange.



Significant results within the AVYS group after the 12-week period, regarding performance variable time to complete the mission:

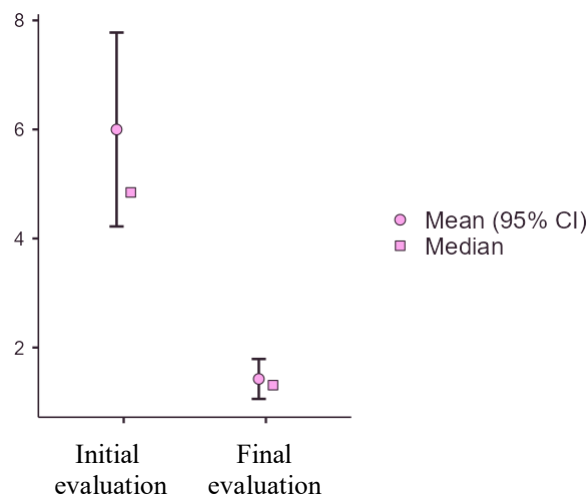


Figure 38 – Yoga group took less time (s) to complete the Touch & Go maneuver after the intervention, with a faster approach on the final assessment (in purple).

Overall, HRV analysis showed improvements correlated with stress resilience, indicated by changes in HRV parameters such as SDNN, RMSSD, LF, and HF. The Wilcoxon rank test revealed significant results regarding better performance variables within the AVYS group, particularly for the Touch & Go maneuver. While Emergency maneuver completion times for the AVYS group didn't significantly differ from the intervention group, the number of errors significantly decreased, with a notable reduction observed in the AVYS group compared to controls.

5.5. RCT Study 2 Results on health, strength and respiratory capacity

The aim of this research was to analyze the effect of a 12-week AVYS program in the general health, strength and respiratory capacity of professional military aviation pilots.

Within AVYS group results

Borg scale values show a significant decrease within the intervention group:

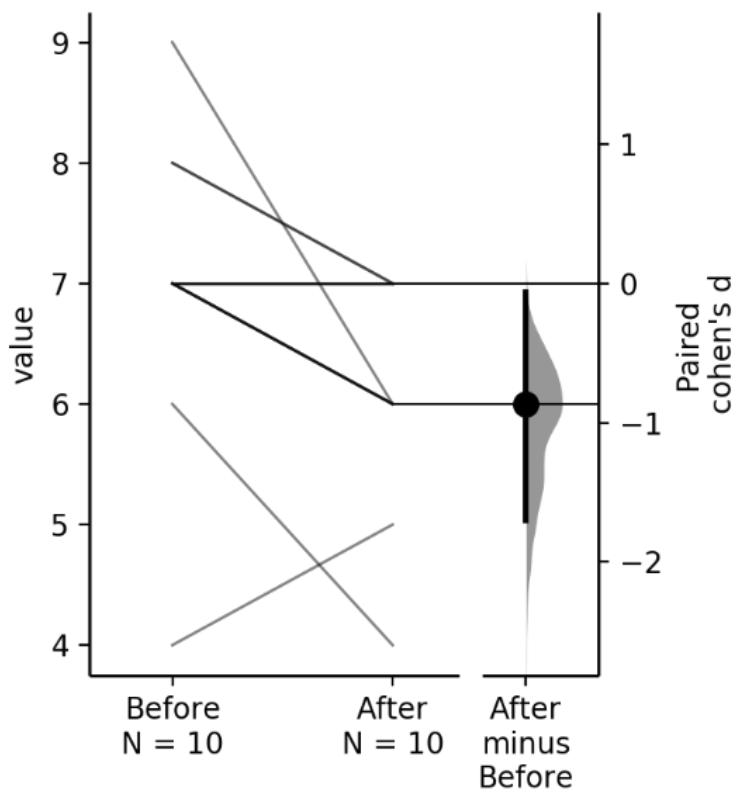


Figure 39 – The paired Cohen's d values between Borg Scale Before and Borg Scale After decreased for the yoga group.



Between groups results

Handgrip strength values show a significant difference between groups, with an increase in the intervention group when compared to the control group:

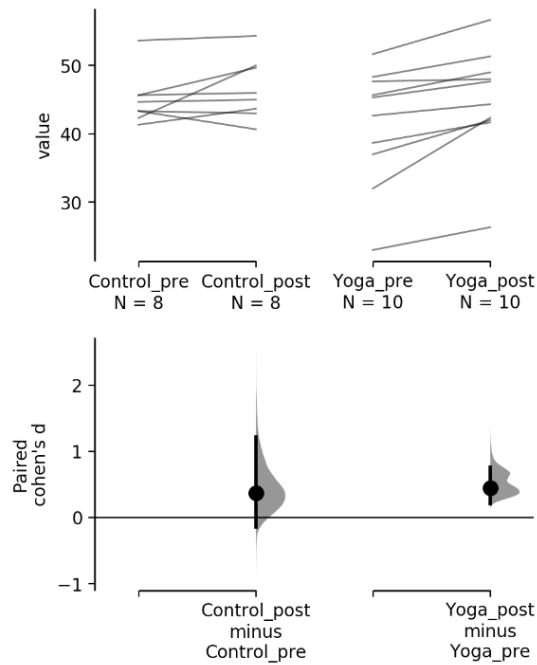


Figure 40 – Handgrip strength (in Kg) for the paired Cohen's d for the control vs AVYS group.

Lung capacity and FEV1% values comparison between groups showed increases in the intervention group when compared to the control group:

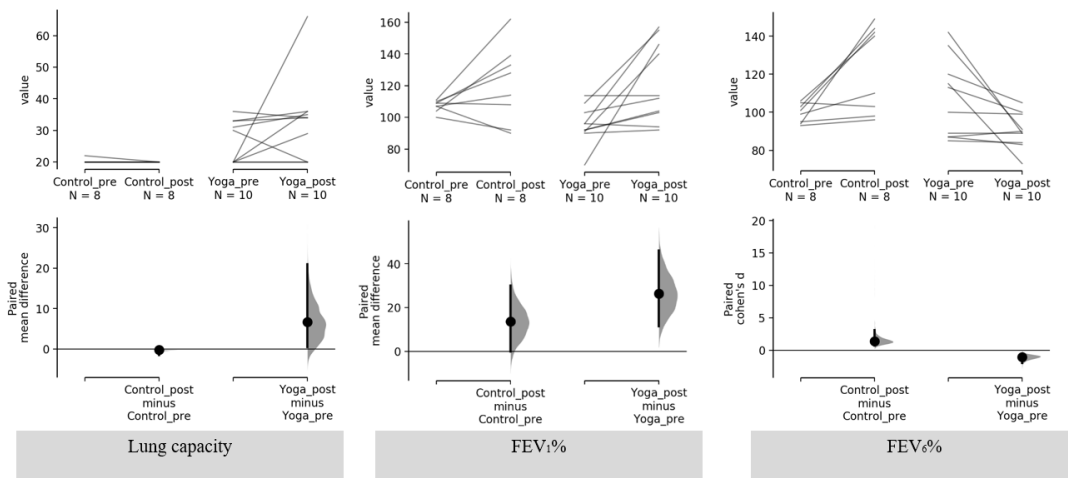


Figure 41 – Lung capacity, Forced Expiratory Volume in 1 second (FEV1%) and Forced Expiratory Volume in 6 seconds (FEV6%) paired mean differences are shown for the control vs the yoga group.

General health SF36 questionnaire comparison between groups showed increases in the intervention group when compared to the control group:

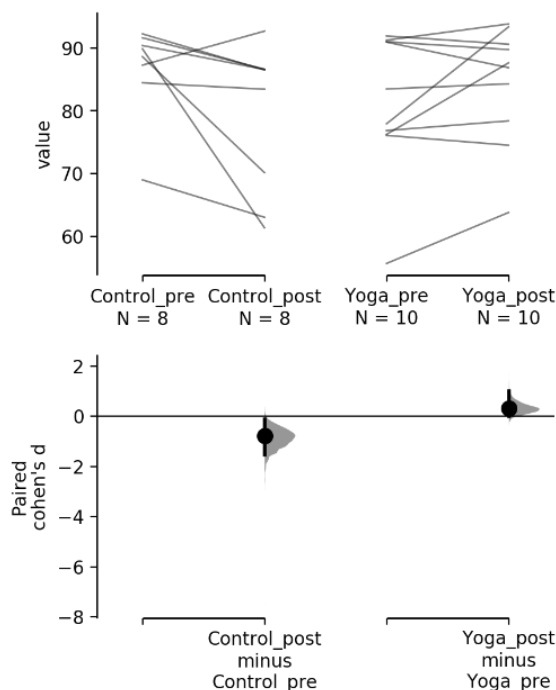


Figure 42 – SF-36 questionnaire total results paired mean difference comparisons between the control vs the yoga group.



Results revealed significant within-group differences pre- vs post-intervention for the AVYS group regarding improved general health, handgrip strength, and FEV1%. There was a significant difference between groups for lung capacity, in the AVYS group when compared to the control group.

The published article can be accessed in: <https://doi.org/10.1007/s10484-025-09719-9>.

5.6. RCT Study 3 Results on linear CoP variables

This study examined the effects of AVYS on CoP displacement in healthy student pilots, using the Biosignals Plux force platform, under the premise that AVYS would lead to improvements in postural control responses.

Linear CoP displacement values

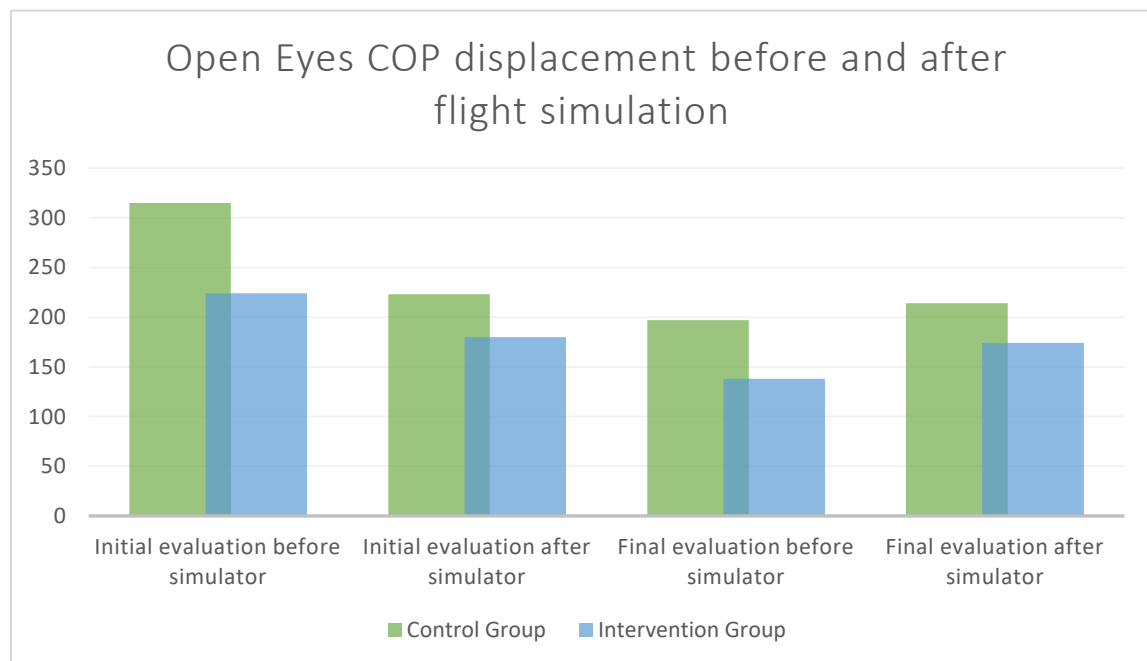


Figure 43 – Center of Pressure displacement mean comparisons between control and intervention groups during open eye bipodal stance, before and after flight simulation on initial and final assessments in mm.

