Original article

The effects of neuromuscular training on the postural control of university volleyball players with functional ankle instability: a pilot study

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Summary

Introduction: In volleyball about 90% of players ever suffer an ankle sprain, being repetitive episodes of main complications. It is suggested that neuromuscular training could improve the functionality of the ankle and decrease the risk of a sprain.
Objective: To determine the effects of a neuromuscular training on postural control in college volleyball players with functional ankle instability (FAI).
Method: Quasi-experimental research. The sample was composed of 12 college volleyball male players between 18 and 23 years old. A neuromuscular training of four weeks was carried out and it was distributed in three weekly sessions from 15 to 25 min, on non-consecutive days, totaling 12 sessions. The volume of training was regulated using a progressive periodization and focused mainly on the lower limb, performing it prior to the regular training of the volleyball players. Pre and post intervention postural control were evaluated on a force platform in conditions of open eyes (OE) and closed eyes (CE). From this evaluation, the following variables of the center of pressure (CP) were calculated: Area, mean velocity, medio-latera (ML) velocity and anteroposterior (AP) velocity. T-student test was applied for comparisons with an alpha level of 0.05.
Results: In OE there was a significant decrease in the ML velocity ($p = 0.036$). In CE significant differences between pre and post intervention were observed in mean velocity ($p = 0.043$), AP velocity ($p = 0.019$) and ML velocity ($p = 0.027$).
Conclusion: A four-week training neuromuscular improved postural control on college volleyball players with IFT included in this study.

Key words:
Ankle. Sprain. Joint instability. Postural balance. Volleyball.

Efectos de un entrenamiento neuromuscular sobre el control postural de voleibolistas universitarios con inestabilidad funcional de tobillo: estudio piloto

Resumen

Introducción: Alrededor de un 90% de los jugadores de voleibol sufren alguna vez un esguince de tobillo, siendo los episodios repetitivos una de las principales complicaciones. Se plantea que el entrenamiento neuromuscular podría mejorar la funcionalidad del tobillo y disminuir el riesgo de volver a sufrir un esguince.
Objetivo: Determinar los efectos de un entrenamiento neuromuscular sobre el control postural en voleibolistas universitarios con inestabilidad funcional de tobillo (IFT).
Método: Estudio cuasi experimental. La muestra fue compuesta por 12 voleibolistas universitarios de sexo masculino, entre 18 y 23 años. Se realizó un entrenamiento neuromuscular de cuatro semanas de duración y se distribuyó en tres sesiones semanales de 15 a 25 min, en días no consecutivos, totalizando 12 sesiones. El volumen de entrenamiento fue regulado usando una periodización progresiva y centrada principalmente en la extremidad inferior, realizándola previo al entrenamiento regular de los voleibolistas. Pre y post intervención se evaluó el control postural sobre una plataforma de fuerza en condiciones de ojos abiertos (OA) y ojos cerrados (OC). A partir de esta evaluación se calcularon las siguientes variables del centro de presión (CP): Área, velocidad media, velocidad medio lateral (ML) y velocidad anteroposterior (AP). Se aplicó la prueba t-student para realizar las comparaciones con un nivel alfa de 0,05.
Resultados: En OA solo hubo una disminución significativa en la velocidad ML ($p = 0{,}036$) posterior a la intervención. En OC se observaron diferencias significativas entre la evaluación pre y post intervención para las variables del CP velocidad media ($p = 0{,}043$), velocidad AP ($p = 0{,}019$) y velocidad ML ($p = 0{,}027$).
Conclusión: Un entrenamiento neuromuscular de cuatro semanas mejoró el control postural en los voleibolistas universitarios con IFT incluidos es este estudio.

Palabras clave:
Tobillo. Esguince. Inestabilidad articular. Balance postural. Voleibol.

