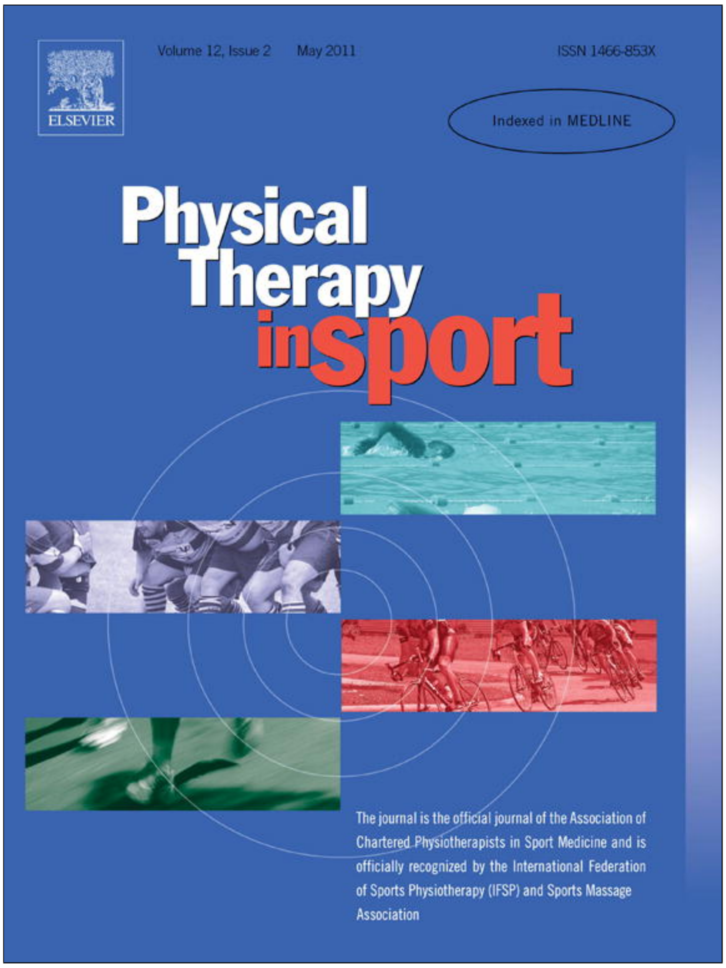
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Original research

The influence of a balance training program on the electromyographic latency of the ankle musculature in subjects with no history of ankle injury

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ABSTRACT

Background: Balance training is often employed for the prevention of ankle injuries. However, until now, most of the studies have focused on the prevention of a recurrent injury. The objective of this study was to look into the effects of balance training on the onset of peroneal muscle activity in healthy subjects.
Methods: 34 participants (mean age = 19.5 years ± 1.5; height = 1.70 m ± 0.12; weight = 62.06 kg ± 11.24), physically active, with no history of injuries took part in this study. The participants underwent a 4-week balance training program using an ankle disk. Onset of peroneal muscles activation was measured using surface electromyography and a trap-door.
Findings: Parametric and non-parametric tests showed no significant differences between the control group and the experimental group ($P > 0.05$).
Interpretation: The results indicate that the use of balance training, for a 4-week period with two training sessions per week, on physically active subjects with no history of injuries in the ankle joint, does not cause noteworthy changes on the onset of peroneal muscles activity.

1. Introduction

In the past years, an evolution has occurred in sports. The athletes are being taken to new levels, both physically and mentally, with the consequence of a greater exposure of the human body to injuries. As such, the incidence of sports related injuries has been increasing. From these injuries, ankle sprains are the most common in sports (Konradsen, Voigt, & Hojsgaard, 1997; Linford, Hopkins, Schulthies, Freland, Draper, & Hunter, 2006) as well as in everyday activities (Leanderson, Eriksson, Nilsson, & Wykman, 1996).