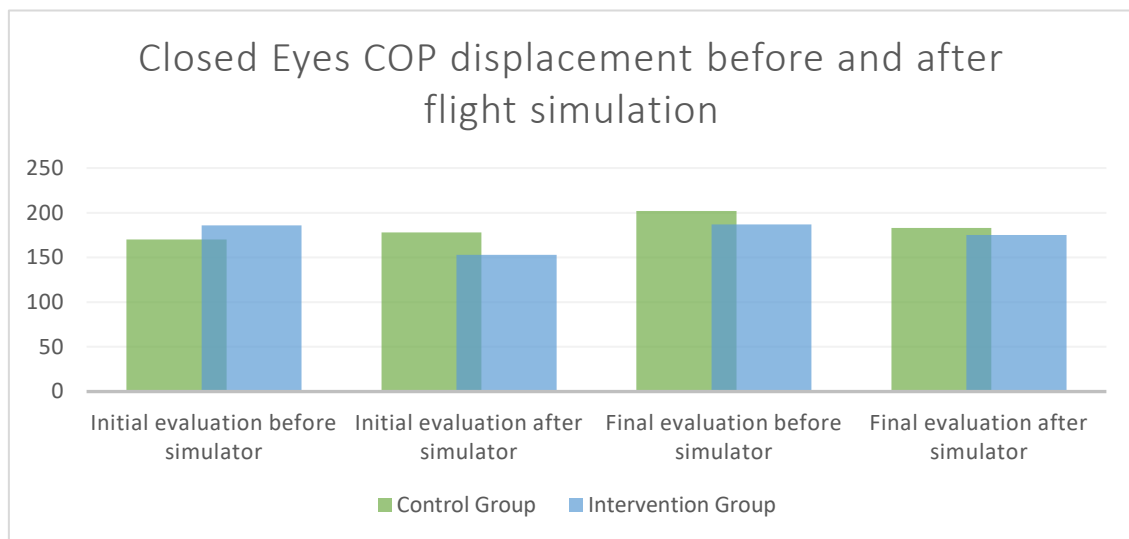


Figure 44 – Center of Pressure displacement mean comparisons between control and intervention during closed eye bipodal stance, before and after flight simulation on initial and final assessments in mm.

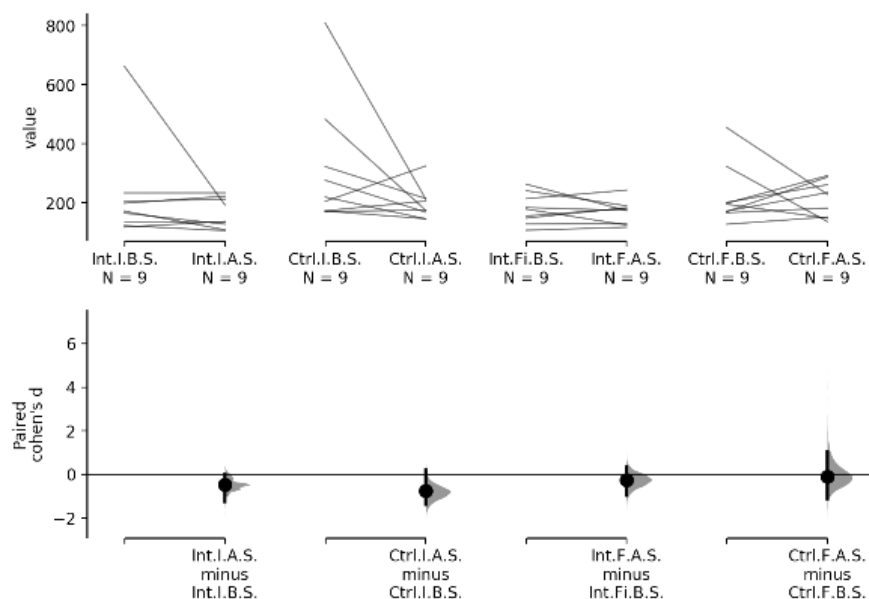


Figure 45 – Open eyed bipodal stance for the paired Cohen's d for the control vs yoga group: between the intervention group (Int) before (B) and after (A) simulation in initial (I) and final (F) data collection (in mm), and the control group for the same parameters without significant differences.



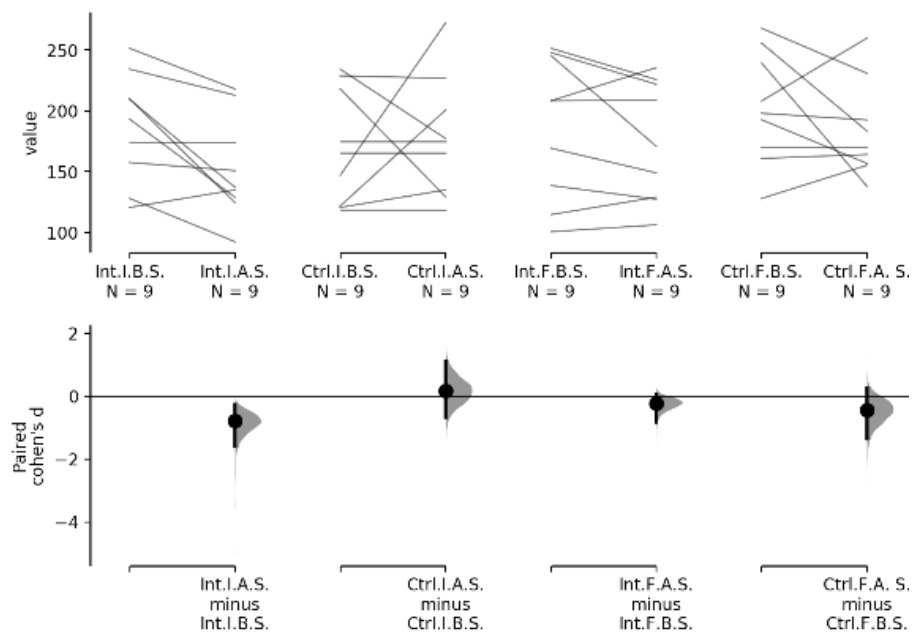


Figure 46 – Closed eye bipodal stance for the paired Cohen's d for the control vs yoga group: between the intervention group (Int) before (B) and after (A) simulation in initial (I) and final (F) data collection (in mm), and the control group for the same parameters without significant differences.

Although the differences observed between groups are not significant, after calculating the effect size, we can theorize that the AVYS group maintains CoP displacement before and after flight and the control group has a higher CoP displacement after flight simulation.

The published article can be accessed in:
<https://doi.org/10.1177/17543371231196340>.

5.7. RCT Study 4 Results on non-linear CoP variables

This study discusses the effects of AVYS on nonlinear variables of CoP displacement in adult healthy pilot students, suggesting that these variables could offer better insights into AVYS 's role in improving postural control responses.

Significant within group results

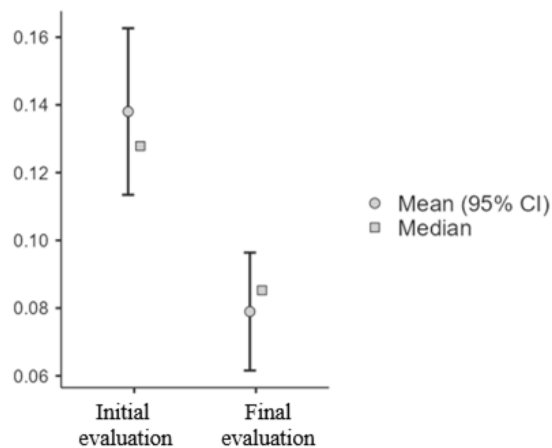


Figure 47 – Mean values for Sample Entropy in Mediolateral plane of movement (San_En_ML) within the yoga group with closed eyes show a significant decrease after the 12 weeks.

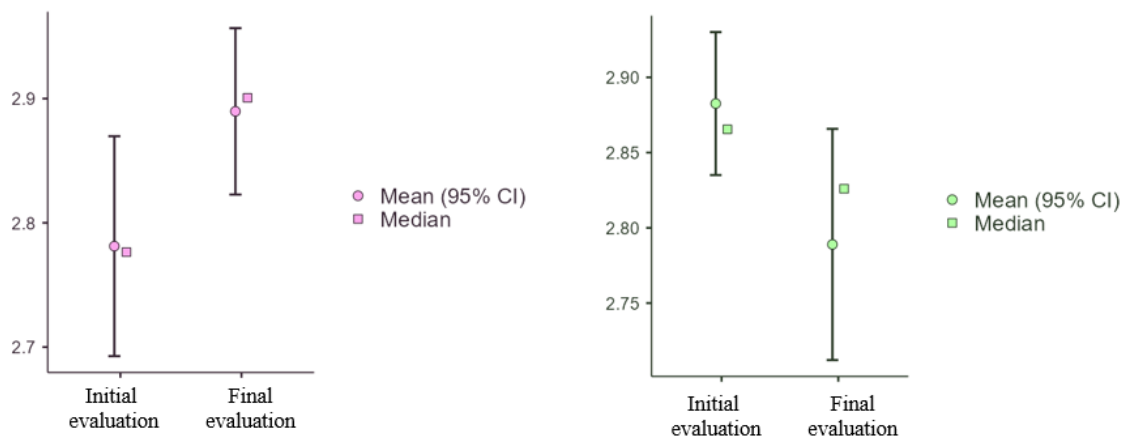


Figure 48 – Mean values for Correlation Dimension in the Anteroposterior plane of movement (CoDim_AP) with open eyes with a significant increase (in purple) after the 12 weeks. Mean values for Correlation Dimension in the Mediolateral plane of movement (CoDim_ML) with closed eyes within the AVYS group decrease (in green).



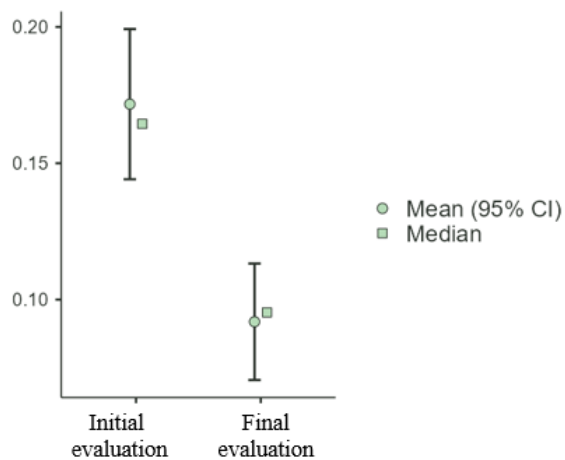


Figure 49 – Mean values for Approximate Entropy in the Mediolateral plane of movement (ApEn_ML) within the yoga group with closed eyes show a significant decrease (in green) after the 12 weeks.

