ACTA GYMNICA, 2023, Volume 53, Article e2023.011
https://doi.org/10.5507/ag.2023.011

OPEN ACCESS

ORIGINAL RESEARCH

The immediate effect of a balance wobble board protocol on knee and ankle joint position sense in female soccer players

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Abstract

Background: Lower limb injuries are widely recognized as the most prevalent injuries among female soccer players. Joint position sense plays a vital role in muscle reflexes, joint stability dynamics, and movement planning for neuromuscular control. Decreased accuracy in joint position sense can be considered an internal injury risk factor. **Objective:** The current study aims to investigate the immediate effect of a short-term balance protocol with a wobble board on knee and ankle joint position sense. **Methods:** Forty female participants were recruited and then randomly allocated into two groups: balance training (BTR; n = 20, age 23.50 ± 1.50 years) and control (CON; n = 20, age 23.10 ± 1.77 years). Knee and ankle joint reconstruction errors were measured using a gyroscope at 60° of knee flexion and 30° of ankle plantarflexion. Following this, the BTR group participated in a short-term balance protocol (one session). Immediately following training and then one hour later, the reconstruction error was measured in both groups. **Results:** A mixed-repeated measures analysis of variance demonstrated that for the BTR group, the absolute angular error (AAE) before and after intervention decreased by 2.14° and 2.95° in the knee (p = .001) and ankle (p = .001) joints, respectively. In addition, an hour after intervention, the AAE remained below the initial value in the two joints (p = .001). Specifically, in the CON group, the AAE in the knee joint did not show a significant decrease, and similarly, no significant change was observed in the AAE in the ankle joint, and also an hour after the intervention. **Conclusions:** A wobble board training session may stimulate the sensory receptors of the knee and ankle joints of female amateur soccer players and increased joint position sense accuracy and is present one hour post intervention.

Keywords: wobble board, knee, ankle, proprioception, reconstruction error

Introduction

Soccer is the most popular sport in the world. (Alimoradi et al., 2022; O'Kane et al., 2017). Previous research has identified the knee and ankle as common sites of injury among female players (Gulbrandsen et al., 2019; Joo, 2022). A five-season prospective injury study of elite men and female soccer players demonstrated that knee and ankle ligament injuries were higher in females (Larruskain et al., 2018). Injury can have a detrimental effect including psychological problems, match absence, long-term disability, and the financial cost of treatment (Li et al., 2020). The incidence of injuries and injury risk is impacted by various factors, some of which are modifiable and include joint position sense (JPS; Navarro-Santana et al., 2020). JPS is provided by mechanical receptors located in the skin, muscles, tendons, joint capsules, and ligaments and transmitted to the central nervous system (Moon et al., 2021). Feedback from JPS receptors play an important role in the dynamic stability and movement planning of neuromuscular control (Alimoradi et al., 2022). The reduction of JPS may increase joint stress by altering joint stability and making the joint vulnerable to injury (Alimoradi et al., 2022).

Ankle and knee joint injuries are related to the dysfunction of these mechanical receptors (Cuğ & Wikstrom, 2018; Schiftan et al., 2015). Disorder in JPS in the lower extremities can have a variety of side effects, including changes in joint stability and movement control (Romero-Franco & Jiménez-Reyes, 2017), postural disorders (Mohammadi Bazneshin et al., 2015), and abnormal joint stress (Yosmaoglu et al., 2013). It is advocated that performing proprioception and balance training has a beneficial effect on injury prevention (Evangelos et al., 2012). Benefits of balance training include improvement of JPS, central nervous system function, adaptation of muscle activity proximal to the knee and ankle and increased dynamic stability in these joints (Yalfani et al., 2017). One form of balance training involves using a wobble board, which allows athletes to

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Article history: Received February 16 2023, Accepted October 1 2023, Published November 2 2023

perform close kinematic chain movements and improve joint balance by reducing instability through multifaceted movements (ALJawaee et al., 2021; de Brito Silva et al., 2018). Wobble board training increases the range of motion (Linens et al., 2016), postural stability and physical functions for activities of daily living (Schiftan et al., 2015).

Most studies have investigated the effect of balance training on JPS performance in various body joints over a duration of greater than 4 weeks (Jain et al., 2014; Tekin et al., 2018). Past studies demonstrated that joint receptors are affected by instantaneous stimulations such as vibration or electrical ones, which stimulate receptors, muscle spindles and brain activity (Babakhani et al., 2020; Forouhideh et al., 2011). Therefore, the main objective of this study was to ascertain whether the implementation of an immediate protocol utilizing a wobble board improves JPS in the knee and ankle joints of female soccer players.

