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Original Research

Do lower limb previous injuries affect balance performance? An observational study in volleyball players

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ABSTRACT

Objectives: To study static and dynamic postural balance control in elite and sub-elite male volleyball players with or without a history of musculoskeletal lower limb injuries.
Design: Cross-sectional study.
Setting: Laboratory.
Participants: Data were obtained from 45 male volleyball players, divided into healthy (CON, $n = 28$) and previously injured (INJ, $n = 17$) players by means of an injury self-reported questionnaire.
Main outcomes measure: Static postural balance parameters were recorded carrying out a monopodalic test with the dominant leg on a stabilometric platform. Dynamic postural balance was assessed with the modified Star Excursion Balance Test (mSEBT) in its version based on three directions (anterior, postero-lateral and postero-medial).
Results: No statistically significant differences were detected between CON and INJ for all the static postural balance parameters considered. Conversely, the mSEBT results underlined a statistically significant decrease of the performance in the three directions ($P < .001$) for INJ with respect to CON.
Conclusions: The mSEBT should be employed in male volleyball players with a history of musculoskeletal lower limb injuries to better assess postural balance control alterations. Moreover, the decrement of the dynamic balance performance may indicate that, before returning to competitions, the rehabilitation protocol should be more focused on dynamic balance exercises.

1. Introduction

Volleyball is a non-contact sport where two teams are separated by a net. For this reason, it is considered a safe sport compared to others where the contact among players is a fundamental part of the rules (Engebretsen et al., 2013; Soligard et al., 2017). However, the high volume of jumps and sport-specific tasks (e.g. blocking, spiking, serving) performed at high intensities puts volleyball players at risk for musculoskeletal injuries (Bere, Kruczynski, Veintimilla, Hamu, & Bahr, 2015). Indeed, a recent review (Kilic, Maas, Verhagen, Zwerver, & Gouttebarge, 2017) has shown that volleyball injury rate ranged from 1.7 to 10.7 injuries per 1000 player hours. Ankle and knee injuries are most often reported (Bahr & Bahr, 1997; Bahr & Reeser, 2003; Barber Foss, Kim D, Myer Greg D., 2014).

Lower extremity injuries have been observed to negatively affect postural balance and to increase the incidence of future injuries (Hrysomallis, 2007). Moreover, postural balance deficits have been detected in individuals with acute or overuse injuries in the lower limbs, both in static (McKeon & Hertel, 2008; Negahban, Mazaheri, Kingma, & van Dieën, 2014; Wikstrom, Naik, Lodha, & Cauraugh, 2010) and dynamic conditions (Aminaka & Gribble, 2008; Doherty et al., 2015b). Conversely, inconsistencies are reported in the static single-leg balance control in people with a history of lower extremities injuries. Indeed, some studies reported deficits (Arnold, De La Motte, Linens, & Ross, 2009; Baltich et al., 2015; Munn, Sullivan, & Schneiders, 2010) while others reported contrary results (McKeon & Hertel, 2008; Ross & Guskiewicz, 2004). Most of the studies have found dynamic balance to be impaired in previously injured subjects compared to healthy

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subjects (Delahunt, Chawke, & Kelleher, 2013; Doherty et al., 2015a; Hale, Hertel, & Olmsted-Kramer, 2007; Herrington, Hatcher, Hatcher, & McNicholas, 2009; Meardon & Klusendorf, 2016).