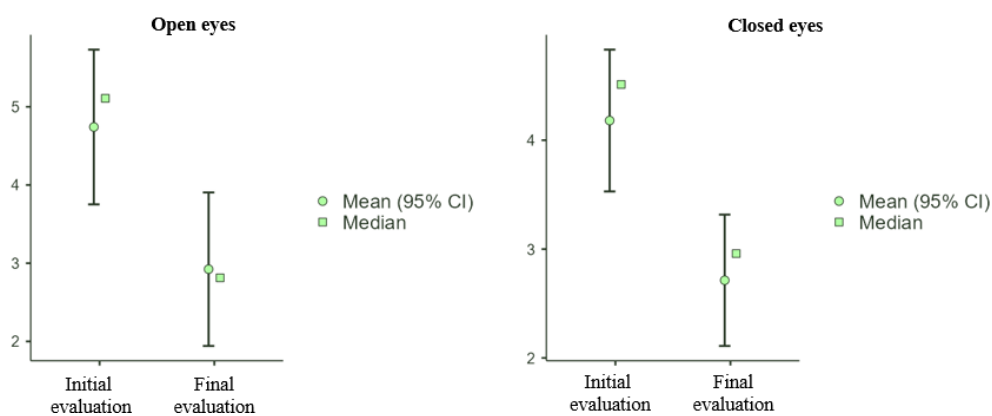


Figure 50 – Mean values for Lyapunov Exponent (in s^{-1}) with open eyes in mediolateral plane within the yoga group decreased after the 12 weeks (in green to the left). Lyapunov Exponent with closed eyes in mediolateral plane within the yoga group also decreased after 12 weeks (in green to the right).

Significant between group results

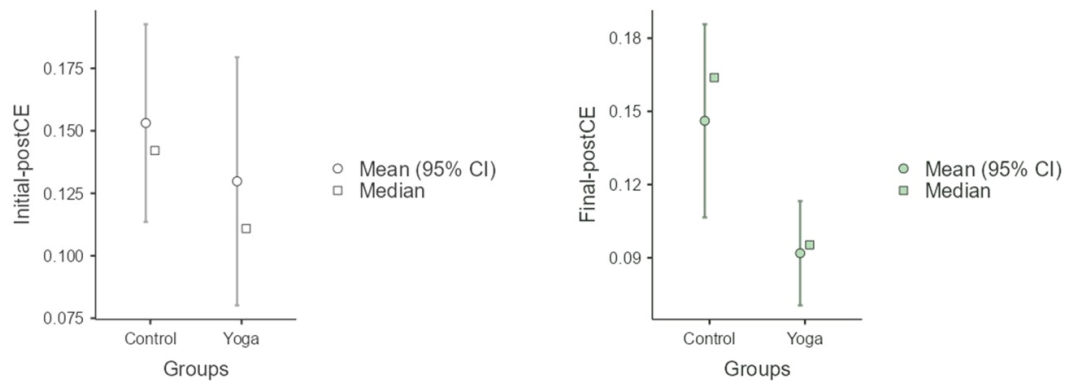


Figure 51 – Mean values for Approximate Entropy in the Mediolateral plane of movement (ApEn_ML) with closed eyes with a significant decrease (in green) after the 12 weeks when comparing control group with yoga group post flight simulator.

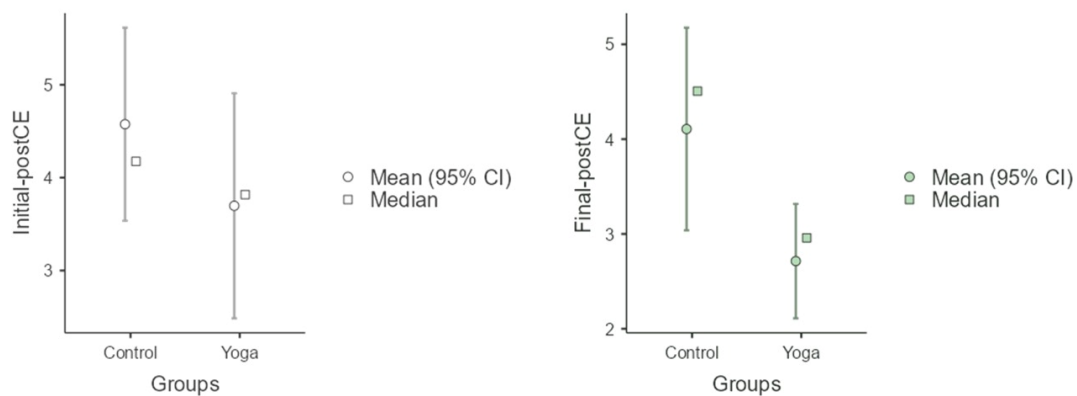


Figure 52 – Mean values for Lyapunov Exponent (in s^{-1}) in the mediolateral plane of movement with closed eyes with a significant decrease (in green) after the 12 weeks when comparing control group with yoga group post flight simulator.



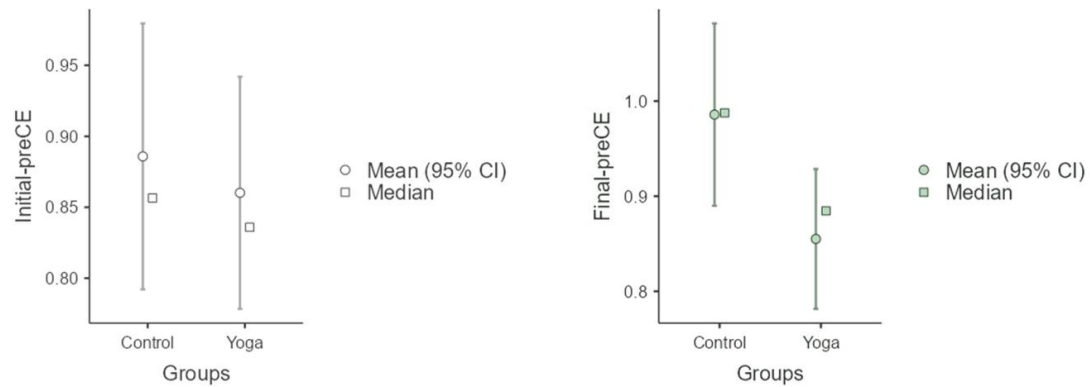


Figure 53 – Mean values for Alfa Entropy in the anteroposterior plane of movement with closed eyes with a significant decrease (in green) after the 12 weeks when comparing control group with yoga group pre-flight simulator.

In the assessment of postural control for within-group comparison with closed eyes in mediolateral plane the sample entropy, correlation dimension, approximate entropy and Lyapunov exponent values showed significant results, as well as correlation dimension for open eyes in the anteroposterior plane. In the assessment of postural control for between group comparison with closed eyes, in mediolateral plane the approximate entropy and Lyapunov exponent values showed significant results, as well as in the anteroposterior plane the alpha entropy values showcased significant results.

5.8. RCT Study 5 Results on decision making capacity for operational performance

This study investigates whether the incorporation of AVYS practice into the training regimen of Portuguese military pilots can reduce stress, enhance decision making capacity, and improve overall performance.

Performance values

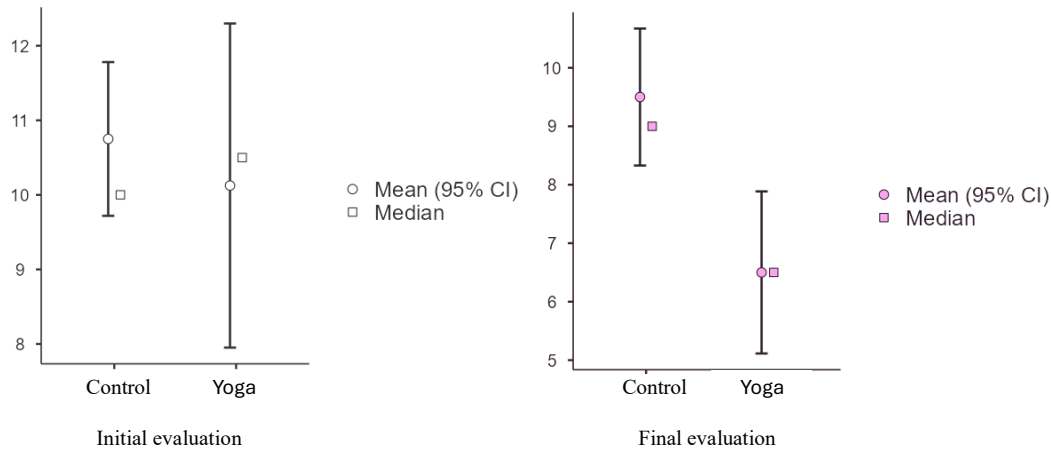


Figure 54 – The mean number of errors generally decreases for both groups (in purple).

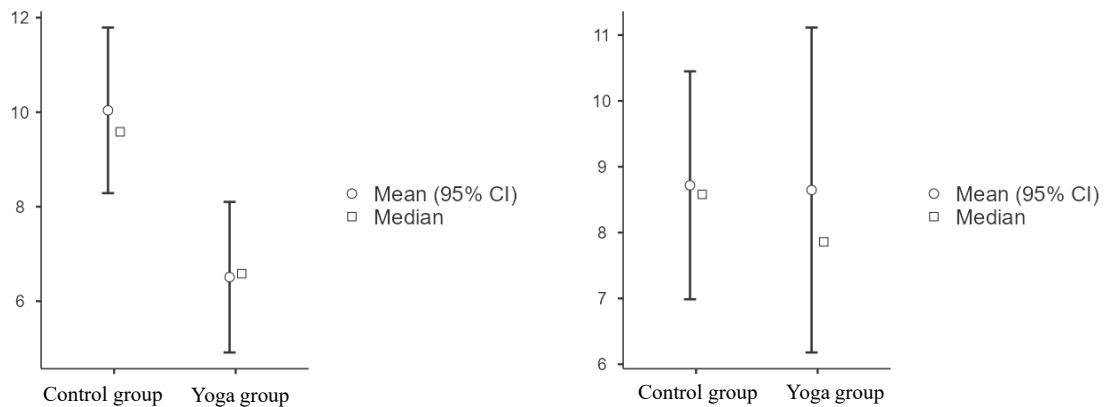


Figure 55 — Before the intervention (left), there is a significant difference between the groups time (in seconds). After the intervention (right), there is no significant difference in time between groups for the duration of the flight emergency simulation solving time.

The performance time considered in this study was the total period of time that each pilot spent inside the flight simulator, from habituation to recovery and included all the maneuvers in the flight simulation.



