

Original Article

## Evaluation of knee joint proprioception and balance of young female volleyball players: a pilot study

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**Abstract.** [Purpose] The main purpose of our study was the evaluation of the effects of long-term volleyball practice on knee joint proprioception and balance of young female athletes. [Subjects and Methods] An observational case-control study was performed. The study enrolled 19 female volleyball players in the experimental group and 19 sedentary counterparts as controls. A Biodex balance system and dynamometer were used for the evaluations. The paired t-test was used to determine the significance of differences between the performance of athletes and controls. [Results] The knee proprioception analysis showed a significant difference at 60° joint position in active and passive tests. A similar trend, but without significance, was found for the 20° joint position. In the postural stability tests both groups showed similar results with no significant differences between them. [Conclusion] In conclusion, the results indicate a significant influence on joint proprioception is elicited by long-term exposure to a team sport like volleyball. However, the postural stability indexes showed similar trends in both groups, highlighting the analogous ontogenesis of the subjects investigated and the low influence of volleyball practice on postural stability.

**Key words:** Injuries, Proprioception, Volleyball

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### INTRODUCTION

Volleyball is one of the most popular sports in the world, and its injury incidence is between 1.7 and 4.2 per 1,000 hours of play, making it the fourth most common source of sports injuries<sup>1, 2)</sup>. Studies have shown that the injury rate in volleyball is lower than in other team sports such as soccer and basketball<sup>3, 4)</sup>. Presumably, this is because of the non-contact nature of the game, as players from opposing teams are separated by a net. However, the scientific literature reports serious knee and ankle ligament injuries in volleyball players. The most frequent incidence of non-contact injury is caused by poor landing<sup>3, 5)</sup>. Women are more prone to injuries than men due to weaker quadriceps and hamstring strength along with poorer proprioception and landing kinematics<sup>3, 5)</sup>. Injuries are incurred more frequently during games than in training sessions<sup>3)</sup>. This applies particularly to knee joints, ankle joints, shoulder joints and the small joints of the hand, as well as the joints of the lower spine regions<sup>6)</sup>. Ankle inversion sprains are the most common acute injuries in volleyball<sup>1, 7)</sup>. According to previous reports, injury pre-

vention should be one of the goals of training programs for volleyball players<sup>8, 9)</sup>. The scientific literature indicates that proprioception and postural control are of great importance for optimal sports injury prevention<sup>9–11)</sup>. Postural control is achieved by the integration of information related to body movement, sensed through the somato-sensory system, into the central nervous system and an appropriate reaction by the musculoskeletal system<sup>12)</sup>. Proprioception is sensed through mechanoreceptors of muscles, ligaments and joints, and it maintains the stability and orientation of the body during static and dynamic movements<sup>13, 14)</sup>. All receptors, which are located in the muscles, tendons, menisci, ligaments and articular capsules, contribute to the perception of movement and position. This makes possible the adjustment of muscle tension, ultimately improving posture<sup>15–18)</sup>. Moreover, there are several mechanisms that may negatively affect neuromuscular motor control, fatigue being one of them<sup>19)</sup>. Han J et al. showed that proprioceptive acuity is significantly associated with the performance levels of elite athletes<sup>20)</sup>. When the effectiveness of balance training was compared with resistance training, it was found that resistance training produced superior performance results for jump height and sprint time<sup>20)</sup>. A recent review of various studies showed that there are significant relationships between balance ability and a number of performance measures<sup>21)</sup>. Based on the available data from cross-sectional studies, gymnasts tend to have the best balance ability, followed by soccer players, swimmers, active control subjects and then basketball players<sup>22, 23)</sup>. Sinsurin et al. studied the sagittal angles and

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moments of lower extremity joints during single-leg jump landing performed by basketball and volleyball players and reported that knee flexion in the forward direction registered a mean value of peak angle (during landing phase) of  $65.2 \pm 10.1$  degrees<sup>24</sup>. The jumping performance and knee muscle strength of under-19 women volleyball players were investigated by Rousanoglou et al., who reported interesting information about optimal knee angles and knee angular velocities during lower body force generation<sup>25</sup>. The assessment and measurement of proprioception is very difficult. The scientific literature suggests several ways to measure proprioception indirectly, and kinesthesia, which is used to detect passive motion, has been used more often and seems to be more reliable<sup>26</sup>. Therefore, the aim of this study was to evaluate the effects of volleyball practice on knee joint proprioception and balance of young female volleyball players.

