

Symmetry of proprioceptive sense in female soccer players

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Purpose: The purpose of the study was to assess the symmetry of proprioceptive sense among female soccer players when trying to reproduce isometric knee extensions (right and left) and to analyze the impact of a given level of muscle force on proprioception. **Methods:** The study involved 12 soccer players aged 19.5 ± 2.65 years. Soccer players performed a control measurement of a maximum 3s (knee at the 90°) position in the joint. Subsequently, 70%, 50%, and 30% of the maximum voluntary contraction (MVC) were all calculated and then reproduced by each subject with feedback. Next, the players reproduced the predefined muscle contraction values in three sequences: A – 50%, 70%, 30%; B – 50%, 30%, 70%; C – 70%, 30%, 50% of MVC without visual control. **Results:** In every sequence, the participants found obtaining the value of 30% of MVC the most difficult. The value they reproduced most accurately was 70% of MVC. Both trial II and trial III demonstrated that the symmetry index SI significantly differed from values considered acceptable (SI_{Ra}). In each successive sequence the largest asymmetry occurred while reproducing the lowest values of MVC (30%) ($p < 0.05$). **Conclusion:** High level of proprioceptive sense is important to soccer players due to the extensive overload associated with dynamics stops or changes in direction while running. Special attention should be paid to develop skills in sensing force of varying levels. It was much harder to reproduce the predefined values if there was no feedback.

Key words: proprioception, symmetry, female, soccer players

1. Introduction

Optimal realization of a motor task is associated with the highest levels of position and movement sense of the body that ensure both economy and smoothness of motion. Proprioception is defined as the combination of sense of limb position in space; kinesthesia, i.e., the ability to sense the body's movement [29]; sense of tension; and sense of muscle effort. Soccer is an example of a discipline in which all the functions of proprioception are manifested. Although neuromuscular control is not conscious, but instead treated as an efferent response to signals from the senses of proprioception [18], receiving information from proprioceptors is essential to providing a soccer player with optimum physical fitness and sense of movement [7]. Due to the proprioceptors, force of muscle contraction in sport-

people is regulated adequately to the increasing load on the reflex arc [28]. High levels of proprioceptive sense are also of particular importance to soccer players due to the extensive overload associated with dynamic stops or changes in direction while running.

Among soccer players, a source of considerable overload and injury while playing soccer is usually external forces acting on the locomotor system. Numerous studies have indicated that ankle joint injuries and knee joint injuries are some of the most common injuries among people practicing team sports [19]. Joint injuries often occur in situations in which there is considerable friction between the foot and the ground, e.g., while playing on an artificial surface. It is therefore crucial to strengthen the passive parts of the locomotor system with exercise that improves the efficiency of the muscle-tendon complex. Additionally, elements enhancing the stability of a limb and

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Received: November 27th, 2014

Accepted for publication: December 1st, 2014

isometric exercise for both limbs should be included in routine training.

Mandelbaum et al. [18] studied the effects of a neuromuscular and proprioceptive training program conducted among female football players that was designed to lower the incidence of anterior cruciate ligament (ACL) injuries. The program for the female athletes aimed to increase the level of perception of external forces and to increase stabilization of the joint in order to protect its structures. Authors of many papers [19], [14], [27] have emphasized the importance of proprioceptive training in order to prevent injuries to joints most exposed to risk.

Such observations seem to be particularly important for women due to the weaker development of the tendon-ligament system compared to men as well as the variable resistance of the tendon-ligament system to injury, which is related to hormonal changes occurring during the menstrual cycle [33]. Wojtys et al. [33] reported a statistically significant increase in ACL injuries among women during the ovulatory phase (day 10–14 of the cycle), when levels of estrogen increase. Results of numerous studies have demonstrated a significant correlation between increased levels of both estrogen and relaxin and a 40% decrease in the synthesis of collagen [6], a protein that is the main building material of tendons and that plays a significant role for high levels of resilience in tendons.

Other causes of overload and injury among women include increased instability of the knee joint or osteoarthritis, as well as increased functional asymmetry or increased muscle tone. Each of these factors in the long term can lead to degenerative changes to bones, joints, and muscles. Because of this, women should participate in a training process aimed at strengthening the passive parts of the locomotor system.

Previous studies have shown that proprioceptive exercise plays an important role both in preventing injury and in strengthening muscle-tendon complex [19], [14], [27]. However, it is the symmetry of proprioception that seems to be a significant issue, especially in football, during which one of the most essential aspects of good training is maintaining a high level of neuromuscular coordination of both limbs.

Therefore, the purpose of this research was to assess the symmetry of the proprioceptive sense when trying to reproduce the isometric tension of the knee extensors of the left and right lower limbs and to analyze the impact of a given level of muscle force (30%, 50%, and 70% of F_{\max}) on proprioception among female soccer players.