Decision making capacity values

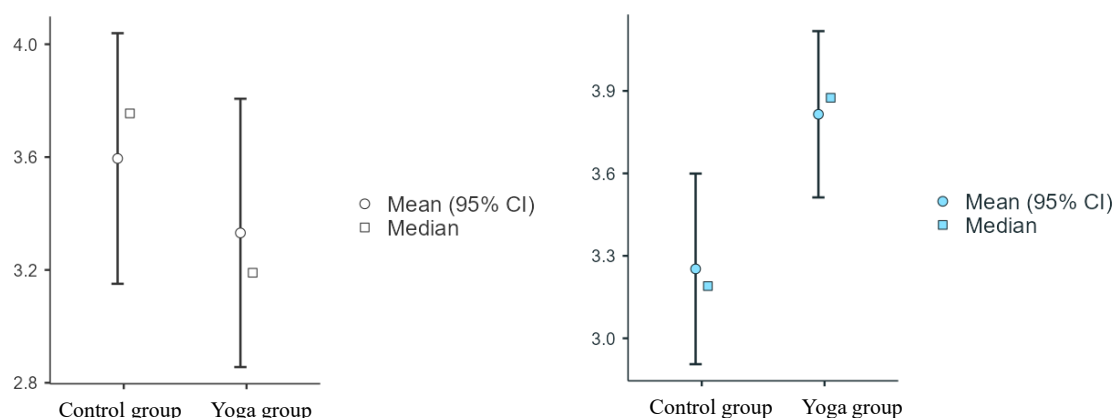


Figure 566 – Five Facet Mindfulness Questionnaire (FFMQ) variable Aware Actions values significantly increased for the yoga group when comparing to the controls in final evaluation (in blue).

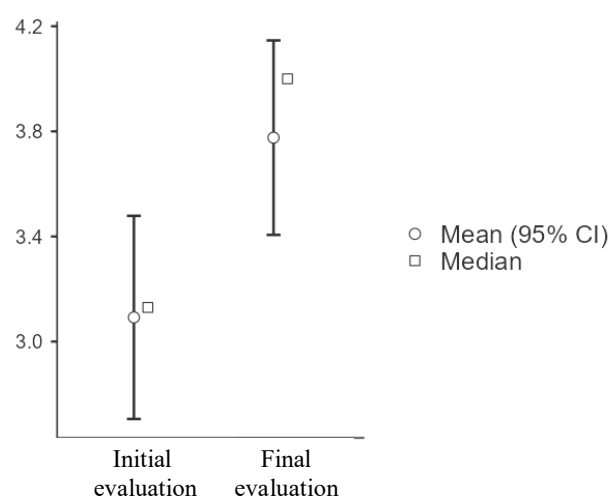


Figure 57 – Five Facet Mindfulness Questionnaire (FFMQ) variable Non-Judgmental Inner Critic values significantly increased within the yoga group.

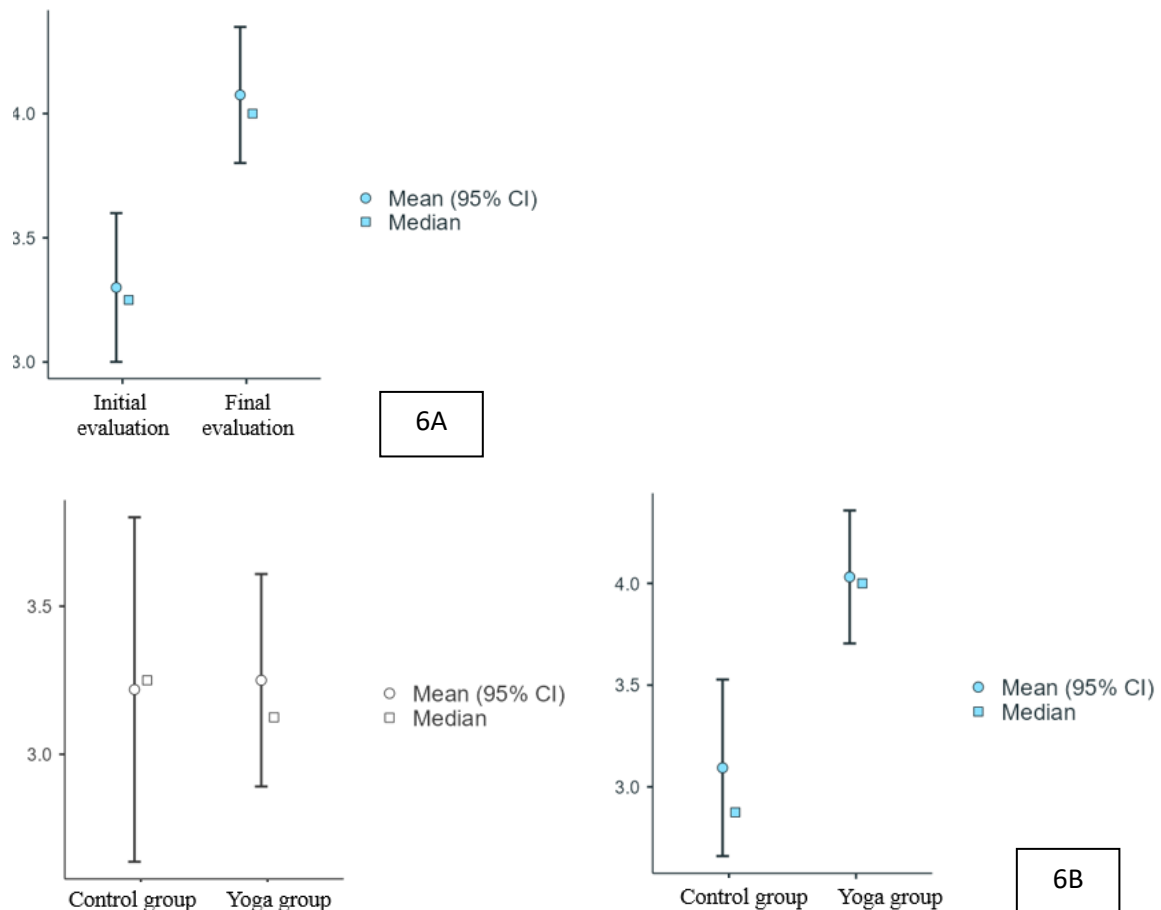


Figure 58 – Multidimensional Assessment of Interoceptive Awareness (MAIA) variable *Noticing* values significantly increased within the yoga group after the 12 weeks (6A). There was also a significant difference between groups with values increasing for the yoga group versus controls in final evaluations (in blue in 6B).



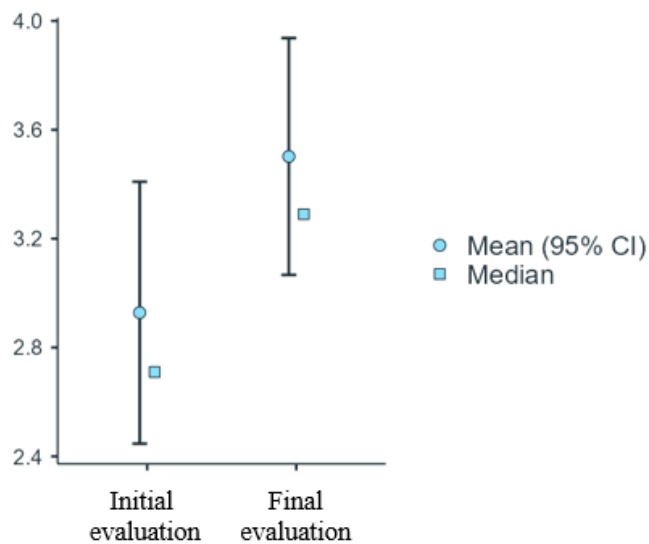


Figure 59 – Multidimensional Assessment of Interoceptive Awareness (MAIA) variable Attention Regulation values significantly increased within the yoga group (in blue).

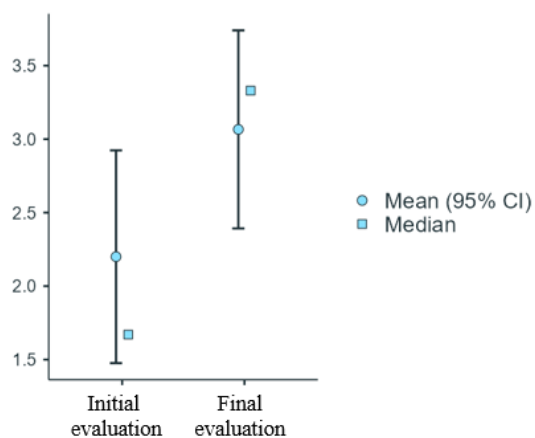


Figure 60 – Multidimensional Assessment of Interoceptive Awareness (MAIA) variable Body Listening values significantly increased within the yoga group (in blue).

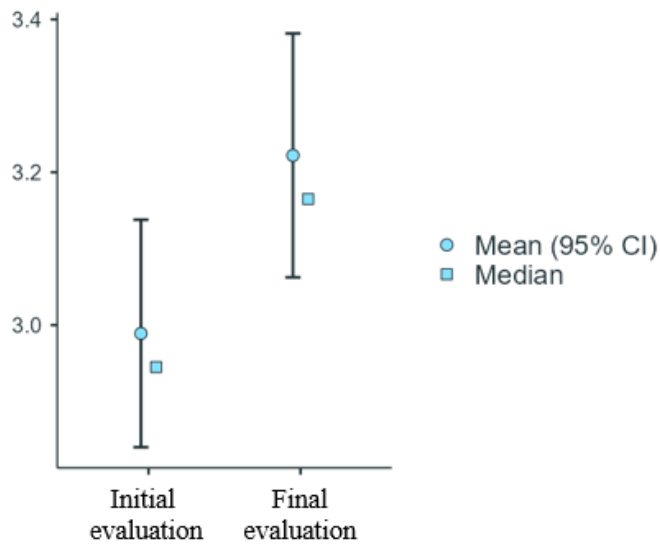


Figure 61 – Aviation Attitude Safety Scale (ASAS) variable Self-Confidence values significantly increased within the yoga group (in blue).

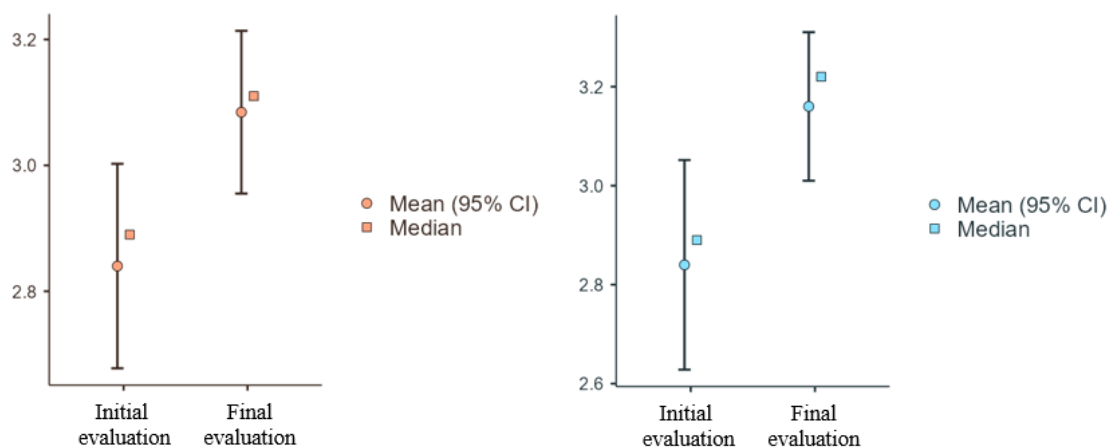


Figure 62 – Aviation Attitude Safety Scale (ASAS) variable Risk Orientation values significantly increased within the yoga group after the 12 weeks (right side in orange). Safety Orientation values significantly increased within the yoga group after the 12 weeks (left side in blue).