Athletes with a history of ankle injury have a high risk of recurrence (Mckay, Goldie, Payne, & Oakes, 2001), since they are five times more likely to sustain a new similar injury. The reasons for this high rate are not quite known (Willems, Witvrouw, Verstuyftt, Vaest, & De Clercq, 2002). A consequence of ankle injury is what several authors have called functional instability, due to the loss of proprioception, peroneal muscle weakness, absent coordination (Eils & Rosenbaum, 2001) and/or a low level of effective control during sudden ankle inversion (Vaes, Duquet, & Gheluwe, 2002).

In proprioception, the input is received from the peripheral afferents (muscle spindles, joint receptors, cutaneous receptors and golgi tendon organs), and provides information on limb awareness, position and force (Lephart, Pincivero, & Rozzi, 1998). Injury may result in proprioceptive deficits and may manifest as a reduction in joint position sense. The ability to detect motion in the foot and make adjustments in posture in response to these detected motions is thought to be crucial to the prevention of injuries in the ankle joint (Willems et al., 2002). So, it appears that an injury to the ankle may lead to a deficit in proprioception and compromise neuromuscular control, thus reducing the ability to detect motion in the foot, and cause inadequate use of anticipatory muscular movements under dynamic conditions.

Balance training is often used as a rehabilitation method for ankle injuries and to reduce proprioception deficits and increase postural control. Several authors (Clark & Burden, 2005; Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; Mcguine & Keene, 2006; Michell, Ross, Blackburn, Hirth, & Guskiewicz, 2006; Mohammadi, 2007; Sheth, Yu, Laskowki, & An, 1997; Stasinopoulos, 2004; Verhagen, Van Der Beek, Twisk, Bouter, Bahr, & Van Mechelen, 2004) have used ankle dish training as an effective form of treatment to reduce proprioception deficits, decrease peroneal latency time and increase postural control. Ankle disk training has been shown to significantly reduce the recurrence of ankle sprains (Verhagen et al., 2004).

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This study aims to fill some gaps identified by various authors, which claim that there is no data to support the development of training programs in order to prevent ankle injuries (Robbins & Waked, 1998) in subjects without a history of ankle ligament injury. According to some authors, more studies need to be conducted on healthy subjects (Stasinopoulos, 2004), and additional preventive strategies need to be developed in order to reduce the impact and cost of rehabilitation (Mckay et al., 2001), since proprioception training can be used to prevent the initial injury (Diamond, 1989).

So, the purpose of this study was to evaluate if, in physically active subjects with no history of ankle injury, a low volume training program performed for one month, composed of two training sessions per week, would be effective in the reduction of the latency time of muscles responsible for ankle stability.

Despite the neural structures and proprioception of the subjects has not been damaged by an injury, we expected that some change could happen if we used a short, but intense, training program. We knew that the program had to be hard in terms of intensity of the exercises, because we accepted that it would be difficult to change latency time in subjects with no history of injury. That was the main reason for choosing the number of exercises and trainings program.

If this training program proves to be useful, it could become an instrument to show that, in physically active subjects with no history of ankle injury, it is possible to promote changes in the ankle stabilization mechanisms that may contribute to prevent the initial injury.

2. Methods

2.1. Subjects

The subjects for this study were university students. The sample consisted of 34 healthy students (18 female, 16 male, mean age = 19.5 years SD = 1.5) physically active, with no history of injuries or surgery in the lower limbs. Prior to participating, the purpose of the study and the experimental protocol was explained and subjects signed an informed consent document. Subjects were randomly assigned to two groups, control ($N = 16$) and experimental ($N = 18$). The control group had 7 male and 9 female students, with a mean age of 20.24 years and an SD of 1.25. The experimental group had the same number of male and female students (9), with a mean age of 19.33 years and an SD of 1.71. The study was approved by the Research Ethics Committee of the Faculty of Human Kinetics from the Technical University of Lisbon in accordance with document number 06/2009.