2. Materials and methods

Research material

The study involved 12 female soccer players aged 19.5 ± 2.65 years from Club MKS Ciechanów. The soccer players were characterized by a high level of physical fitness. They performed three training sessions per week. The minimum training experience for each player was two years. Participants were characterized by a mass of 60.3 ± 10.57 kg and a height of 165 ± 5.2 cm. Participants' BMI, which was calculated from anthropometric parameters, showed that the soccer players met norms for a given age and gender group (22 ± 3.68). All participants were healthy, with no prior injuries. They had not undergone physical therapy associated with overloads and injuries to limbs. On the basis of interviews on the lateralization of the body, the right limb was found to be the dominant limb for all participants. The interview also contained questions related to the performance of motor actions specific to soccer (e.g., which limb the athletes used to perform penalty kicks and which limb was the leading limb when the participant performed front lunges from a standing position).

Research methods

The study was conducted in the laboratory of the Department of Biomechanics of the University of Physical Education in Warsaw. The standard method was used to measure muscle torque values under static conditions by maintaining the principles of statics and providing the proper stabilization of the body. The position used for measuring is presented in Fig. 1.

Lever arm (r_z), on which the force sensor to the axis of rotation in the joint was disposed, was determined individually for each participant at a constant height; therefore, only F_z was measured while measuring the reproduction of predefined muscle tension. Force measurement was conducted with an accuracy of 0.1 N. Arm force, being the shortest distance of the force vector to the axis of rotation in the joint, was conducted with an accuracy of 0.5 cm. Since the set arm was supposed to be different for the right and left limbs, the calculated values of torque were used in the analysis.

In the first part of the research, the football players performed a control measurement of a maximum 3-second contraction of the right and left knee extensors at the 90° position in the joint.

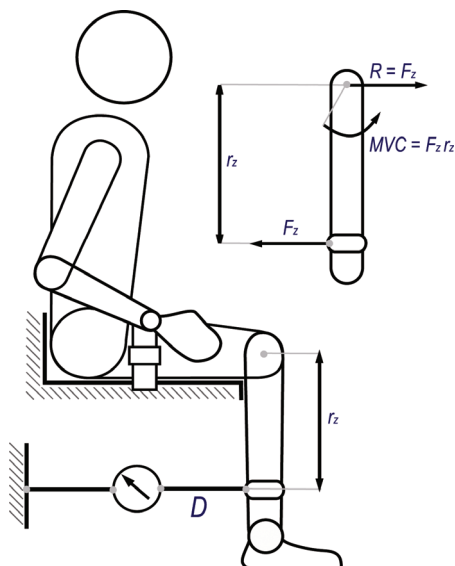


Fig. 1. The measurement position for torque of the knee extensors in which the balance conditions of the bone lever (lower leg) were preserved. D – dynamometer, F_z – external force (reaction force of imposed constraints), r_z – arm of external force

Subsequently, 70%, 50%, and 30% of the maximum voluntary contraction (MVC) were calculated; each participant then reproduced them with feedback. For this purpose, a monitor was set perpendicularly at a distance of 0.5 m, at eye level, where a participant could control the gained force values. After reaching the level, participants maintained a given value for 5 seconds in order to memorize it.

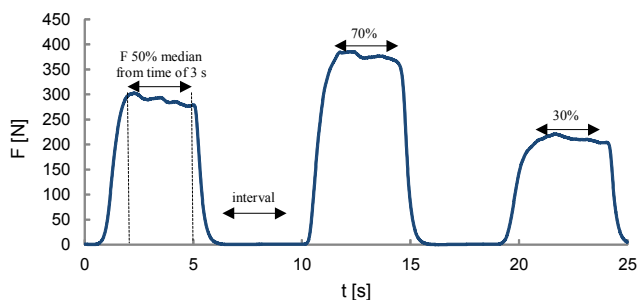


Fig. 2. An example of a reproduction of predefined muscle tension during one of the sequences (50%, 70%, and 30% of F_{max})

After a rest break, the soccer players reproduced the predefined muscle contraction values without visual control in three sequences. The sequences were classified as follows: A – 50%, 70%, 30%; B – 50%, 30%, 70%; C – 70%, 30%, 50% of F_{max} . Participants randomly selected the order of the predefined sequences. The reproductions of the predefined contractions were performed at intervals of 5 seconds of tension followed by 5 seconds of break. The middle 3-second interval of maintaining the predefined force

was chosen from each test to calculate the median taken for analysis (Fig. 2). The last measurement was a repeat of the maximum muscle contraction in order to verify fatigue. In adhering to the accepted scheme, the entire experiment was performed for the right limb, then repeated for the left limb.

The experiment was conducted using the Max program. Figure 2 presents an example of reproducing a sequence performed in the order of 50%, 70%, and 30% of F_{max} .

Methods of statistical analysis

Statistical analysis included the calculation of the mean values of the analyzed parameters, standard deviation of the analyzed parameters, and percentage differences between the results obtained.

When assessing the accuracy of the reproduction of predefined muscle force, a relative error was separately calculated for each limb

$$x = \frac{\Delta x}{x_0} = \frac{x - x_0}{x_0}$$

where

x – measured value,

$\Delta x = (x - x_0)$ – absolute error.