Methods

Participants

Forty-four female soccer players aged 20–25 years from three amateur soccer clubs were recruited by one researcher who attended the clubs and provided an explanation of the study. The inclusion criteria were:

1. Participants were soccer players from soccer clubs of Tehran city with at least three years of experience playing soccer and attended a minimum of 4 training sessions weekly.
2. No history of injury or surgery in the lower extremities within the last year.
3. No previous participation in an injury prevention program.

Forty participants were eligible for inclusion. Participants were randomly allocated by a mobile app (Random Name Picker, version 4.3.15), into two groups: balance training (BTR, n = 20) and control (CON, n = 20). Demographics are reported in Table 1.

Table 1 Basic sample characterization ($M \pm SD$)

Variable	Balance training (n = 20)	Control (n = 20)
Age (years)	23.50 ± 1.50	23.10 ± 1.77
Height (cm)	177.65 ± 4.32	177.55 ± 4.10
Weight (kg)	70.80 ± 5.55	72.40 ± 5.59
Body mass index (kg/m^2)	22.59 ± 1.92	23.62 ± 2.85

Informed consent was obtained from all subjects involved in the study. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee in Research of the Shahid Bahonar University of Kerman (Code: IR.UK.VETMED.RED.1400.093).

Procedure

The dominant leg was determined by asking participants which leg would be their dominant leg for kicking a ball (van Melick et al., 2017) and JPS in the pre-test was measured in the dominant leg at the knee and ankle joints. Prior to commencing the intervention program, the BTR group was verbally instructed and given a practical demonstration on how to perform the wobble board protocol by one of the researchers who was trained in the protocol and the use of the gyroscope. During the BTR protocol, the CON group adopted a supine position to reduce the potential for proprioceptive receptor simulation, which can occur in walking and standing. Both groups of participants underwent a warm-up session, which included five minutes of slow running and dynamic stretching exercises focused on the lower limbs, specifically targeting the quadriceps, hamstring, and gastrocnemius muscles. This warm-up aimed to prepare the participants for the study.

Prior to commencing the intervention, the participants rested for two minutes to reduce potential fatigue effects and then the intervention was performed by the BTR group for six minutes with a wobble board and this protocol is reported in Table 2. A wobble board (Tavan Gostar Company, Tehran, Iran) was used as it is a portable piece of equipment and affordable for soccer clubs. The program was developed by (Clark & Burden, 2005) and consists of five levels. Firstly, the BTR group completed the lowest level (one out of five) and then performed other levels sequentially. During the protocol, all exercises were performed for one set and the program took six minutes per participant. The duration of each level of the program was controlled by a chronometer. The effect of the balance training was evaluated through repeated measurements, including a post-test and a follow-up test conducted one hour later. In the follow-up test in order to control activity, during an hour break after the post-test, the participants were instructed to remain seated on chairs without engaging in any specific movements.

Table 2 Balance training program protocol

Level	Exercise description
1	Stand and keep your feet parallel to the board, and then move the board in back and forward directions. Continue for 30 s, and then rest for 10 s.
2	Stand and keep your feet parallel to the board and move from side to side. Continue for 30 s, and then rest for 10 s.
3	Stand on the board with your legs in 20° knee flexion and move the board from the front to the sides in a circular motion. Continue moving for 30 s, and then rest for 10 s.
Repeat exercises 1–3 in 20° knee flexion and with your hands placed on your hips.	
4	Stand on your dominant leg on the board with your non-dominant foot not touching the board. Maintain balance for 10 seconds. Repeat the exercise 6 times with a 10-s rest between each repetition.
5	In stage 5, if balance can be maintained on dominant leg with your non-dominant foot not touching the board without losing stability of the board, then complete with your eyes closed.

JPS measurement of the knee and ankle joints

To measure JPS, angles of 60° for knee flexion and 30° for ankle plantar flexion were used due to their widespread utilization in soccer (Dejnabadi et al., 2005; Paschalis et al., 2010). A triaxial gyroscope (Danesh Pajoohan HC-05; Danesh Pajoohan Javan Company, Tehran, Iran) was used to measure the absolute angular error (AAE), which has good intra-rater reliability (ICC = .96; Aslan et al., 2018). AAE is defined as the difference between achieved and target angles (Kang et al., 2020).

Knee JPS test

To measure JPS of the dominant knee joint, participants were instructed to sit on the edge of a table with their knee in 0° flexion (full extension) with 2 cm of space between the table and the popliteal fossa (Figure 1). The JPS was tested in 60° flexion (Thomas & Simon, 2012); the gyroscope device was placed by a strap on the superior tibia. The system was then calibrated by measuring the 90° knee angle manually for each participant using a goniometer. Additionally, a practice calibration was provided before each trial to minimize any potential learning effect. Following calibration, the tester (K.H.) asked participants to move their knee to the target angle of 60° knee flexion, hold this position for three seconds and memorize the position. The trial was repeated three times. Afterwards, to eliminate visual feedback, the participant was asked to close their eyes, wear a blindfold and move their knee joint actively to the predetermined angle for three trials. The difference between the two types of movement was calculated and the mean of three trials and AAE was recorded (Aslan et al., 2018).