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Introduction

An ankle sprain is one of the most common musculoskeletal injuries, with a prevalence of 16%[1]. With regard to the types of sprain, the lateral ankle sprain (LAS) accounts for between 77% and 85% of cases[2]. Around 90% of volleyball players have suffered this injury on at least one occasion, with repeated episodes being one of the main complications[3]. Moreover, almost 40% of sprains progress to functional ankle instability (FAI)[4], a concept used to described repeated sprains and/or the feeling of instability[5].

A neuromuscular deficit caused by a ligament injury has been associated with the development of FAI[6]. As the cause of instability, initial theories pointed to a loss of sensory information of the ankle joint, based on an essentially feedback model, caused by a proprioceptive deficit and a motor response deficit[5]. At present, the most widely accepted sensorimotor model is that proposed by Hertel (2008), arguing that not only is there a feedback mechanism caused by the ligament injury, but a feedforward mechanism is also generated associated with the motor control deficit. The initial ligament injury results in immediate ankle proprioceptive deficits, sensorimotor integration and efferent muscle activity. A number of studies have shown that individuals with FAI have a delayed muscle response[7,8]. This alteration of the reflex motor responses would indicate that the spinal motor control mechanisms are clearly affected. Given that proprioception requires the conscious awareness of the joints and muscles, it is reasonable to assume that, in some way, supraspinal aspects of motor control are also altered with FAI[6].

Postural control is considered to be a complex motor skill derived from the interaction of multiple sensorimotor processes directed at controlling the body in space[9]. This includes interaction between the sensory system, the central nervous system (CNS) and the motor system9. In relation to the quantification of postural control, the most common method is the centre of pressure (CP) displacement through a force plate that measures the postural sway experienced by a person in a bipedal stance[10]. Based on the PC, it is possible to obtain variables such as area, velocity and the medial-lateral (ML) and anterior-posterior (AP) components of its displacement[10]. The greater the value of these variables, the lower the postural control. It has been established that individuals with ankle instability show a deterioration in postural control in both the injured and uninjured lower limbs[8,11-13]. Furthermore, it has been shown that, for university athletes, the postural control deficit is a risk factor for FAI[14]. The presence of bilateral deficits in postural control in individuals with FAI provides clear evidence of the central changes in neuromuscular control[6].

FAI rehabilitation over the last decade has been directed at establishing exercise programmes intended to prevent the recurrence of ankle sprains. Different types of training have been recommended for the conservative treatment of this injury, based on exercises: proprioceptive, strengthening, and postural control[15,16]. However, in order to improve neuromuscular control in athletes, there is a need to train all these aspects as a whole and not separately[15,16]. This has led to the term neuromuscular training, used to describe the combination of proprioceptive, strength and postural control exercises as part of a comprehensive rehabilitation program[17]. Studies show that neuromuscular training improves the functionality and reduces the risk of a further ankle sprain[17]. However, few works have reported evidence of the effectiveness of neuromuscular training on FAI in athletes[15].

In this regard, the purpose of this study was to determine the effects of neuromuscular training on the postural control of university volleyball players with FAI.

Material and method

This is a quasi-experimental study. The sample was selected non-probabilistically and for convenience. All participants read and voluntarily signed an informed consent form based on the ethical principles set out in the declaration of Helsinki.

Participants

The sample comprised 12 young male adults, aged between 18 and 23 years, forming part of the men's volleyball team of the Santo Tomás University, Talca, Chile. The following inclusion criteria were considered: 1) History of at least one lateral ankle sprain in the last 12 months that had required immobilization and/or taking the weight off the ankle for at least three days[8]; 2) last episode of a lateral ankle sprain between three to 12 months prior to the study[8] 3) feeling pain, instability and/or weakness in the ankle[8]; 4) score of ≤ 22 points in the questionnaire *Ankle Joint Functional Assessment Tool* (AJFAT)[18]. The study excluded volleyball players who had shown the following characteristics over the last 24 months: 1) vestibular disorders; 2) history of a fractured ankle; 3) acute lower limb injury; 4) history of lower limb surgery; 5) pain in any joint at the time of assessment; 6) those who did not attend at least 70% of the intervention sessions considered in the study.