2.2. Equipment

A custom-designed trap-door mechanism, similar to that used by other researchers (Clark & Burden, 2005; Konradsen et al., 1997; Lofvenberg, Karrholm, Sundelin, & Ahlgren, 1995; Sheth et al., 1997; Vaes et al., 2002), was used to simulate the inversion movement of the ankle sprain (Fig. 3). This system consisted of two movable platforms, with a non-skid surface, which was electromechanically controlled by an operator, who was responsible for opening one of the platforms. When activated, the system opens one of the platforms (previously selected), causing a simulation of an ankle sprain mechanism, but also generates an electrical signal that indicates the beginning of the movement.

The EMG recordings (Fig. 1) were made using an electromyography system (Biovision, Werheim, Germany) and silver surface electrodes (Neuroline, Ambu A/S, Ballerup, Denmark) with an area of 95 mm^2. In order to increase electric conductance, the skin was shaved and rubbed with alcohol before applying the electrodes. The electrodes were placed 2 cm apart, at the most prominent part of the muscle bellies as follows: Tibialis Anterior 8 cm below the tibial tuberosity and 3 cm lateral of the anterior border of the tibia; Peroneus Longus 8 cm below the head of the fibula in the line connecting the head of the fibula and the lateral malleolus; Peroneus brevis 5 cm above the lateral malleolus, just behind the fibula; Gastrocnemius Lateralis 8 cm below the popliteal fossa line. The reference electrode was placed on the distal tibia to guarantee the same electrode position during pre and post-training measurements; electrode placement was marked on the skin with indelible ink. Twice a week the ink marks were checked and renewed exactly on the same point.

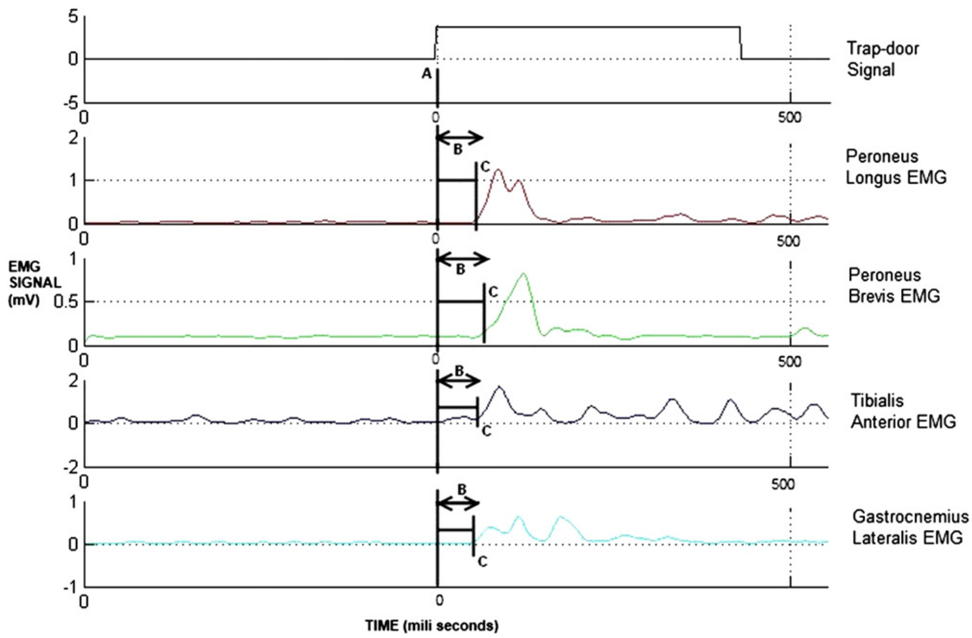

Fig. 1. Trap-door signal and rectified EMG signals of monitored muscles: A – Trap-door opening; B – Latency Time; C – EMG Onset.