Ankle JPS test

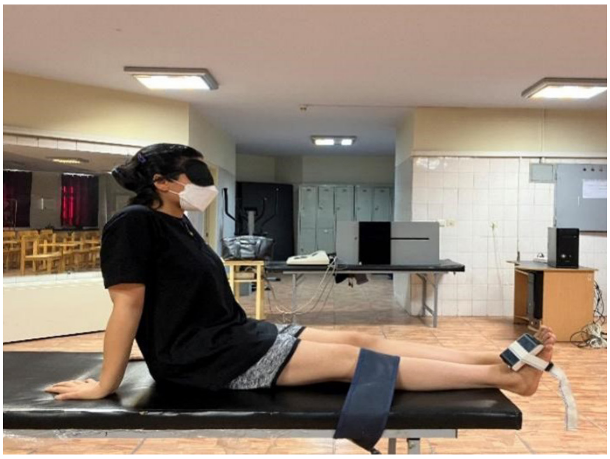
To measure JPS of the ankle joint, participants adopted a sitting position (Figure 2). This non-weight-bearing position was chosen to minimize receptor activity, considering that most ankle sprains occur when the foot is lightly touching the ground, making the detection of limb position without loading crucial (Spanos et al., 2008). Similar to the knee joint assessment, the JPS of the ankle was measured with the gyroscope device. To calibrate the system, we manually measured the 90° ankle angle for each participant using a goniometer. Additionally, we conducted a practice calibration before each trial. Following calibration, participants were instructed to move their ankle to the target angle of 30° ankle plantarflexion. They performed this movement three times, holding the position for three seconds and memorizing its location with each repetition then participants were blindfolded and asked to actively reproduce the target angle during three trial attempts. The calculation of the AAE for the ankle joint followed the same procedure as that for the knee joint (Kang et al., 2020).

Statistical analysis

Data was analyzed using IBM SPSS software (Version 26; IBM, Armonk, NY, USA) and the significance level for all statistical analyses was set at $\alpha = .05$. A Shapiro-Wilk test and Levene's test were used to confirm the normality and the homogeneity of variance of data ($p > .05$). A mixed-model analysis of variance was conducted to assess the effect of the intervention, with the between-group factor consisting of two levels (experimental and control) and the within-group factor consisting of three levels (pre-test, post-test, and follow-up test). A Bonferroni post-hoc test was applied to compare within-group results when main or interaction effects were indicated. Effect size (η_p^2) was determined for all parameters, where η_p^2 of .02, .13, and .26 wase defined as small, medium, and large, respectively (Pallant, 2020).

Figure 1 Measuring knee joint position sense with the gyroscope

Figure 2 Measuring ankle joint position sense with the gyroscope



Results

The comparison of the JPS in the knee and ankle joints of the two groups in the pre-test, post-test and follow-up test is presented in Table 3. The results of mixed-model analysis of variance, as shown in Table 3, indicate a significant difference in time effect ($p < .05$), group effect ($p < .05$), and group × time interaction ($p < .05$) for knee flexion at 60° and ankle plantarflexion at 30°.

Table 3 Means and standard deviations (in degrees), and one-way analysis of variance of joint position sense of knee and ankle in each group based on degrees of error

			Analysis of variance		
Variable	Balance training	Control	Time effect	Group effect	Group × Time interaction
Knee flexion 60°					
Pre-test	3.00 ± 1.27	3.10 ± 1.81	F = 9.87	F = 7.11	F = 8.29
Post-test	0.86 ± 0.99	3.23 ± 1.14	p = .001	p = .001	p = .001
Follow-up test	0.76 ± 0.73	2.86 ± 1.38	η_p^2 = .15	η_p^2 = .55	η_p^2 = .21
Ankle plantar flexion 30°					
Pre-test	4.05 ± 1.08	3.80 ± 1.52	F = 39.35	F = 20.67	F = 21.19
Post-test	1.10 ± 0.87	3.88 ± 1.32	p = .001	p = .001	p = .001
Follow-up test	1.04 ± 0.83	2.73 ± 1.09	η_p^2 = .61	η_p^2 = .25	η_p^2 = .48

The Bonferroni post-hoc test was conducted to further examine the pairwise comparisons between different time points for the BTR and CON groups in terms of the AAE in the knee and ankle joints. For the BTR group, the Bonferroni post-hoc test revealed a significant reduction in AAE from the pre-test to the post-test in both the knee and ankle joints (p = .001). This indicates that the Balance Training intervention led to improved joint position sense, as demonstrated by a decrease in AAE. On the other hand, for the CON group, the pairwise comparisons of the pre-test, post-test, and follow-up tests did not show any significant differences in AAE. This suggests that there were no significant changes in joint position sense over time in the CON group.