AJFAT Questionnaire

The AJFAT questionnaire was used as an assessment tool to discriminate between stable ankles and those with functional instability. The AJFAT contains 12 questions, divided into 3 sub-items: 1) limitations relating to pain, stability, stiffness, strength and false steps; 2) activities such as walking on uneven surfaces, changing direction when running, jogging and walking on stairs; 3) ability of the ankle to respond to a rollover[18]. Each question has five response options, with scores ranging from zero to four points. A high score indicates greater stability, with the maximum test score being 48. It has been reported that individuals with FAI have a score of under 23 points in the AJFAT questionnaire[18].

Assessment of postural control

The assessment was carried out at the biomechanical laboratory of the Santo Tomás University, Talca, Chile. In order to determine postural control, the CP displacement was assessed using an ArtOficio (Artoficio Ltda., Santiago, Chile) force plate, size 40x40 cm. The data were acquired with a 40 Hz sampling rate. For the calculation of the CP variables, the Igor Pro version 5.01 software was used (WaveMetrics Inc., Oregon, USA). Postural control measurement was made under eye-open (EO) and eye-closed (EC) conditions. Each visual condition had a duration of 30 seconds. Participants were instructed to maintain the bipedal stance as still as possible with their arms relaxed by their sides, and with their feet shoulder-width apart. Three attempts were made for each stance and these were averaged to give the CP variables. Based on the displacement of the CP in the ML and AP directions, the following variables were obtained: area of the CP (m^2), mean CP velocity (m/s), CP velocity in the ML direction (m/s) and CP velocity in the AP direction (m/s).

Neuromuscular training

The neuromuscular intervention had a duration of four weeks and was structured into three weekly sessions of 15 to 25 minutes, on non-consecutive days, totalling 12 sessions. The training volume was regulated using progressive periodisation and primarily centred on the lower limb, performed prior to the normal training of the volleyball players. All the sessions contemplated circuits with 30 second work stations consisting of coordination exercises on agility ladders, hurdles, step, going up and down stairs, squat exercises, mini-tramp jumping, and Bosu ball squats. Each participant had to perform three sets of the complete circuit per session, considering both limbs in the case of unipedal exercises. During the first week, all exercises were performed bipedally. During the second and third weeks, the physical exercises were performed unipedally, adding active movements of the upper limbs. During the last week, in addition to performing unipedal exercises, the motor tasks on unstable surfaces were performed with eyes closed.

Statistical analysis

The SPSS 20.0 (SPSS 20.0 for Windows, SPSS Inc., IL, USA) statistical software was used and the mean and standard deviation were calculated for all variables. Furthermore, the data distribution was determined with the Shapiro-Wilk test. The student's paired sample t test was used to compare the assessments before and after the intervention. An alpha level of 0.05 was considered for the entire analysis.

Results

All the study participants completed the intervention (n=12). The baseline characteristics of the study participants were on average 21.5 years, 82.3 kilogram of body weight, and a bipedal height of 1.81 metres.

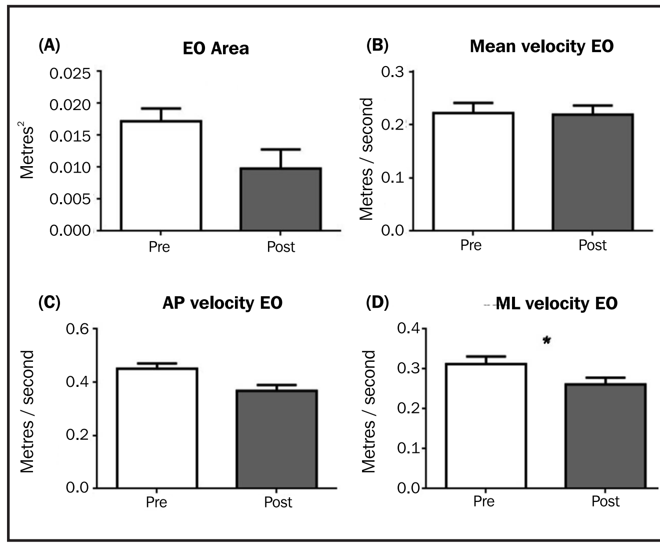
For EO there was a significant reduction in the ML velocity ($p = 0.036$) subsequent to the intervention. With regard to the area, mean velocity and AP velocity, a reduction in the values was observed, which were not statistically significant (Figure 1).