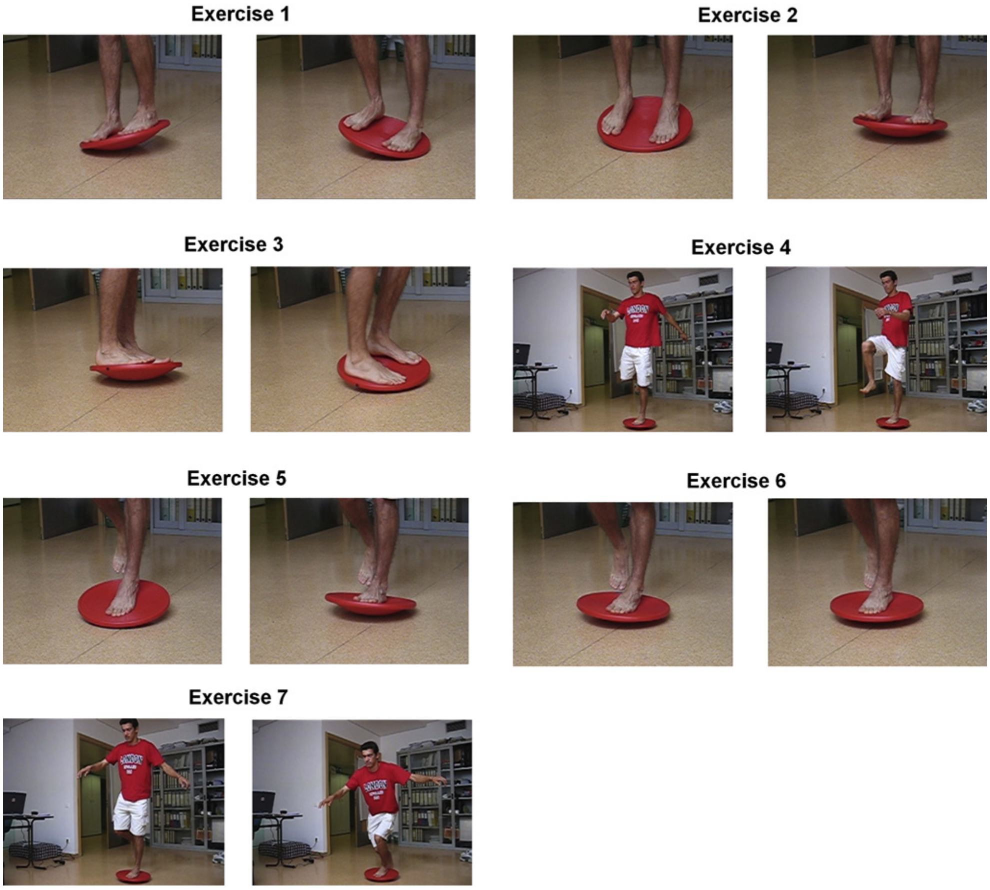

Fig. 2. The different exercises of the balance training program.

For the balance training, an ankle disk platform, 40 cm in diameter, was used (Wolfcare, Portugal).

2.3. Experimental protocol

The experimental protocol consisted of one evaluation prior to the balance training program, and one evaluation after. In each evaluation, subjects underwent three measurements of the latency time on their dominant leg. The dominant leg was determined by a test that consisted of simply asking the subjects to go one step up on a stair. The first leg that they used was considered the dominant leg. The interval between evaluations was four weeks, in which time the subjects in the experimental group completed the training program.

The balance training program consisted of seven exercises (Clark & Burden, 2005; Mcguine & Keene, 2006), that had a duration of 30 s each, with an interval of 15–30 s. In each session, the subjects were asked to do the training protocol twice, with a 1 min interval between training programs. Each subject successfully did two training sessions per week, in a total of eight training sessions during a month. Every session had a qualified assistant watching the subjects, making sure that the exercises were performed in a correct manner.

The exercises were conducted in the following order (Fig. 2):

Exercise 1: Stand with both feet on the ankle disk, rock the board side to side;
Exercise 2: Stand with both feet on the ankle disk, rock the board forward and back;
Exercise 3: Stand with both feet on the ankle disk, rock the board in circular movements;
Exercise 4: Stand with the dominant leg, keep the board levelled while doing swing movements with the free leg;
Exercise 5: Stand with the dominant leg on the ankle disk, rock the board forward and back;
Exercise 6: Stand with the dominant leg on the ankle disk, rock the board side to side;