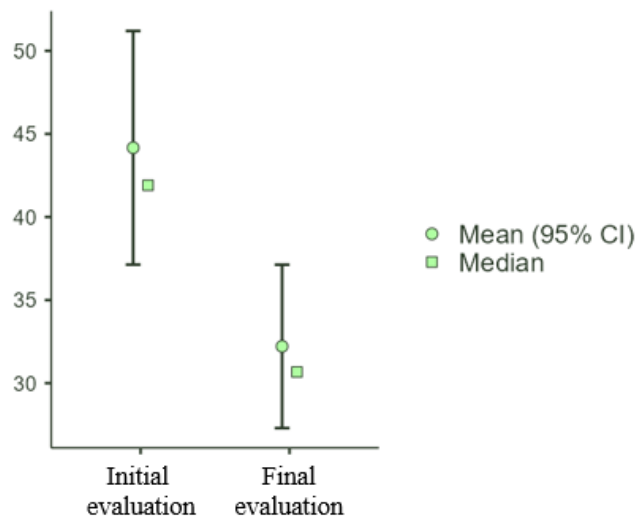


Figure 63 – Trail Making Test version B values significantly decreased within the yoga group after the 12 weeks (in green).

The results showed significant reductions in the number of errors within the AVYS group after the intervention. In the FFMQ, Aware Actions and Non-Judgmental Inner Critic improved significantly within the AVYS group. The MAIA showed significant improvements in Noticing, Attention Regulation, and Body Listening within the AVYS group. The ASAS indicated significant increases in Self-Confidence, Risk Orientation, and Safety Orientation within the AVYS group. The TMT showed significant improvements in cognitive flexibility (TMTB) within the AVYS group.

The published article can be accessed in:
<https://doi.org/10.1016/j.jatrs.2025.100075>.

6



CHAPTER 6 | Discussion



6.1. General Discussion

The findings of this study align with previous information about cognitive performance being essential in military operations, as impaired function significantly contributes to accidents (Vrijkotte et al., 2016). Instructors should prioritize the physical and psychological well-being of trainee pilots (Yun et al., 2019). Enhancing sensory systems, particularly through vestibular habituation, can improve sensory processing and integration, thereby supporting decision making and action planning (Appiah-Kubi et al., 2019).

High-cognitive-load tasks markedly alter autonomic nervous system activity, especially under hypoxic conditions. Understanding this response is crucial, given that military personnel often face high cognitive loads of unpredictable duration and frequency during flight operations. This challenge is likely compounded by heightened autonomic nervous system activity from pre-flight activities and the anticipation of combat-related outcomes (Wittels et al., 2024). The task of designing exercise programs for these individuals while addressing all these factors, and the fact that the pilot's bodies are already adapted through military training is a very complex challenge.

Regular yoga practice has been shown to enhance postural control, muscle strength, and vestibular function, increasing plasticity in pathways related to vestibular responses (Appiah-Kubi et al., 2019). Ashtanga Yoga, based on Patanjali's teachings, integrates the body, breath, mind, and emotions (Desikachar et al., 2005), supporting the overall cognitive and physical readiness of pilots. The general strength gains observed with AVYS, could imply potential benefits in injury mitigation for Air Force pilots. Strengthening muscles, especially in key areas such as the core and spine, may help pilots better withstand the physical demands of flight, including the high G-forces that often lead to musculoskeletal issues (Chayrez et al., 2024). By enhancing overall body strength and flexibility, AVYS might reduce the likelihood of injuries, promoting better long-term physical health for pilots.

AVYS, as per the study's findings, can address these military demands, since it prepares the pilots to better respond to their workload difficulties.

6.2. Stress in expert vs rookie aviation military pilots



In the case-control study, the first take-off induced the highest stress due to unfamiliarity, resulting in increased sympathetic modulation (Hormeño-Holgado et al., 2019b). Anticipatory anxiety prepares the body and mind for potential threats (Clemente-Suárez et al., 2013) and has been examined in military (Svensson et al., 1997; Mansikka et al., 2016) and high-stress civilian contexts, including commercial pilots (Zhang et al., 1997; Lehrer et al., 2010), sports (Clemente-Suárez et al., 2018; Belinchón-deMiguel et al., 2019), healthcare (Redondo-Flórez et al., 2020; Sánchez-Conde et al., 2019), and academia (Beltrán-Velasco et al., 2019; Mendoza-Castejon et al., 2020; Ramírez-Adrados et al., 2021).

During the three emergency take-offs, all pilots exhibited higher parasympathetic modulation due to familiarity and the absence of immediate emergency. However, Emergency 2 (engine failure) elicited the strongest sympathetic response and the lowest RMSSD and SDNN values due to limited decision making time, despite a high likelihood of returning to base. Overall, emergencies resulted in lower HRV and heightened sympathetic modulation compared to simulated combat (Fuentes-García et al., 2021; Hormeño-Holgado et al., 2019a; Villafaina et al., 2021), likely due to greater uncertainty in emergencies versus clearer combat objectives.

Real flight conditions amplify cardiovascular and sympathetic responses compared to simulations (Hormeño-Holgado et al., 2019b; Delgado-Moreno et al., 2019). The perception of physical danger intensifies stress (Vicente-Rodríguez et al., 2020a). When comparing expert and rookie pilots, experts displayed a similar or higher sympathetic stress response in some maneuvers. Habituation theory suggests that more exposure to stress reduces responses (Groves et al., 1970), yet experienced pilots (EPs) had more flight time, while rookie (RPs) had more simulator time. High-stress environments complicate habituation (Ruisoto et al., 2020; Ramírez-Adrados et al., 2022).

In military contexts, experienced individuals often show greater psychophysiological responses that enhance performance and mission success (Sánchez-Molina et al., 2019a; Sánchez-Molina et al., 2019b). Psychological factors also influence stress responses and habituation in high-stress environments (Martín-Rodríguez et al., 2021; Rodriguez-Besteiro et al., 2021). This study indicated that expert pilots performed better despite similar or higher stress levels, suggesting that information processing and action under stress are crucial in military settings.

6.3. Stress in a simulated flight emergency for aviation military pilots

In RCT Study 1 on HRV and pilot performance, the AVYS group showed positive changes in HRV metrics across various flight conditions, reflecting improved stress management.

A significant increase in heart rate during habituation indicated higher sympathetic activation levels (Hormeño-Holgado et al., 2019; Pulopulos et al., 2018). Decreased parasympathetic activity during the second flight, seen in RMSSD and HF increases, suggested less relaxed and recovered states (Fuentes-Garcia et al., 2021; Shaffer et al., 2017). Results in SD1% across multiple maneuvers indicated greater short-term sympathetic activation (Bustamante-Sánchez et al., 2020; Shaffer et al., 2014), most likely towards keeping attention and focus (Degroote et al., 2020). Reductions in LF, SDNN, and the SNS Index further reflected increased sympathetic activity (Tornero-Aguilera et al., 2018; Johannes et al., 2017).

In both the control and AVYS group, an increase in SD2% indicated augmented autonomic flexibility, indicating that the body is more capable of responding to stress and recovering effectively (Schaffer et al., 2014; Baevsky et al., 2017).

Overall, these findings highlight the impact of specific flight conditions on stress responses and support the value of AVYS in maintaining sympathetic activity for focused attention, showing better cognitive performance, as well as improving stress resilience in high-pressure environments like military aviation (Villafaina et al., 2021; Massaro et al., 2019; Santos et al., 2021; Degroote et al., 2020).

AVYS also led to shorter completion times for *Touch & Go* maneuver, suggesting a faster approach. Both groups showed performance improvements, with the AVYS group making fewer errors, enhancing pilot safety and precision during critical maneuvers (Hormeño-Holgado et al., 2019; Bustamante-Sánchez et al., 2020). These results emphasize the benefits of targeted stress management interventions in demanding environments (Tornero-Aguilera et al., 2018; Degroote et al., 2020).

These findings underscore the critical importance of interventions aimed at enhancing autonomic flexibility, such as this tailored AVYS program., as a decrease in HRV is associated with impaired physiological recovery and greater susceptibility to stress-related performance issues, particularly in high-stakes environments such as military aviation.

6.4. Health, strength and respiratory capacity of aviation military pilots



In RCT Study 2 on health, strength, and respiratory capacity, pre-intervention health scores were similar between the control and AVYS groups. Post-intervention, the control group showed a significant decline in overall health, while the AVYS group exhibited a slight improvement, indicating that AVYS may help mitigate some negative effects of military training. The control group had no significant changes in handgrip strength, whereas the AVYS group demonstrated notable improvements, suggesting a positive effect of AVYS. The incorporation of stretching, balance, and isometric exercises engages various muscles (Dubey et al., 2022; Mandanmohan et al., 2003; Thangavel et al., 2014). Controlled breathing and mindfulness may enhance muscle engagement and neuromuscular coordination, thereby improving grip performance (Dubey et al., 2022; Mandanmohan et al., 2003; Thangavel et al., 2014).

The study found no significant lung capacity differences between the intervention and control groups when comparing baseline to post-12-week values. Although the control group showed a small effect size in lung capacity, the AVYS group demonstrated a large change. The lack of significance may relate to prior pilot training (MacIntyre et al., 1982; Cochet et al., 2014). Combined AVYS and military training positively impacted lung performance, favoring AVYS. While no pre-intervention differences were noted, the post-intervention data suggested higher lung capacity in the AVYS group, consistent with findings from larger studies employing varied pranayama techniques (Dubey et al., 2022; Mandanmohan et al., 2003; Thangavel et al., 2014; Choudary et al., 2023; Durmic et al., 2015; Sheetal et al., 2012; Abel et al., 2013; Dinesh et al., 2015).

Significant differences in FEV1% emerged in the AVYS group post-intervention, indicating improved lung function, while the control group displayed no significant changes. Both groups exhibited large effect sizes for pre- to post-intervention differences. The control group's higher post-intervention variability suggests influences beyond the intervention, whereas the AVYS group's improvement likely stems from reduced airway obstruction and enhanced ventilation (David et al., 2022). Significant differences in FEV6% were also noted, with the AVYS group's improvement surpassing that of the control group, indicating a substantial impact on respiratory function (David et al., 2022). Changes in FEV1% and FEV6% may result from adjusted breathing patterns, emphasizing the benefits of AVYS's breathing techniques (Wang et al., 2018).