For EC, a significant improvement was observed in the postural control of the volleyball players in the variables for mean velocity ($p = 0.043$), AP velocity ($P = 0.019$) and ML velocity ($p = 0.027$) of the CP after being subject to neuromuscular training. The area was reduced following intervention, however this was not statistically significant (Figure 2).

Discussion

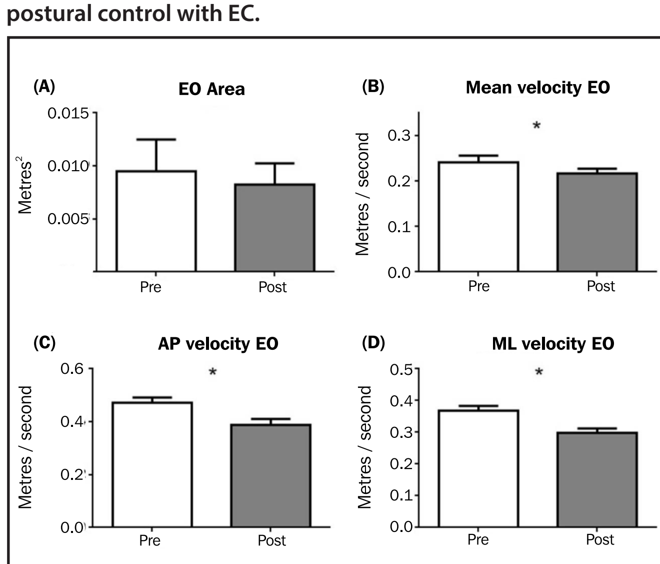
The main study outcome meets the proposed goal and indicates that four weeks of neuromuscular training improves the postural control of university volleyball players with FAI.

Figure 1. Pre- and post intervention results of the assessment of postural control with EO.



*Statistically significant differences ($p < 0.05$). EO: Eyes-open; AP: anterior-posterior; ML: medial-lateral.

Figure 2. Pre- and post intervention results of the assessment of postural control with EC.



Statistically significant differences ($p < 0.05$). EC: Eyes-closed; AP: anterior-posterior; ML: medial-lateral.

Over the last few years, studies have been made on the deterioration of postural control in subjects with ankle sprains and FAI, as well as the different types of training required for their rehabilitation[17]. The literature indicates that neuromuscular exercises improve postural control, muscle strength, proprioception, muscle latency and functionality[15]. Furthermore, these exercises reduce the risk of a further sprain for individuals with FAI[15-17]. However, it has been pointed out that the evidence of the effectiveness of neuromuscular training on FAI is limited[15].

The results of this study show that four weeks of neuromuscular training improves the postural control of university volleyball players with FAI, evidenced in a reduction of the CP variables. Similar findings have been reported in other investigations[5,17,19]. However, with regard to athletes, evidence is scarce. The neuromuscular training programs implemented in persons with FAI indicate that the time spent at the sessions is between 20 to 30 minutes with a duration of four to six weeks[17]. A similar prescription was used in our intervention.

Lateral ankle sprains are among the most common sports injuries and their recurrence is a factor associated with the development of FAI[3]. Postural control deficit in persons with FAI has been attributed to sensory receptor damage caused by the ligament injury[5]. Current literature includes studies on healthy subjects, with no findings of sensorimotor control deficits when simulating an ankle ligament injury[20,21]. This would indicate that the sensory information is not solely due to damage to the ligament, but that other receptors are also involved (i.e. capsular, muscle-tendon and cutaneous receptors) that are there to permit good sensorimotor control[20,21]. The postural control deficit detected in both the injured and uninjured ankles of the volleyball players would explain why not only do local sensorimotor deficits exist, but also centrally mediated deficiencies[6,8]. For this reason, the neuromuscular training applied in our study considered the performance of exercises with both limbs for unipedal tests.