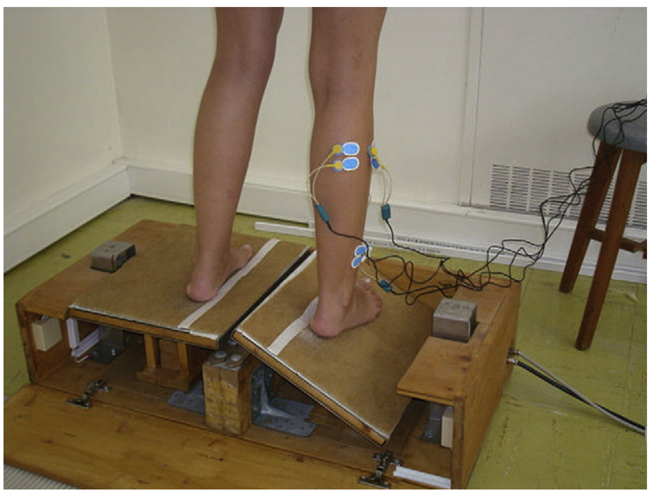

Fig. 3. Trap-door mechanism.

Exercise 7: Stand with the dominant leg on the ankle disk, keep the board levelled while doing ½ squat movement (30–45°).

2.4. EMG analysis

DASYLAB® (Version 7.0, National Instruments Corporation, Austin, Texas, USA), was used to capture the raw EMG signals, as well as the signal from the trap-door. The EMG signals were A/D converted, sampled with a frequency of 1000 Hz and digitally filtered with a low pass (500 Hz) and high pass (10 Hz) filters. Then, the EMG signals were fullwave rectified.

A specific mathematic routine was created using Matlab® (Version R2006a, The Mathworks Inc., Natick, Massachussets, USA), in order to calculate the latency time. This routine began by smoothing the rectified EMG through a low pass filter of 50 Hz and then estimating the baseline EMG amplitude during a time window of 250 ms before the opening of the trap-door. Finally, the routine identified the instant where the trap-door was opened and the muscle EMG onset in order to calculate latency time. The threshold criteria to calculate the latency time was 3 SD above the baseline during a window of 25 ms (Hodges & Bui, 1996).

2.5. Statistics

Mean average and standard deviation of the latency time was calculated for both groups, in the two evaluations that were made. A Shapiro–Wilk test was conducted in order to ascertain if there was a normal distribution among the subjects. Both parametric tests (*t test for paired samples)* and non-parametric tests (*Wilcoxon test)* were used to compare the same muscles, before and after the training period. To compare between groups, it was necessary to use the *Mann–Whitney test*, because not all of samples recorded had a normal distribution.

To compare pre and after exercises tests between groups, it was necessary to use the *Mann–Whitney test*, because not all of the samples recorded had a normal distribution.

3. Results

The values for the EMG latency time for the muscles studied from both groups in pre and post-training are presented in Table 1.

Muscle reaction times that were measured ranged from 66 to 77 ms, when taking in account all of the muscles in both evaluation moments. When taking in account all of the measurements of peroneal latency time, for the two groups and the two evaluations the results showed a mean $= 68.12 \pm 12.74$ ms for Peroneus Longus and a mean $= 67.81 \pm 13.86$ ms for Peroneus Brevis. The evaluation of latency time before the training program showed for the control group a mean $= 69.23 \pm 11.58$ ms for the Peroneus Longus and 67.74 ± 12.44 ms for the Peroneus Brevis. For the experimental group mean average was 70.06 ± 14.26 ms for the Peroneus Longus and 69.62 ± 13.47 for the Peroneus Brevis.

After the training program, the measurements showed a latency time for the control group of 67.19 ± 11.15 for Peroneus Longus and 66.13 ± 12.7 for the Peroneus Brevis. As for the experimental group, mean average for Peroneus Longus was 66.06 ± 13.43 and for Peroneus Brevis was 67.60 ± 16.39.