The Borg CR10 scale revealed that AVYS participants experienced significantly reduced perceived exertion post-intervention (Scherr et al., 2013). This reduction, along with improved lung function, suggests that AVYS enhances physical capabilities and

adaptability that are key during maneuvers like AGSM (Dinesh et al., 2015). Specific pranayama types may also help delay fatigue onset (Prakash et al., 2007; Seltsmann et al., 2020).

These findings emphasize AVYS's advantages in optimizing physical performance, well-being, and operational effectiveness in military aviation settings.

6.5. SpatDis and postural control of aviation military pilots

Linear variables

In RCT Study 3 on linear CoP variables, for the open-eye stance, there was a medium effect before the flight simulation and a large effect after it. For the closed-eye stance, there was a small effect before the simulation and none after. These results suggest that pilots' postural control improved with visual input after the AVYS intervention but not without it.

The larger effect size in open-eye tests implies a visual preference for maintaining stability, a pattern also observed in previous research on commercial pilots (Polak et al., 2022; Stanney et al., 1999; Min et al., 2004; Chardonnet et al., 2017). This highlights the need for personalized AVYS practices that incorporate eye-closing to reduce reliance on vision during flight missions.

Despite the small sample size, the study showed that the Biosignals Plux platform effectively measured the AVYS intervention's impact on CoP. The intervention group exhibited similar CoP behavior in both conditions, consistent with studies showing minimal differences between open- and closed-eye measurements (Le Clair et al., 1996; Lin et al., 2008; Doyle et al., 2007). The control group, however, showed increased displacement with eyes open and decreased with eyes closed, indicating a greater reliance on visual information.

After the AVYS intervention, visual input became less critical for postural control, aligning with findings that commercial pilots reduce reliance on vision as an adaptive response to the simulator environment (Polak et al., 2022).

Non-linear variables

In RCT Study 4 on non-linear CoP variables, Sample Entropy with closed eyes in the mediolateral plane within the AVYS group decreased after 12 weeks, reflecting



reliance on a fixed strategy for maintaining balance rather than employing adaptable strategies (Richman et al., 2000; Rhea et al., 2011; Yentes et al., 2021; Saraiva et al., 2022). This reduction in complexity suggests a shift toward more predictable and stable control. Similarly, Approximate Entropy decreased in the same plane within the yoga group and comparing between groups were also significantly lower for the yoga group, confirming more stable and efficient postural control (Yentes et al., 2021).

The Correlation Dimension with open eyes in the anteroposterior plane increased within the AVYS group, indicating the engagement of more degrees of freedom, using a broader range of muscle coordination patterns, thus enhancing adaptability and flexibility (Gurses et al., 2013; Esteves et al., 2022). In contrast, the Correlation Dimension decreased with closed eyes in the mediolateral plane, implying a more efficient system that simplified movement strategies for balance (Gurses et al., 2013; Esteves et al., 2022).

Lyapunov Exponent values decreased with both open and closed eyes in the mediolateral plane within the AVYS group, and in the ML plane they decrease as well when comparing between the control and the AVYS group's post-intervention, indicating reduced sensitivity to perturbations and less chaotic behavior (Rosenstein et al., 1993; Kantz et al., 2004; Ashtiani et al., 2017; Kedziorek et al., 2022).

Alpha entropy values in the AP plane with closed eyes were lower for the AVYS group when comparing with the control group post 12-weeks, showcasing rarer fluctuations in sway regularity (Richman et al., 2000; Rhea et al., 2011; Yentes et al., 2021; Saraiva et al., 2022).

This suggests that the AVYS group developed more stable postural control, relying less on visual input and more on internal cues such as vestibular and somatosensory feedback mechanisms, making them better equipped to maintain stability in dynamic aviation environments. The control group exhibited no significant changes, indicating that AVYS positively influences postural control beyond military training alone.

Use of the Force Platform

The Biosignals Plux (Portugal) force platform proved to be a non-invasive, rapid way to collect objective data to establish or improve training protocols for military pilots (in this case a program tailored to improve vestibular system responses), in relation to their balance responses by assessing CoP displacement.

Using cognitive tasks and non-linear analyses under sensory deprivation produced significant results (Sample et al., 2016; Szekely et al., 2020), particularly when comparing bipedal stance conditions. The analysis highlighted that the non-linear variables effectively captured differences in postural strategies, suggesting AVYS enhances postural control, especially without visual input. These findings underscore the balance between stability and adaptability in postural control systems, with AVYS training contributing to improved efficiency and reliability, especially under sensory-deprived conditions. Such insights may influence better training approaches for military aviation pilots.

6.6. Decision making capacity for performance of aviation military pilots

In RCT Study 5 on decision making capacity, the AVYS effectively reduced errors, indicated by significant within-group improvements and large effect sizes. This suggests that AVYS may enhance cognitive function, focus, or stress management in high-pressure situations like flight emergencies. Although the AVYS group responded faster to emergencies before the intervention, no significant improvements in response time were observed post-intervention, indicating that while errors decreased, speed was mostly unaffected.

The AVYS positively impacted mindfulness facets such as *Aware Actions*, *Non-judgmental Inner Critic*, indicating enhanced mindful behavior in pilots. Big and medium effect sizes in *Non-Reactivity*, *Observation* and *Description* suggest potential improvements that may become significant with larger samples. These findings highlight AVYS's role in helping pilots manage stress and make deliberate decisions, crucial for aviation safety, aligning with benefits observed in other interventions (Chen et al., 2022; Nassif et al., 2023).

Additionally, AVYS significantly improved interoceptive awareness in *Noticing*, *Attention Regulation*, and *Body Listening*, enhancing pilots' ability to monitor bodily sensations, vital for aviation. Although some subscales showed no significant changes, medium effect sizes indicate further research could reveal more substantial improvements.

The intervention also enhanced pilots' *Self-Confidence*, *Risk Orientation*, and *Safety Orientation*, with large effect sizes demonstrating practical significance. Increased *Self-Confidence* suggests AVYS boosts pilots' belief in their skills, essential in high-stress situations. For the increase both in *Risk Orientation* and *Safety Orientation* it seems that



the pilots are likely willing to engage in calculated risks while maintaining a strong commitment to safety protocols. This dual orientation can foster an environment where innovation and effective risk management coexist, enhancing operational efficiency without compromising safety. Such pilots are often well-equipped to handle challenging situations, ensuring both adaptability and adherence to safety standards in their flying practices.

Finally, the 12-week AVYS improved cognitive flexibility during task switching, notably in TMTB scores, with medium effect sizes in TMTA indicating potential benefits for visual attention and processing speed, warranting further investigation.

The findings indicate that AVYS may enhance cognitive abilities critical for aviation, suggesting its integration into training programs could have long-term benefits. Ongoing assessments of cognitive and visuomotor capabilities are essential to ensure peak operational performance for pilots (Maltez-Laurienti et al., 2021; Maruta et al., 2023).

Overall, AVYS enhances stress management and precision in high-pressure scenarios, contributing to a significant reduction in errors. AVYS may also enhance cognitive flexibility, focus, and stress management, possibly contributing to improve performance and safety in high-pressure flight aviation environments. However, the increased completion times of some maneuvers highlight the need to balance the benefits of improved precision with the necessity of maintaining time efficiency. Integrating AVYS into pilot training could be a valuable strategy for enhancing operational performance, particularly in complex and demanding scenarios, by improving pilots' ability to manage stress and maintain optimal compliance by following protocol and reducing mistakes. It should however be carefully managed to ensure that the improvements in stress resilience and precision do not come at the expense of operational speed.

6.7. Strengths

A notable strength of this intervention lies in its practicality and cost-effectiveness. Furthermore, all exercises are executable without the need for additional materials and can be conducted in spaces already designated for training, such as a gym room or outdoors when weather conditions permit. The intervention proposed is both practical and cost-effective, addressing the challenges military pilots in Portugal face in

maintaining their fitness without a structured training regimen. This makes the research applicable and feasible for real-world implementation.

This research offers a unique contribution by studying the hard-to-access population of military aviation pilots, who face high stress and lack a structured training regimen. This adds significant value to the research as it provides rare insights into a unique and hard-to-reach group, due to security and workload constraints. The study's findings could influence policymakers to implement mandatory exercise programs, enhancing military aviation pilot's work safety. These insights are also applicable to commercial and civil aviation sectors.

The benefits of this study for individual Airforce pilots, are the tools and knowledge for enhancing control and alertness during flights, especially in challenging situations like demanding maneuvers or high-G flights.

In the Masters in Military Aeronautics Course, these observed improvements can lead to better aircraft handling, smoother maneuvers, and more precise execution of exercises. Enhanced control, self-awareness and alertness during training can result in more focused and effective debriefs, helping pilots refine their performance and improve their learning outcomes. Additionally, biofeedback after simulated flight missions aids in monitoring and adjusting their physical state and makes debriefs easier and more precise. This, in turn, raises the overall quality of the training program, better preparing military pilots for the challenges they'll face in real and simulated aviation operations.

For the broader Portuguese Airforce, these improvements in pilot performance enhance flight safety, reduce unnecessary maneuvers, conserve fuel, and save money.

By incorporating these insights into coaching and training programs, athletes can improve their execution of techniques, make better decisions under pressure, and analyze their performance more effectively after games or events. This ultimately raises safety standards, reduces the risk of injury, and contributes to better overall fitness and performance in sports.

6.8. Limitations

The main limitation of the present research was the low number of participants analyzed, that can be explained by the difficulty to access such specific sample of elite pilots, as well as the protected involvement that surrounds these types of specialized environments. The sample size may present challenges in interpreting results and deducing the practical relevance of the study. The study's limitations include a relatively



small sample size, as it represents the entirety of the Tirocinium Pilots in the Portuguese Air Force, making it impossible to have a larger sample. This may affect the generalization of the findings. Recognizing the limitations of the small sample size's potential impact on result robustness, yet it's essential to consider that the sample represents 100% of the specific population being studied. Working with focused populations often entails smaller sample sizes. Furthermore, due to COVID-related interruptions in Airforce class scheduling, the population size nearly doubled during data collection (having one class repeating the interrupted Tirocinium along with the next class of pilots in the scheduled Tirocinium as well), presenting a distinct situation from its usual size. Additionally, the reliance on simulations instead of real flight tests may limit the generalization of the results.

The short duration of the intervention may not capture all the long-term effects of AVYS on HRV and performance. Challenges in maintaining blinding among pilots also present potential limitations. These are mitigated by including the totality of this population, designating the control group as a waiting list, offering them the same intervention subsequently, and ensuring blinding for all investigators except the study coordinator.

The findings from our study, where the AVYS group exhibited significant increases in sample entropy, correlation dimension, and the Lyapunov Exponent in the mediolateral plane with closed eyes, as well as significant changes in the anteroposterior plane with open eyes, align with previous studies (Perrin et al., 2002; Schmit et al., 2005) in which specialized training led to distinct enhancements in postural control. Previous studies (Schmit et al., 2005) demonstrated stability and reduced sway for ballet dancers, while others (Perrin et al., 2002) showed that judo athletes exhibited superior sensorimotor adaptability and balance control. Our AVYS group showed increased complexity and adaptability, particularly under challenging conditions such as closed-eye balance. These findings highlight how specific training can refine postural control beyond what general physical training, like military drills, can achieve. Research into specific balance training shows that athletes and highly trained individuals may use different motor control strategies when faced with challenging, non-specific tasks (Akbas et al., 2022; Michalska et al., 2022). In this study, the AVYS group exhibited more irregular patterns in non-linear variables, indicating greater variability in postural control. However, further studies with larger samples and longer intervention periods are needed to better understand these adaptations in high-performance populations. Also, due to

differences in data treatment, analysis methods, and statistical tests used across the several studies available, direct correlations are not possible (Rhea et al., 2015). However, a meta-analysis or standardized data re-analysis could offer a more comprehensive comparison and deeper insights into the effects of various interventions on postural control.