## SUBJECTS AND METHODS

### Subjects

The study was performed in compliance with the Declaration of Helsinki and informed consent was obtained from each subject, according to Ankara University policy. Thirty-eight subjects were recruited for this study and they were divided into two groups, an experimental group (EG) and a control group (CG). To meet the purpose of investigation we recruited nineteen female volleyball players and nineteen healthy sedentary female counterparts with no history of lower extremity injury. As mentioned above, the volleyball players were assigned to EG (age:  $16.21 \pm 0.71$  years; weight:  $62.53 \pm 6$  kg; height:  $178.42 \pm 2.73$  cm) while the sedentary subjects were assigned to SG (age:  $16.21 \pm 0.42$  years; weight:  $55.37 \pm 5.66$ ; height:  $164.58 \pm 4.89$  cm). The EG were recruited according to the following inclusion criteria: at least five years of constant volleyball practice at sub-élite level and training 6 times per week; no history of lower extremity injuries; and no diagnosis of postural neuromuscular deficits (data were obtained through an anamneses form administered at the start of the experimentation). The CG subjects were selected according to the following inclusion criteria: a similar age; from a similar geographic province; (3) no participation in regular exercise training for at least 12 months, no history of lower extremity injuries; and no diagnosis of postural neuromuscular deficits (see above)<sup>27</sup>. Participants' height and weight were obtained using a stadiometer (Seca,  $22 \pm 1$  mm approximation, Hamburg, Germany).

### Methods

A Biodex Stability System (BSS; Biodex Medical Systems, Shirley, NY, USA) was used to evaluate postural stability, and a Biodex Dynamometer for proprioception<sup>28</sup>. Different methods have been used to measure postural stability but the Biodex Stability Systems seems to be reliable and accurate<sup>28-31</sup>. The dominant leg, which was defined operationally as the leg preferred to kick a ball, was used for both tests. Postural control was evaluated by using the BBS Athlete Single Leg Protocol with the eyes open and closed<sup>28</sup>. The postural balance test was conducted with the subjects standing on the dominant leg on the fixed circular

foot plate of the BBS, aligning the center of gravity which was visualized on a monitor, at the center of the circular plate. Body weight shifts into 4 quadrants (anterior, posterior, left, and right) were traced and recorded, with the eyes both open and closed, as the indexes of overall instability (OSI), anterior/posterior instability (API), and medial/lateral instability (MLI), respectively. To evaluate proprioception, all the participants completed 3 trials of 60- and 20-degree of knee extensions both actively and passively. They sat in the Biodex chair and wore a blindfold to eliminate visual cues. Subjects were barefoot and an inflated pneumatic sleeve was placed around the lower leg to minimize the effects of external factors such as feedback between limb and dynamometer. The subjects were then asked to hold the extended leg at the target angle. The test was initiated with the knee positioned at 90 degrees. The participants were instructed to press a button to stop as soon as they perceived motion in the knee and could identify the direction. One practice trial was performed before each of the tests to familiarize the subjects with the test method. In addition, the functional capacity and the active and passive motion perception of the knee at 60 degrees and 20 degrees were analyzed. All data were coded in an Excel file. The normality test (Shapiro-Wilks) was performed for all anthropometric characteristics. The paired t-test was used to detect the significance of differences between CG and EG performances. The sample size was obtained with a fixed power goal of 0.70 (N vs. Power; Alpha = 0.05 and a standardized effect = 0.60). A p value lower than 0.05 was considered statistically significant. StatSoft's STATISTICA software (Windows, Vers. 8.0; Tulsa, OK, USA) was used for the analyses.

## RESULTS

Thirty-eight female subjects participated in this study. The results of the postural analysis showed no significant differences between the groups (Table 1). However, there were significant differences in the groups' dynamometer performances (Table 1), with both active and passive knee joint proprioception of EG at 60° degrees being significantly better than that of CG ( $p < 0.01$  and  $p < 0.05$ , respectively). A similar tendency was observed in the results of active and passive knee proprioception at 20° degrees, but the difference was not significant.