Postural balance performance can be measured by means of different tools which can be included in two main categories: laboratory tests or field-based tests. Laboratory tests usually quantify the postural balance performance during bipedal or unipedal standing task throughout a stabilometric platform which measures the center of pressure trajectory. Field-based tests have been developed to give physical therapists, coaches, and sports scientists the opportunity to evaluate postural balance performance in a less expensive and easier to implement way. Among these, the star excursion balance test (SEBT) is a dynamic test which requires at the same time proprioception, coordination, strength and flexibility (Kinzey & Armstrong, 1998). It is widely used in sport and clinical setting and consists of a series of single leg squats, in which the participants have to touch with the tip of the non-stance foot as far as possible along specific directions identified by lines drawn on the ground. Although the SEBT was originally designed in 8 directions, it was then recommended to be performed only in 3 directions (anterior, posterior-medial, posterior-lateral) due to the great redundancy of results (Hertel, 2008). The SEBT and its variants have been extensively adopted by researchers and clinicians with several aims as differentiate pathologic conditions (Gribble, Hertel, & Denegar, 2007; Herrington et al., 2009), quantify rehabilitation/training interventions in injured (Hale et al., 2007; Mckeon et al., 2008) and healthy (Bouillon & Baker, 2011; Filipa, Byrnes, Paterno, Myer, & Hewett, 2010) individuals and predict the injury risk to lower extremity joints (Plisky, Rauh, Kaminski, & Underwood, 2006).

Despite a large number of scientific papers have demonstrated how lower limb injuries negatively affect postural balance performance, only few studies have investigated these aspects in volleyball players. Moreover, although most of the players present different injuries regarding both the anatomical site where the injury occurs (e.g. hip, knee, ankle, …) and the anatomical tissue involved (e.g. muscle, tendon, ligaments, …), the majority of scientific studies investigated only the effects of a specific injury on postural balance performance. Therefore, on the relevance of the previous investigations, the purpose of our study was to investigate static and dynamic postural balance control in previously injured and uninjured elite and sub-elite volleyball players. It was hypothesised that postural control differences would exist between injured and uninjured players with an overall better performance among uninjured players.

2. Methods

2.1. Participants

Data were collected from 45 male volleyball players (mean age = 22.7 ± 3.4 y, height = 188.6 ± 8.8 cm, weight 82.6 ± 8.7 kg; training frequency 10.4 ± 5.4 h per week) competing in the Italian Superlega (Division I, n = 10), Serie A2 (Division II, n = 2), Serie B (Division III, n = 10) and Serie C (Division IV, n = 23). In particular, we enrolled 9 setters, 11 receiver-hitters, 9 middle blockers, 9 liberos, and 7 opposites. The sample numerosity was defined throughout an a priori power analysis calculation (see the statistical analysis paragraph for details). The players were recruited on a voluntary basis among local volleyball teams in Padova, Italy. Inclusion criteria included the absence of ongoing acute and overuse orthopedic injuries as well neurological pathologies, sight, hearing and vestibular disorders. All players had at least 3 years of volleyball experience at the time of the study.

2.2. Protocol

The tests were performed either in the nutrition and exercise physiology laboratory of the university or in the teams training base. The testing conditions were the same in the two sites. Each player performed all the tests on the same day. At the time of testing all the players were cleared for regular volleyball practice according to the teams medical staff.

Prior to data collection, they were informed about the experimental procedures and signed an informed consent. The study was approved by the ethical committee of the department. A questionnaire regarding age, height, body mass, team volleyball experience, and number of weekly training hours was completed before the execution of the tests. Moreover, they were asked to self-report the number and the location of the lower limb musculoskeletal injuries (hip, knee, ankle, and foot) which stopped their volleyball activity for greater than seven days (Fuller et al., 2006; Meardon & Klusendorf, 2016). The length of the dominant leg, defined as the preferred leg in kicking a ball, was measured from the anterior superior iliac spine to the center of the ipsilateral medial malleolus. On the basis of the questionnaire filled out, players without musculoskeletal injuries were allocated in the control group (CON; n = 28) while those with previous lower limb musculoskeletal injuries formed the injury group (INJ; n = 17). A graphical representation of the experimental protocol is reported in Fig. 1.