Another limitation of the study is that we only tested pilots in flight simulations rather than real flight scenarios. Our testing equipment was not designed to be used inside airplanes, and some of the missions prohibit civilian equipment with antennas due to their classified nature. Additionally, certain tests in real flights would need to be conducted on the landing field, which would likely disrupt military workflow.

As civilians, we secured explicit authorization to conduct this study within a military setting. Compliance with specific military regulations, legal constraints, and adherence to classified information protocols were paramount. Notably, due to operational constraints, especially in classified, restricted or warzone areas, the team could only study and publish information from active pilots taking their Tirocinium. The team was able to study the pilots while they worked, gaining hands-on experience and practical skills before assuming their full duties. Testing moments had to synchronize with the pilots' professional commitments and occur in non-classified areas. The study focused solely on Tirocinium Pilots, given the limitations in examining expert Airforce Pilots (in this specific case Airbase 5 in Monte Real, which houses the two teams of fighter jet specialist pilots, had many limitations because of the nature of their work, not allowing for the study to be developed there). These measures ensured alignment with legal, security, and operational considerations during the study.



7



CHAPTER 7 | Conclusion



The results of this research revealed that experimented and novel pilots presented increased sympathetic stress responses when submitted to different types of stressful situations like the occurrence of aircraft emergencies during the flight. Nevertheless, these increases are similar and, in some cases, higher than those observed in experimented pilots during real flight situations. However, concerning flight competences, experienced pilots showed higher performance solving flight emergency tasks than novices.

The results of this research related to HRV measures revealed that in various flight maneuvers AirForce pilots that participated in this 12-week AVYS program showcased improved parasympathetic activity and autonomic balance, decreased sympathetic nervous system activity and lower stress levels.

This study highlights the benefits of integrating AVYS as an adjunct intervention to enhance strength, underscoring its holistic approach to physical well-being. The practice of AVYS seems to also influence forced expiration volume, possibly due to increased respiratory muscle strength and endurance from pranayama training.

Combining military training with AVYS practices showed notably enhanced postural control in pilots, especially under sensory-deprived conditions, emphasizing the significance of internal cue and vestibular system utilization changes found in motor control.

Regarding performance, the AVYS group pilots were slower within their group during the touch & go maneuver and slower when compared to the control group solving the emergency maneuver but had a significant reduction in errors when solving the simulated flight emergency.

Regarding decision making capabilities, AVYS showcased enhancements in pilot's cognitive flexibility, focus, and stress management, contributing to improve performance and safety in high-pressure flight aviation environments.

To conclude this thesis here are the answers to the proposed questions on the primary and secondary outcomes:

Primary outcomes

1. Does the practice of AVYS improve pilots' performance during their work, thereby preventing human error and consequently increasing flight safety?
Yes, it seems like AVYS has a positive impact on pilot's performance in pilot's work, especially when AVYS group pilots were making less



mistakes when compared to the control group pilots. Less mistakes or less human error will lead to increased flight safety.

2. Can we enhance the pilot training process with this practice?

Yes, it seems like AVYS can be implemented in the pilot's work schedule without disturbing their workflow and the practice had positive impacts that went beyond the ones military training alone brings, in the aspects of operative performance, stress and HRV and vestibular system control responses.

Secondary outcomes

1. AVYS practice influences overall health?

Not in all evaluated variables. Our overall health results were not significant when comparing changes in Body Composition: we found no differences between groups. We found significant differences in the SF-36V1 questionnaire, handgrip strength and lung capacity, pointing to a positive impact of AVYS practice on overall health regarding these three variables.

2. AVYS practice influences postural control and balance?

Yes, with CoP linear values showcasing a trend on size effect towards a more homogenous response from pilots in the AVYS group, to non-linear values showcasing significant values towards an improvement in postural control responses, especially when visual input is absent, we can say AVYS has a positive impact on postural control and balance mechanisms.

3. AVYS practice influences the functioning of the vestibular system?

Yes, with CoP linear and non-linear values showcasing bigger effect sizes and significant values, when comparing open versus closed eyes conditions, we can infer that AVYS has a positive impact on postural control and balance mechanisms at the level of the vestibular system.

4. AVYS practice influences risk perception? *No. As shown by the Aviation Safety Attitude Scale, it seems risk perception might be influenced by other factors, like pilot's age and experience in real life missions.*

5. AVYS practice influences stress levels? *Yes, AVYS had a positive impact on stress management as shown by the Five Facet Mindfulness and*

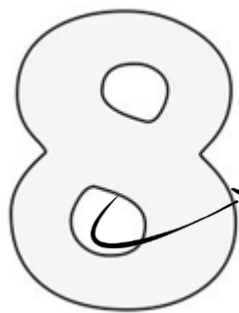
Multidimensional Assessment of Interoceptive Awareness Questionnaire results.

6. AVYS practice influences attention capacity? *Yes, AVYS has a positive impact on cognitive flexibility during task switching as shown by the results of Trail Making Test – B.*

7. AVYS practice influences decision making?

Yes, the AVYS group pilots made less errors than the control group pilots, when completing the flight emergency protocol in the flight simulator, and showcased a good balance between Risk and Safety Orientation when responding to the ASAS questionnaire, indicating AVYS practice positively influences decision making.





CHAPTER 8 | Practical applications and future perspectives



REFERENCES

The Portuguese Air Force's Health and Exercise Department lacks an official training program for pilots, who currently train at their discretion to meet mandatory physical testing requirements. Findings from this study could inform a structured training program and improve future military health policy and legislation, with potential applications in other Airforce departments.

Broadening the study's relevance to diverse contexts, the methods, results, and discussions generated by this project have the potential to be extrapolated to diverse military contexts, beyond military aviation, exploring applications of human intervention in different military settings, such as incorporating new training techniques for: airfield operations officers, paratroopers, armored vehicle operators, tank crews, navy divers, military paratroopers, and others, where the improvement of physical and cognitive abilities aligns with the outcomes of this study. Furthermore, the applicability of the project's findings extends to high-demand environments beyond military, including civil aviation (both for pilots and air traffic controllers), professional race car or motorcycle drivers and skydiving companies – professions where the optimization of physical and cognitive capabilities may offer valuable insights and benefits. High-performance situations involving factors such as stress, spatial disorientation, cognitive flexibility, postural control, operational performance, strength, lung capacity, and sensory deprivation are critical factors for performance and safety, especially in environments requiring rapid decision making under pressure can benefit from this study. Insights from this study could guide the development of structured training programs, being occupational health related or sports performance related.

Future studies should extend the intervention period across multiple years of *Tirocinium* cohorts or include other Airforce teams for comparative analysis. Yoga programs could also be researched in other high-stress populations, such as motorsports, where precise control under pressure is crucial. Larger samples are necessary to better understand psychophysiological stress responses in these demanding contexts (Johannes et al., 2017; Degroote et al., 2020; Beltrán-Velasco et al., 2021). Objective data on pilots' psychophysiological workload during flights could assist in pilot selection and mission assignment (Zhang et al., 1997; Lehrer et al., 2010).

Further research is needed to understand the long-term effects and integration of tailored training programs like yoga in military aviation, focusing on stress management, operational performance, and flight safety. Sequential testing with low-stress and high-



stress emergency protocols should compare intervention impacts across varying stress intensities. Analyzing the recovery phase could reveal how quickly participants return to baseline autonomic functioning, and cortisol testing may enhance study robustness (Degroote et al., 2020).

For postural control assessments, future studies should analyze more than just p-values for practical insights. A larger sample, a longer yoga protocol, or the inclusion of other countries could strengthen findings. It would also be useful to compare CoP displacement with stress levels and simulator data with real flight scenarios, investigating differences between senior and student pilots, and examining psychophysical correlations (e.g., HRV, stress) with CoP displacement.

Standing posture, compared to sitting, impacts task-switching difficulty, suggesting that balancing during cognitive tasks influences brain focus (Stephan et al., 2018). This is relevant for pilots, as flight simulator tasks requiring balance might affect their task management abilities. Changes in CoP measures before and after simulations indicate that postural engagement may enhance cognitive function, emphasizing the link between physical posture and cognitive performance in high-demand environments (Bonnet et al., 2023). Future studies could measure CoP variables while sitting and during tasks for comparison.

Spatial disorientation is a major aviation problem. Training pilots to perceive roll-angular displacements could improve their spatial awareness during coordinated flight turns (Brink et al., 2024). The AVYS intervention likely enhanced core stability, leading to controlled movements and reduced sway, especially in the ML plane (Koncz et al., 2024; Zemkova et al., 2022). Technologies like EMG or functional MRI could clarify which muscles show increased activation and explain observed improvements in ML variability and AP stability.

Proprioception and sensory feedback are critical for balance, particularly in unipodal stances, which demand higher neuromuscular control. A longer yoga protocol for military pilots, especially those less trained, could improve balance, injury prevention, and performance. Additionally, international studies could examine similar parameters in student pilots from other Airforce teams to increase sample sizes.

Future studies should target injury prevention and performance optimization through interventions like yoga, focusing on flexibility and core stability. Securing permissions to use equipment inside aircrafts and on the landing field would allow for real-flight data comparisons without disrupting military missions.

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Appendix 1





Appendix 1

Oral presentations:

Santos, S., Parraça, J. A., Alegrete, J., Cabo, C. A., Melo, F., & Fernandes, O. (2022). *The effects of a 12-week yoga program on the COP of military pilots before and after a flight emergency simulation* [Oral presentation]. TAPAS 2022: International Conference on Technology in Physical Activity and Sport.



Figure 64 – Certificate of Oral Presentation from TAPAS. This presentation was invited to be published as an article.



Cabo, C., Fernandes, O., Melo, F., Parraca, J., & Santos, S. (2023, October 30-31). Efeito de um programa de yoga de 12 semanas na saúde geral e performance operacional de pilotos militares. In A. Figueiredo, A. Pereira, A. Azevedo, C. Vasconcelos, F. Mendes, J. L. Esteves, & P. Eira (Eds.), *Livro de Resumos do 4.º Fórum da REDESPP – Desporto, Comunidades e Qualidade de Vida* (p. 19). REDESPP e Escola Superior de Educação – Instituto Politécnico de Viseu. <https://doi.org/10.34633/978-989-35325-3-9>.



Figure 65– Certificate of Oral Presentation from REDESPP.

Appendix 1

Santos, S., Villafaina, S., Fernandes, O., Melo, F., & Parraca, J. (2024, April 24-26). *How to go from a PhD class to a partnership between governmental institutions to improve existing processes – a practical example*. IV Congreso Internacional de Innovación Docente, Universidad de Extremadura, Cáceres, España.