Discussion

The main objective of this study was to determine whether a single session of a balance training protocol could lead to reduced absolute angular error and improved JPS in the knee and ankle joints among female soccer players and whether these effects would persist for up to an hour after the intervention. The results indicated that the BTR group that underwent the balance training protocol exhibited a lower mean than the CON group in both the knee (0.86 vs. 3.23) and ankle (1.10 vs. 3.88) JPS tests following the intervention, and the effects were sustained during the follow-up test. Therefore, the present protocol appears to be effective in improving proprioception in the lower limb joints. Previous studies have indicated that performing balance training with a wobble board is effective in improving balance and neuromuscular control in long-term protocols of more than 4 weeks (Pirasteh et al., 2022; Silva et al., 2018) however, there is a paucity of research that has investigated immediate effects. The performance of closed kinematic chain exercises has beneficial effects on the improvement of neuromuscular control because these exercises can promote the performance of mechanical receptors and neuromuscular control (Tagesson et al., 2008).

Performing balance training can reduce absolute angular error (Clark & Burden, 2005) as balance training increases the electromyographic activity of muscles by improving the performance of motor control units and increasing the activity of muscle spindles (Clark & Burden, 2005). Delayed reaction time in lower limb receptors to stimuli may increase the risk of musculoskeletal injuries in athletes (Chittrakul et al., 2020). These beneficial effects of balance training may be effective in decreasing starting reflective response time (Clark & Burden, 2005). The starting reflective response is part of a muscle activation pattern response to a sudden perturbation and increases joint stiffness so that the joint adopts a safe position increasing stiffness of the joint (Clark & Burden, 2005). Balance training is most commonly performed on unstable surfaces such as a wobble board (Cimadoro et al., 2013) and unstable surface stress muscles and joints in multiple directions and are more challenging and require greater perturbation than a flat surface (Cimadoro et al., 2013; de Brito Silva et al., 2018). Therefore, exercising on unstable surfaces may improve JPS and within our study, immediate beneficial effects were demonstrated.

The proprioceptive system is crucial for sensing the position, movement, and forces acting on our limbs and joints, aiding motor control and coordination (Ouattas et al., 2019). Proprioceptors and sensory receptors located in muscles, tendons, ligaments, and joints, enable this system (Ouattas et al., 2019). Efferent neurons transmit signals from the central nervous system to the muscles, while afferent neurons relay sensory information back to the central nervous system (Chien et al., 2019). These signals allow the brain to perceive and interpret the positioning and motion of body parts, facilitating our ability to move and coordinate our actions (Chien et al., 2019). This system encompasses two aspects of JPS: static and dynamic (Ergen & Ulkar, 2008). The proprioceptive system provides conscious orientation of one body part with respect to another (static sense) and also provides the neuromuscular system with feedback about the rate and direction of a movement (dynamic sense; Ouattas et al., 2019). This feedback is not dependent on motion but can be accurately and precisely quantified through a static and passive test (Ouattas et al., 2019). Therefore, this system forms a neuromuscular process that allows the body to maintain stability and orientation during both static and dynamic activities (Ergen & Ulkar, 2008). This process is disrupted in injured athletes and the continuation of information processing is reduced, which escalates the risk of injury and decreases the level of performance (Ben Moussa Zouita et al., 2008). Therefore, the role of JPS is critical for the prevention of knee and ankle injuries in female soccer players due to the high injury incidence in this cohort (Souglis et al., 2022).

The current study contained some limitations. Prospective investigations could explore whether the cumulative use of this wobble board program at every training session has long-term benefits in improving balance ability. Furthermore, conducting injury surveillance alongside the implementation of the wobble board program would allow for the determination of potential impact on injury rates. Although our findings are limited to the use of a wobble board as a training intervention, it is worth noting that the wobble board holds practical benefits due to its portable and low-cost nature. Moreover, the field-based nature of our study offers more practical applications than laboratory-based studies. Our study did not employ a passive threshold proprioceptive test, which measures the absolute minimum proprioceptive threshold for detecting passive motion. This limitation may have impacted our assessment of proprioceptive abilities. Finally, it is crucial to recognize that our findings are confined to the activities provided within the wobble board intervention, and other proprioceptive training methods or interventions may yield different results.

Conclusions

The study demonstrates that the use of a balance training protocol decreases the absolute angular error of knee and ankle joints and therefore the wobble board may potentially have use in injury prevention and could form part of a warm-up protocol. Coaches and athletes could consider the implementation of such a protocol prior to commencing training and competition.

Acknowledgments

The authors gratefully acknowledge all participants involved in the study.

Conflict of interest

The authors report no conflict of interest.

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