2.3. Monopodalic balance test

Players were instructed to stand with eyes open in the center of a stabilometric platform (RGMD S.p.a., Genova, Italy) with arms relaxed at their sides and to gaze a red line vertically placed on a wall at a distance of 80 cm from the platform. Then they were asked to lift the non-dominant leg. The recording automatically started after 5s at a sampling rate of 100 Hz. Two 20-s trials were collected for each player. A trial was considered invalid if a player displaced his standing leg or touched the floor with the contralateral leg. All trials were performed barefoot. Static postural balance performance was assessed by means of the following parameters: (1) the area of the confidence ellipse [mm^2]; (2) the sway path [mm/sec]; (3) the sway area [mm^2/sec]; (4) Maximal oscillation in the anterior-posterior (AP) and mediolateral (ML) direction [mm]. The trial with the lower area of the confidence ellipse was selected for the analysis.

2.4. Modified star excursion balance test (mSEBT)

The mSEBT was performed with the players standing in the middle of a grid formed by three lines drawn on the ground. The player was asked to reach as far as possible along each of the three lines, making a light touch of the line with the tip of the foot, and returning to a double-leg stance in the center of the grid. Players were not allowed to touch the floor while returning with the foot to the center of the grid. Moreover, they were not allowed to raise the

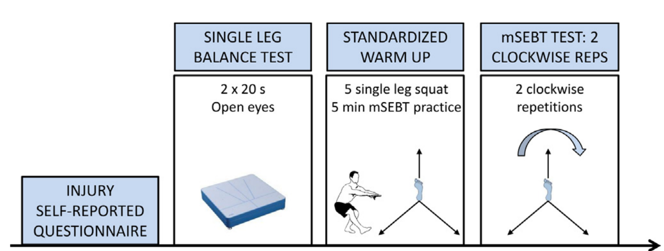

Fig. 1. Graphical representation of the experimental protocol.

heel or any other part of the foot which was on the floor to maintain the single leg stance. If this compensation happened, the trial was discarded and repeated. After a standardized warm-up consisting of five single leg squats for the dominant leg, players performed 5 minutes of practice to avoid any possible learning effect. Players then performed the two trials in each of the three directions, starting with the anterior and following a clockwise progression. The investigator measured each distance reached by the tip of the foot from this point to the center of the grid. Each distance was then normalized to the participants' lower limb length (Gribble & Hertel, 2003). A composite mSEBT score was also determined by summing the three normalized measures. The second trial of each player was used for the analysis.

2.5. Statistical analysis

An a priori power analysis was performed with the G*Power 3.1.9.2 software (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the convenient sample size. For a large effect size ($d > 0.80$) (Cohen, 1988), a required power ($1-\beta$) of 0.80 and an α error = 0.05, the total sample size resulted in 42 players. Therefore the 45 players enrolled represented an appropriate sample. Unpaired t-tests were carried out to compare the INJ and CON stabilometric balance test results and mSEBT scores. The level of significance was set at $p < .05$. Data analysis was performed using the software package GraphPad Prism version 4.00 for Windows (GraphPad Software, San Diego California USA).

3. Results

The average number of lower limb injuries reported for the dominant leg of INJ was 2,18 ± 2,32. No statistically significant differences were detected between CON and INJ for all static postural balance parameters (Table 1). Conversely, all mSEBT scores were significantly shorter (anterior direction, $P < .0001$, Effect Size = 1.42; posterior-lateral direction, $P = .0063$, Effect Size = 0.89; posterior-medial direction, $P = .0039$, Effect Size = 0.98) for INJ compared to CON (Fig. 2). Also, the composite mSEBT score was lower for INJ compared to CON ($P < .0001$; Effect Size = 1.67).