## DISCUSSION

The effects of stability training on performance enhancement are well documented in the literature<sup>9, 11, 32-35</sup>. Butcher SJ et al.<sup>33</sup> showed that trunk stability training may provide a more stable pelvis and spine from which the leg muscles can generate action, may better link the upper body to the lower body, and may enhance leg muscle activation, thus promoting optimal force production during sporting activities such as a vertical jump<sup>33, 35</sup>. Atsushi Imai et al. conducted a 12-week stabilization exercises program for youth soccer players, and found significant improvements in maximal oxygen consumption, vertical jump and sprint performances<sup>36</sup>. The aim of the present study was to evaluate whether there was a difference in the balance and knee joint proprioception between

**Table 1.** Subjects balance and proprioception results

	Experimental group (19)	Control group (19)	P
OSI-OE	3.95 ± 1.89	4.25 ± 0.96	
OSI-CE	8.85 ± 2.07	9.46 ± 1.34	
API-OE	3.39 ± 2.06	3.97 ± 1.14	
API-CE	7.42 ± 2.00	8.32 ± 1.35	
MLI-OE	1.51 ± 0.62	1.67 ± 0.62	
MLI-CE	3.55 ± 1.18	3.94 ± 1.04	
KP 20-A	24.15 ± 4.82	25.85 ± 5.49	
KP 20-P	23.15 ± 4.77	24.77 ± 3.92	
KP 60-A	59.44 ± 2.97	62.44 ± 2.69	**
KP 60-P	59.99 ± 2.47	61.62 ± 2.33	*

Significant difference: \*\*:  $p < 0.01$ ; \*:  $p < 0.05$

OSI-OE: open eyes overall instability index; OSI-CE: closed eyes overall stability index; API-OE: open eyes anterior/posterior instability; API-CE: closed eyes anterior/posterior instability; MLI-OE: open eyes medial/lateral instability; MLI-CE: closed eyes medial/lateral instability; KP 20-A: active knee joint proprioception at 20° degrees; KP 20-P: passive knee joint proprioception at 20° degrees; KP 60-A: active knee joint proprioception at 60° degrees; KP 60-P: passive knee joint proprioception at 60° degrees

volleyball players (EG) and a control group of non-athletes (CG). We hypothesized that athletes would outperform non-athletes but our results indicate that there was no statistically significant difference between the mean balance scores of EG and CG. However, there were significant differences in the perception of active and passive movement of the knee at 60 degrees flexion. In agreement with our findings Sinsurin et al. noted that the peak knee angle of volleyball players during landing (after jump) ranges from 55 degrees to 65 degrees<sup>24</sup>). Their study may explain why our EG participants were so familiar with 60-degree knee-joint proprioception. Selmanovic et al. reported that just one volleyball or basketball session a week is sufficient to produce significant changes in children motor abilities<sup>37</sup>). However, Gil et al. found a relationship between the quantity of practice and the development of cognitive expertise, and recommended that young players dedicate at least 4 hours weekly to training to achieve a significant improvement in cognitive expertise<sup>38</sup>). The better perception at 60 degrees of knee flexion may have been the result of repetition of many technical movements at 60 degrees<sup>24</sup>), or the receiving position having a similar knee flexion angle in volleyball<sup>8, 39</sup>). This particular result has not previously been reported in the literature and further investigations are required to empirically clarify the cause. As mentioned above, the scientific literature suggests that proprioception can, in addition to bettering athletic performance, prevent some sports injuries. Caraffa et al. showed that specific proprioceptive training can significantly reduce the incidence of anterior cruciate ligament (ACL) injuries in soccer players<sup>40</sup>).

A weak point of our present study is its small size, so we cannot generalize the results. Nevertheless, the need to integrate traditional training with a specific proprioceptive

training programs is evident<sup>22, 33, 41–43</sup>). Furthermore, some studies have suggested that fatigue, during a match, affects the overall anterior posterior stability and ultimately the functional capacity of the lower limbs<sup>41, 44–48</sup>). Hewett et al. introduced a program combining multiple neuromuscular training components that appears to provide a reduced risk of ACL injury<sup>48</sup>). In this context, biomechanical analysis consistently has shown the effectiveness of plyometric training combined with technique training at reducing the incidence of ACL injuries<sup>49</sup>). Moreover, Swanik et al. reported that plyometric training results in great improvements on proprioception<sup>42</sup>). In conclusion, the method we used seems to be a promising way of measuring and evaluating the knee proprioception both in athletes and non-athletes. The results also indicate that trainers should give more importance to proprioceptive training to enhance performance and reduce the risk of injuries. The absence of significant differences in balance, and partially in proprioception, between athletes and non-athletes may raise some concerns, but our cohort was too small to draw definitive conclusions and other studies with different cohorts and larger sample sizes are needed.

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