Figure 66 – Certificate of Scientific Committee participation from IV Congreso Internacional de Innovación Docente.





Figure 67 – Certificate of Oral Presentation from IV Congreso Internacional de Innovación Docente.

Appendix 1

Santos, S., Fernandes, O., Cabo, C. A., Espada M., Melo, F., & Parraça, J. A. (2024, December 13–14). *Yoga practice in mental health – an innovative low-cost solution for the Portuguese Airforce* [Oral presentation]. III Jornadas Internacionais em Prescrição do Exercício e Promoção da Saúde, Escola Superior da Educação e Ciências Sociais – IPLeiria, Leiria, Portugal.



Certificado

Para os devidos efeitos certifica-se que

SARA SANTOS

apresentou a Comunicação intitulada: Esforço percebido e capacidade pulmonar dos pilotos da aviação da Força Aérea Portuguesa após 12 semanas de treino de Yoga no local de trabalho, da autoria de Sara Santos, Orlando Fernandes, Carolina A. Cabo, Mário Espada, Filipe Melo, José A. Parraça, nas III JORNADAS INTERNACIONAIS EM PRESCRIÇÃO DO EXERCÍCIO E PROMOÇÃO DA SAÚDE, realizadas nos dias 13 e 14 de dezembro de 2024, organizadas pelo Curso de Mestrado em Prescrição do Exercício e Promoção da Saúde, na Escola Superior de Educação e Ciências Sociais do Politécnico de Leiria.

O Diretor da ESECS – Instituto Politécnico de Leiria

Assinado por: PEDRO GIL FRADE MOROUÇO
Num. de identificação: 11933582
Data: 2024.12.19 15:55:22+0000
Certificado por: Diário da República
Atributos certificados: Diretor da Escola Superior de Educação e Ciências Sociais - Instituto Politécnico de Leiria



Campus 1 - Rua Dr. João Soares - Apartado 4045 2411-901 Leiria - Portugal - NIF: 506 971 244

Figure 68 – Certificate of Oral Presentation from III Jornadas Internacionais em Prescrição do Exercício e Promoção da Saúde 2024.



Santos, S., Parraça, J. A., Cabo, C. A., Melo, F. & Fernandes, O. (2025, February 21–22). *Entropia e control postural em pilotos aviadores militares portugueses antes e depois de 12 semanas de yoga* [Oral presentation]. CNB 2025: XI Congresso Nacional de Biomecânica, Hotel do Mar, Sesimbra, Portugal.



Figure 69 – Certificate of Oral Presentation from Behaviour Change Conference 2025.

Appendix 1

Santos, S., Melo, F., Cabo, C. A., Espada M., Fernandes, O., & Parraça, J. A. (2025, February 27–28). *Yoga practice in mental health – an innovative low-cost solution for the Portuguese Airforce* [Oral presentation]. III International Congress cieqv 2025: Innovation and Sustainability for a Quality Future, ESE – IPSetúbal, Setúbal, Portugal.



Figure 70 – Certificate of Oral Presentation from III International Congress cieqv 2025.



Santos, S., Fernandes, O., Cabo, C. A., Parraça, J. A., & Melo, F. (2025, April 2–3). *Does a 12-week yoga program influence the decision-making capacity of military aviation pilots?* [Oral presentation]. Behaviour Change Conference 2025: Health & Sustainability, UCL Centre for Behaviour Change & NOVA Escola Nacional de Saúde Pública, Lisbon, Portugal.



Figure 71 – Certificate of Oral Presentation from Behaviour Change Conference 2025.

Appendix 1

Posters:

Santos, S., Parraça, J., Cabo, C., Fernandes, O., & Melo, F. (2022, November 3-4). *Effect of a 12-week yoga program on the operative performance of military pilots: Study protocol for a randomized controlled trial* [Poster presentation]. 3rd Annual Summit of the Comprehensive Health Research Centre (CHRC), University of Évora, Évora, Portugal.



Figure 72 – Certificate of Poster from 3rd CHRC Summit.



Santos, S., Villafaina, S., Parraça, J., Fernandes, O., & Melo, F. (2023, May 25-26). *Effects of a yoga practice on respiratory capacity in military pilots from the Portuguese Air Force* [Poster presentation]. 4th Comprehensive Health Research Centre Annual Summit, University of Évora, Évora, Portugal.



Figure 73 – Certificate of Poster from 4th CHRC Summit.

Appendix 1

Santos, S., Alegrete, J., Cabo, C. A., Parraca, J. A., Fernandes, O., & Melo, F. (2024, September). *Yoga in military aviation pilots partnership protocol between UÉvora/CHRC and the Portuguese Air Force* [Conference poster]. 5th CHRC Annual Summit. <https://doi.org/10.13140/RG.2.2.22339.82728>



Figure 74 – Certificate of Poster from 5th CHRC Summit.














CIDESD is funded by FCT (UIDB/04045/



This is to certify that the scientific work entitled **"Linear vs non-linear methods of evaluation of postural control: how to test the effectiveness of balance training modalities?"** authored by **Sara Santos, José Parraça, Carolina A. Cabo, Mário C. Espada, Filipe Melo and Orlando Fernandes** was presented as a poster presentation at the **CIDESD 2025 International Congress***, held at the University of Beira Interior, Covilhã, Portugal, from June 5th to 7th, 2025.

Daniel Marinho
Chair of Scientific Committee CIOESD 2025

Henrique Neiva
Chair of Organizing Committee CIOESD 2025



*Certified by the Portuguese Institute of Sport and Youth (IPDJ) with 3.2 ECTS credits for TPTEF/DI and TPTD, and by the Portuguese Scientific-Pedagogical Council of Continuing Education for Teachers (codes 260 and 620) with 16 hours.



PhD classes:

Santos, S., Adsuar, J., Gonzalez, R., & Parraça, J. (2023, November). *Como desenvolver a fiabilidade de instrumentos nas ciências do desporto* [PhD class]. Seminário de Doutoramento em Motricidade Humana, Universidade de Évora, Évora, Portugal.



Declaração

José Alberto Parraça, professor no Departamento de Desporto e Saúde da Universidade de Évora, e responsável pelo Seminário de Doutoramento em Motricidade Humana: *“Evolução dos sistemas de controlo do equilíbrio”* declaro para os devidos efeitos que a Professora Sara Santos, foi assistente convidado na leção de parte do seminário tendo como responsabilidade o desenvolvimento do módulo: *“Como desenvolver a fiabilidade de instrumentos nas ciências do desporto”*

Com os melhores cumprimentos,

José Alberto Parraça
Professor Dep Desporto e Saúde



Assinado por: José Alberto
Ferreira Martins Parraça
Identificação: B112416271
Data: 2024-06-18 às 15:16:21

Figure 77 – Teaching Certificate for the Human Motricity PhD Seminar in Évora University.

Appendix 1

Parraça, J. A., & Santos, S. (2024, February). *Estrutura e redação do Relatório da Tese* [PhD class]. Seminário de Desenvolvimento da Tese II, Programa de Doutoramento em Ciências e Tecnologia da Saúde e Bem-Estar, Auditório da Escola de Enfermagem da Universidade de Évora, Largo do Sr. da Pobreza 2B, 7000-811 Évora, Portugal.



DECLARAÇÃO DE DOCÊNCIA

Prof. Doutor Manuel Lopes, Diretor do Programa de Doutoramento em Ciências e Tecnologia da Saúde e Bem-Estar da Universidade de Évora, declara que a Profª Doutora Sara Santos exerceu funções de docência no âmbito do Seminário de Desenvolvimento da Tese II, especificamente sobre o tema “*Estrutura e redação do Relatório da Tese*”.

Durante o seminário, a Profª Doutora Sara Santos abordou e desenvolveu os seguintes tópicos principais:

- Estrutura do Relatório da Tese
- Redação Científica
- Planeamento e Organização do Trabalho

A professora Sara Santos demonstrou um elevado compromisso e competência na orientação dos doutorandos, fornecendo-lhes as ferramentas necessárias para a elaboração de relatórios de tese coerentes, rigorosos e bem estruturados, de acordo com os padrões académicos exigidos pela Universidade de Évora.

Évora, junho de 24

Assinado por: **Manuel José Lopes**
Num. de Identificação: 05654353
Prof. Doutor Manuel Lopes
Diretor do Programa de Doutoramento
Ciências e Tecnologia da Saúde e Bem-Estar
Universidade de Évora

Figure 78 – Teaching Certificate for the Thesis Structure and Writing PhD Seminar in Évora University.



Guest assistant in supervising part of the Masters study at Institute of Physical Education and Sports and the Graduate Program in Public Health at the Federal University of Ceará (PPGSP-UFC), with the development of the article: “The use of yoga for mindfulness in school-age children: a systematic review.”



DECLARAÇÃO

Ricardo Hugo Gonzalez, docente do Instituto de Educação Física e Esportes e do Programa de Pós-Graduação em Saúde Pública da Universidade Federal do Ceará, declaro para os devidos efeitos que a Professora Sara Santos, da Universidade de Évora- Portugal, foi assistente convidada na orientação de parte do estudo de Mestrado Acadêmico do PPGSP-UFC, da estudante Gabriela Nogueira, tendo como responsabilidade o desenvolvimento do artigo: "The use of yoga for mindfulness in school-age children: a systematic review"

Com os melhores cumprimentos,

Fortaleza, 18 de junho de 2023

Documento assinado digitalmente
gov.br RICARDO HUGO GONZALEZ
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Verifique em <https://validar.itd.gov.br>

Prof. Dr. Ricardo Hugo Gonzalez
IEFES/PPGSP

Figure 79 – Teaching Certificate for the supervising part of the Masters study at PPGSP-UFC.

Appendix 1

Parraça, J. A., & Santos, S. (2024, November). *A Evolução Dos Sistemas De Controlo Do Equilibrio* [PhD class]. Seminário de Doutoramento em Motricidade Humana, Universidade de Évora, Évora, Portugal.



DECLARAÇÃO DE DOCÊNCIA

Prof. Doutor José Alberto Frade Martins Parraça, responsável pela Unidade Curricular Seminários em Motricidade Humana 2 (DES13433D) - "*A EVOLUÇÃO DOS SISTEMAS DE CONTROLO DO EQUILIBRIO*", do Programa de Doutoramento em Motricidade Humana da Universidade de Évora, declara que a Prof^a Sara Alexandra Santos exerceu funções de docência na U.C. supramencionada.

Durante o seminário, a Prof^a Sara Santos abordou e desenvolveu os seguintes tópicos principais:

- O Sistema Vestibular dos Pilotos de aviões;
- Intervenção para prevenção de quedas através do Ioga;
- Avaliações de equilíbrio com plataforma de equilíbrios;
- Análise de dados.

Por ser verdade e para que conste oportunamente, assino esta declaração.

Évora, 2024

Assinado por: José Alberto Frade
Martins Parraça
Num. de Identificação: 12436271
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Prof. Doutor José Parraça

Responsável pela U.C.

Universidade de Évora

Figure 80 – Teaching Certificate for the Human Motricity PhD Seminar in Évora University.