Despite the various studies conducted in this area, it is still not clear which type of rehabilitation training is the most effective in the prevention of recurrent ankle sprains[16]. It could be considered that the restoration of proprioception would be the principal treatment to improve ankle stability[16,22]. However, adequate proprioception does not ensure that the muscle strength and activation are sufficient to respond to rapid and unexpected disturbances such as landing on an uneven surface[16]. With regard to muscle strength, some controversy exists with regard to its relationship with ankle instability. While some studies report that individuals with FAI exhibit weakness of the peroneus muscles and dorsal flexors of the ankle[23], other studies found no link between muscle weakness and instability[24]. For its part, the role of muscle activation on ankle instability appears to be slightly clearer, given that a number of studies have demonstrated that athletes with FAI exhibit an increased reaction time of the peroneus muscles[7,8]. For this reason, during rehabilitation it is suggested to include physical exercises on unstable surfaces and/or changes of direction that are demanding on the motor system, in order to provoke short-latency muscle responses, promoting adequate postural control[8].

Neuromuscular training focussed on balance or postural control is the most common rehabilitation treatment for individuals with FAI. The majority of the literature has reported positive therapeutic effects on this type of intervention[25,26]. However, it has been pointed out that the evidence is weak for the application of functional physical body weight-bearing exercises and balance activities on unstable surfaces[27]. In view of the above, over the last few years a combination of proprioceptive, strength and postural control exercises has been proposed for the treatment of individuals with FAI[17]. The neuromuscular training bases not only seek to stimulate the sensory system but also the centrally mediated mechanisms which interact in different kinetic chains of movement.

Our results show that postural control primarily improved in the EC position. Vision is an extremely important sense for postural control. It is believed that, even when the somatosensory input is interrupted due to injury, the visual information can provide an adequate amount of feedback to compensate the deficits in the central pathways[9]. When the eyes are closed, there is greater postural sway due to the inhibition of one of the sensory systems contributing to postural control[9]. Therefore, the possibilities of maintaining stability are decreased and, in compensation, the involvement of the somatosensory and vestibular systems increases. This means that the EC test is more demanding that the EO test and the differences are more evident. For this reason, rehabilitation exercises are performed with eyes open and eyes closed alike. It has been reported that the effects are greater when the training sessions are made in the absence of visual input[28].

The significant changes in the postural control of the university volleyball players following neuromuscular training were observed in the CP velocity variables. Although the CP area and velocity are the most representative measurements of postural sway, it has been established that velocity is the most reliable variable to represent postural control[29]. Wikstrom, Fournier and McKeon (2010) reported that one of the most sensitive variables to identify the deterioration of postural control in individuals with FAI is the CP velocity in the ML direction[30]. In our study, the intervention significantly reduced the ML velocity for EO and EC and the AP velocity for EC. This could be attributed to the fact that neuromuscular training would optimise the responses of the fibular and tibialis anterior muscles responsible for the ML[31] and AP stability[8] of the ankle, respectively. It has been demonstrated that athletes with FAI exhibit a greater reaction time for these muscles8. The postural control deficit is closely related to the increased reaction time of the muscles involved in joint stability[12].

The limitations of this study include the small sample size, the convenience sampling of participants and the lack of a control group. This will probably limit the external validity of the study. Despite this, the statistical significance observed in each comparison reflects the effectiveness of the intervention.

In conclusion, our study indicates that four weeks of neuromuscular training improved the postural control of the university volleyball players with FAI included in this study. We would suggest that this type of training should be applied to both the injured and uninjured limb, considering the central alterations caused by the injury. Furthermore, in order to enhance the effects of the training, we would recommend including physical exercises in EC conditions.

Conflict of interest

The authors have no conflict of interest at all.

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