4. Discussion

The aim of our study was to investigate static and dynamic postural balance among previously injured and uninjured elite and sub-elite volleyball players. Indeed, injuries to lower extremities in volleyball have been demonstrated to be frequent (Kilic et al., 2017) and to negatively influence the postural balance as well (Hrysomallis, 2007). Thus, the maintenance of postural stability is very important in several volleyball actions where at least one foot of the player is in contact with the floor, such as receiving a serve, defense, digging and setting. Since the ability of a volleyball player to control his or her postural balance is strictly related to the accuracy of these actions (Kuczyński, Rektor, & Borzucka, 2009), the development of postural control skills are considered an important goal of the volleyball conditioning training.

The mSEBT results indicated a worse dynamic balance performance of INJ with respect to CON. These findings are consistent with previous work in other populations. Indeed, using this tool, deficits were detected in subjects with and without chronic ankle instability, ACL reconstruction and patellofemoral pain (Gribble, Hertel, & Plisky, 2012). Although none of the previous studies specifically examined volleyball injuries, our experiment revealed mSEBT to be sensitive enough to distinguish players with and without a history of injuries. Moreover, since in others sport as basketball it has been hypothesised that decreased normalized reach distances on the mSEBT may predict lower extremity injury (Plisky et al., 2006), our mSEBT results guarantee future researches among volleyball players. Conversely, no differences were detected between the two groups in the monopodalic balance test. These findings are in agreement with similar studies on single-leg balance assessment (Arnold et al., 2009; Baltich et al., 2015), but also in contrast with others that reported differences in sway measures between healthy subjects and subjects with chronic ankle instability, functional ankle instability (FAI) or previous injuries (Matsusaka, Yokoyama, Tsurusaki, Inokuchi, & Okita, 2001; McKeon & Hertel, 2008).

Therefore, the results of the present study did not confirm our initial hypothesis that previous musculoskeletal lower limb injuries could worsen both static and dynamic balance performance since no statistically significant differences were detected in the static balance test. A possible explanation is that static balance tests may not be adequately challenging to detect balance deficits consequent to previous injuries exposure. For instance, Ross and Guskiewicz (Ross & Guskiewicz, 2004), comparing individuals with FAI and healthy subjects, found no differences in sway measures. However, the FAI group took significantly longer to stabilize in the frontal and sagittal planes of motion during single-leg jump landing. To this extent, in a recent review (Petró, Papachatzopoulou, & Kiss, 2017), it has been reported how dynamic balance tests may provide more information on postural control of the participants by challenging them with functional tasks, perturbations or requiring them to perform complex movements. Moreover, it has been suggested to assess dynamic balance rather than static balance in order to find a possible relationship between specific parameters and injuries (Marcolin et al., 2016). Therefore, since static balance tests may be even less demanding in athletes as compared to a general population due to athletes' higher levels of physical performance, we recommended performing dynamic tests in male volleyball athletes to better challenge their postural control mechanisms. Moreover, dynamic field tests as the mSEBT employed in our research, are cheap and practical to use.

There are some limitations to our study. Injuries were recorded by means of a self-reported questionnaire, without these being confirmed by medical reports. Self-report of injuries are likely subject to recall bias. However, we asked about injuries which stopped the volleyball activity for greater than seven days (Fuller et al., 2006). Thus, we expected players should remember adequately those injuries that left them out of practice for that time span. Moreover, injury recall accuracy seems to increase as the level of details requested decrease (Gabbe, Finch, Bennell, & Wajswelner, 2003). For this reason, similarly to a previous study (Dallinga, van der Does, Benjaminse, & Lemmink, 2016), no specific information was asked in the questionnaire, the number of injuries and the injuries location the most relevant questions. Thus, we expect the players' answers to be sufficiently accurate.

Table 1
Results of the static postural stability test on the stabilometric platform.

	CON	INJ
Ellipse area [mm^2]	433.7 ± 174.5	357.8 ± 150.8
Sway path [mm/sec]	40.7 ± 10.8	38.1 ± 11.9
Sway area [mm^2/sec]	109.3 ± 45.9	92.0 ± 51.3
Max AP oscillations [mm]	34.5 ± 10.3	30.9 ± 7.1
Max ML oscillations[mm]	26.5 ± 5.7	24.3 ± 5.0

Abbreviations: CON, uninjured volleyball players; INJ, volleyball players that suffered at least one lower limb injury.
*Values are expressed as mean ± SD.