The Shapiro–Wilk test was conducted in order to ascertain if the groups had a normal distribution. According to the results of this test, we conducted the Wilcoxon test to compare Peroneus Brevis and the *t*-test to compare Peroneus Longus, for the experimental group. When comparing the results of both peroneal muscles before and after the training program, we can see that no significant differences were found ($P > 0.05$). The two other muscles that were also measured (Tibialis Anterior and Gactronemius Lateralis), also did not present significant differences, when comparing pre and post-training ($P > 0.05$).

In the control group, no significant changes were found for all the muscles, when comparing the measurements of both evaluations.

Also in order to examine the effects of the training program, a comparison between the control group and the experimental group (*Mann–Whitney test*), for both peroneal muscles, Tibialis Anterior and Gasctronemius Lateralis was made before and after the training program. No differences were found between groups before or after the training program.

4. Discussion

The first aim of this study was to investigate the outcome of a low volume balance training program, and look into its effect on the onset of peroneal muscle activity in young and healthy adults. Much has been written on training programs that test subjects with recurrent injuries, meaning that they had multiple similar injuries in the same ankle. We chose to use subjects with no history of injury to better understand the behavior of the peroneal muscles, in order to inform the development of training tools that may help prevent ankle injuries.

Additionally, we also analyzed if there were any effects of the balance training program on the EMG onset of Tibialis Anterior and Gastrocnemius Lateralis, two muscles that are not important as ankles stabilizers but that are strongly involved in the dorsi and plantar flexion movements.

The mean onset times of the Peroneus Longus muscle were consistent to the times reported by another study that used surface electrodes for parallel activities (Linford et al., 2006). The mean onset times for Peroneus Brevis were also similar to the ones reported by Benesch, Putz, Rosenbaum, & Becker, 2000. Measuring peroneal reaction times in sudden inversion movements have been shown to be reliable (Benesch et al., 2000; Eechaute, Vaes, Duquet, & Gheluwe, 2007; Lynch, Eklund, Gottlieb, Renstrom, & Beynnon, 1996) and are commonly used as a procedure for assessment of proprioceptive abilities (Benesch et al., 2000; Konradsen et al., 1997; Lofvenberg et al., 1995; Sheth et al., 1997).

Table 1
Pre and post-training EMG muscles latency time (ms) and corresponding *p* value in experimental and control groups.

Muscles	Experimental group				*p* value	Control Goup				*p* value
	Pre-training		Post-training			Pre-training		Post-training		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Peroneus longus	70.06	14.26	66.06	13.43	0.088	69.23	11.58	67.19	11.15	0.396
Peroneus brevis	69.62	13.47	67.60	16.39	0.290	67.74	12.44	66.13	12.70	0.331
Tibialis anterior	73.20	17.34	75.20	17.99	0.867	76.67	22.65	77.40	28.62	0.712
Gastrocnemius lateralis	70.78	17.76	73.74	21.89	0.693	67.66	17.35	65.55	17.89	0.378

A reflex action to a sudden inversion movement begins at a peripheral level by the inversion movement itself. This movement is detected by the receptors near the ankle joint, followed by a reaction pattern mediated by the motor control centres (Konradsen et al., 1997), which can be adaptated by balance training, which also influences sensory systems (Taube, Gruber, & Gollhofer, 2008). So it seems that balance training can be an efficient tool to prevent injury. It has been shown that balance training helps to regenerate neuromuscular structures after injuries (Eils & Rosenbaum, 2001; Freeman, Dean, & Hanham, 1965) and also helps to prevent recurrence (Mcguine & Keene, 2006; Verhagen et al., 2004).

The balance training program that was used in this study was proven to be non-effective in causing noteworthy differences in peroneal latency time. The absence of training adaptations could be explained by two different reasons. The first one is the reduced volume of the training program, eight training sessions of 15 min each over a month. The other possible cause could be the fact that the subjects that participated in this study were young and healthy adults with no history of injuries in the ankle. Probably, one or both of the previous mentioned features explain why the training protocol was insufficient to cause any changes in peroneal latency time or in Tibialis Anterior and Gactronemius Lateralis.