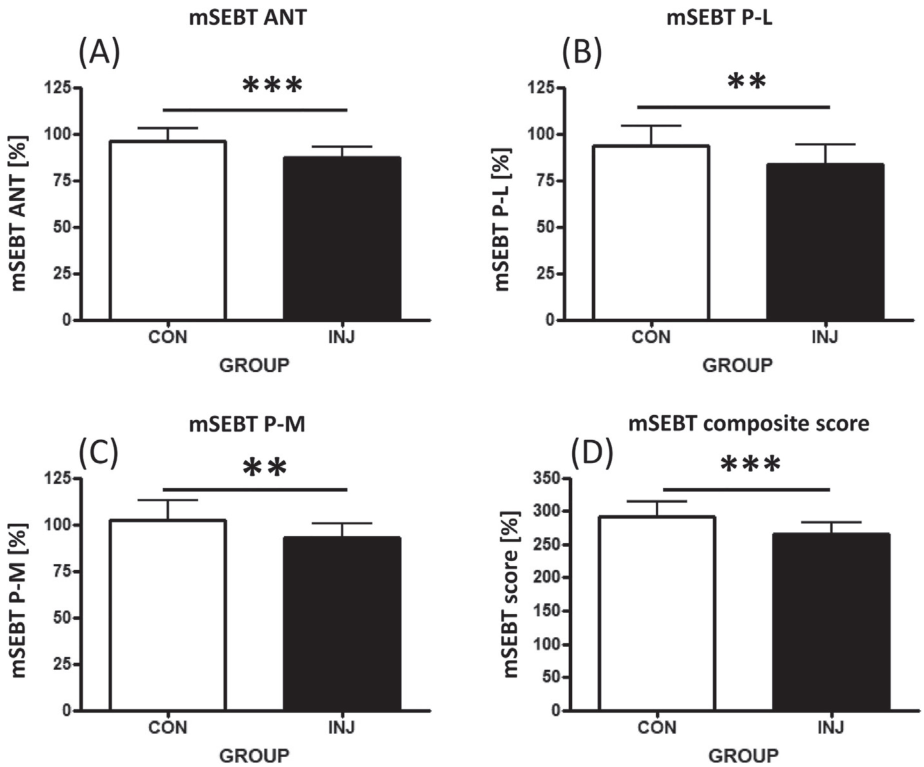

Fig. 2. Results of the modified star excursion balance test (mSEBT) for the anterior (A), postero-lateral (B), and postero-medial (C) direction. The composite score is also presented (D). mSEBT ANT = modified star excursion balance test score in the anterior direction; mSEBT P-L = modified star excursion balance test score in the postero-lateral direction; mSEBT P-M = modified star excursion balance test score in the postero-medial direction; CON = uninjured volleyball players; INJ = volleyball players that suffered at least one musculoskeletal lower limb injury. Data are expressed as percentage of the lower limb length (see text).

5. Conclusions

No differences were noted during a monopodalic static test performed on a stabilometric platform comparing volleyball players with and without a history of musculoskeletal lower limb injury. Differently, we found dynamic postural control to be impaired in INJ group, suggesting deficits in dynamic postural control in the previously injured leg. Therefore we suggest to assess the postural balance performance by means of both static and dynamic tests. Moreover, the decrease of the dynamic balance performance in previously lower limb injured male volleyball players may indicate that, before returning to competitions, the rehabilitation protocol should include more dynamic balance exercises.

Ethical approval

The experimental protocol adhered to the principles of the Declaration of Helsinki. The study was approved by the ethical committee of the Department of Biomedical Sciences, University of Padova.

Conflicts of interest

None to declare.

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