When looking at the results of the peroneal muscles, we can see that similar results were reported by another study (Sheth et al., 1997). The authors also reported no significant differences in latency time, after training everyday over a period of eight weeks with healthy subjects. Each training session was fifteen minutes duration.

They suggested that, despite the fact that no changes were visible in latency time, the results showed a development of a muscle contraction pattern that helped the correction of an excessive inversion movement of the ankle, which can cause an injury. Therefore, they concluded that balance training with a wobble board helps to prevent ankle injuries, by establishing a muscle contraction pattern that would aid the correction of excessive inversion movements. More recently, a study that evaluated peroneal latency time while walking in healthy subjects (Coughlan & Caulfield, 2007), had equivalent results. They found no considerable differences before and after the training program, which was set into practice with healthy subjects over a four week period, with five sessions per week, with different balance training materials compared to the ones used in this study.

If we take a look at the studies with a wider scope, including other forms of evaluation like balance and postural sway, and also different training methods, we can see that the results are opposed to the ones found in this study. The effect of a multi-station proprioceptive program was studied over a period of six weeks with subjects that had ankle instability (Eils & Rosenbaum, 2001). The results demonstrated a decrease in peroneal latency time after the training period. More recently a very similar study to ours, but with subjects with ankle instability (Clark & Burden, 2005), showed that a balance training program with a wobble board, with three training sessions per week, in a total of four weeks, significantly reduced peroneal latency time. A training program which included several exercise methods, with the duration of six weeks, with three sessions in each week, was applied to a group of healthy subjects (Linford et al., 2006). EMG measurements taken after the training program showed a decrease in latency time, when compared to the ones taken at the start of the study. According to the authors, this reduction in latency time may be caused by the training program, which had many aspects of rehabilitation and/or training, including strength, flexibility and neuromuscular control. A training protocol which had proprioceptive and strength training exercises was applied to subjects with a history of ankle sprains (Mattacola & Lloyd, 1997). The results revealed that this type of training program can improve balance, assessed by a dynamic method.

The results of this study by Mattacola and Lloyd (1997), as well as the other studies, seem to show that balance training as a single intervention in a training program is effective in reducing recurrence (Verhagen et al., 2004), but it is not clear if the same applies to subjects without a history of ankle injuries. This idea is supported by a review article made recently on this subject (Hrysomallis, 2007). There is some contradictory evidence to this fact, presented in a study conducted with healthy subjects (Hoffman & Payne, 1995), but the evaluation method was postural sway, and not latency time. It seems that a multifaceted intervention can be more efficient in preventing ankle injuries, when compared to a single intervention training protocol. The studies that were presented here (Clark & Burden, 2005; Eils & Rosenbaum, 2001; Linford et al., 2006) give support to this idea, but more research is needed in order to verify this hypothesis, because there is a lack of research on prevention of the initial injury.

5. Conclusion

If we can develop efficient training protocols that are less time consuming, there would be a reduction in the costs of rehabilitation, as well as a decrease in the amount of time that a person needs to spend preventing this type of injury. This was the reason we tried to find out if a short volume of training would be effective in the reduction of the reflex latency of the muscles related with ankle stability in healthy subjects.

The conclusion of this study is that a balance training program with a wobble board, for a four week period, with two sessions per week, did not influence the latency time in the peroneal muscles, tibialis anterior and gastrocnemius lateralis, when subjected to a sudden inversion movement in healthy subjects. Two reasons could explain these results: (1) the low volume of the training protocol and (2) a reduced sensibility of the subjects of the experimental group to the training effect. Since they had no previous history of injury in the ankle and the neuromuscular control is undamaged and working efficiently, it is possible that the stimulus caused by the balance training program was insufficient to produce changes in the latency time.

Further research on this matter in the future should account for comparisons between physically active and non-active subjects. Also a training program with a bigger time window should be studied to verify if it would influence peroneal latency time, as well as influence the intensity level of muscle contraction.

Ethical statement

Ethical approval for the study was ratified by The Scientific Board of Human Kinetics – Technical University of Lisbon.

Conflict of interest

None.

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