Symmetry index (SI) was calculated by normalizing the differences between the values of parameters for the left and right limbs with regard to the value gained by the dominant limb [22]. This is the most commonly used method to assess symmetry. It was also applied by Zifchock et al. [35]

$$SI = 2 \cdot \frac{X_R - X_L}{X_R + X_L} \cdot 100\%$$

where

SI – symmetry index,

X_R – value obtained for the right limb,

X_L – value obtained for the left limb.

SI = 0 indicates symmetry, while negative values in the numerator indicate asymmetry. These values are quite rigorous; therefore, the reference value of symmetry SI_{Ra} , being the mean value of the calculated index of symmetry in trials to measure the maximum torque, was used in this study. The obtained standard deviation was the area of acceptable asymmetry. This approach was prompted due to the minimal differences between the results obtained for the right and left limbs when measuring muscle torque under static conditions. The minimal differences were due to the limited impact of the movement technique [30].

The software package STATISTICA 10 was used for statistical analysis. Analysis of variance (ANOVA)

was applied in order to compare the predefined values (30%, 50%, and 70% of F_{\max}) with those obtained during the trial performed with visual control. This analysis was also used in comparing values for maximum muscle torque obtained before and after the sequences.

Multivariate repeated measures analysis of variance was applied in order to determine the influence of selected factors (right and left limb and levels of predefined muscle force: 30%, 50%, and 70% of F_{\max}). Because the results did not indicate normal distribution, they were subjected to a logarithmic transformation. All statistical analyses were performed on the logarithmic values. Tables include the real values.

3. Results

The results of the experiment were shown in several sections comparing the before- and after-experiment maximum values for both limbs. Research included analysis of the results of reproducing the predefined levels of force. Analysis took into account factors hindering the accomplishment of a task, visual control and lack thereof, and different percentage values of the maximum values. Also taken into consideration was the effect of fatigue, which could occur and which could affect the results.

The results of maximum muscle torque

Table 1 presents the maximum values that participants produced separately for right and left limbs before and after the experiment.

Table 1. The mean values \pm SD of maximum torque (MVC), obtained before and after the completion of all the trials for the right limb (L_R) and the left limb (L_L)

	MVC [N m]	
	before $\bar{x} \pm SD$	after $\bar{x} \pm SD$
L_R	168.6 \pm 16.47	162.4 \pm 17.37
L_L	175.2 \pm 24.29	165.8 \pm 25.43

Analysis showed no significant difference between the results obtained for the right and left limbs; the fatigue effect was not observed. Participants obtained similar MVC values before and after the completion of all the sequences for both the right and left limbs ($F_{(1,22)} = 0.795$; $p = 0.382$). A slight fatigue effect was found for the left limb; the difference in this case was 5.3%. Due to the lack of significant differences

between the values obtained for the right and left limbs, it was assumed that the symmetry index calculated from the maximum values obtained prior to the experiment, along with the standard deviation ($SI_{Ra} = 1.21 \pm 0.86$), would be the reference value for the results gained both during measurements with visual control and during reproduction in sequences A, B, C without control based on feedback. A lack of absolute values in the meter indicated which of the sides had a significant impact on the values of asymmetry [22].

The results of the reproduction of predefined level of force with feedback

Trial I, which was to reproduce a predefined level of muscle force, was made with visual control. Participants were asked to reproduce and maintain predefined levels of 30%, 50%, and 70% of MVC for 5 seconds. Levels were calculated from the maximum values obtained before the main study. This trial was also used to make the participants memorize predefined torque values. Table 2 shows the mean values \pm SD of the predefined and obtained torque.

Table 2. The mean values \pm SD of predefined torque and torque reproduced in trials with visual control for the right limb (L_R) and the left limb (L_L)

		% MVC [N m]	
		predefined $\bar{x} \pm SD$	reproduced $\bar{x} \pm SD$
L_R	70%	118.0 \pm 11.03	115.8 \pm 12.85
	50%	84.3 \pm 8.23	80.7 \pm 7.46
	30%	50.6 \pm 4.94	47.0 \pm 5.24
L_L	70%	122.6 \pm 17.00	119.5 \pm 17.06
	50%	87.6 \pm 12.14	84.9 \pm 11.93
	30%	52.6 \pm 7.29	49.5 \pm 6.60

The analysis of variance demonstrated that participants with visual control reproduced the predefined muscle torque with a very high accuracy. There was no significant interaction of factors such as a reproducing limb (L_R , L_L) and predefined force value of 70%, 50%, and 30% of MVC ($F_{(2,66)} = 0.709$; $p = 0.496$) found in the overall analysis. For both limbs, the results were very similar.

However, the factor of predefined torque level alone determined the possibility of reproducing the level ($F_{(2,66)} = 13.64$; $p < 0.001$) for both limbs at the same time. The participants found it the hardest to control 30% tension of reproduction (Fig. 3); the highest precision of reproduction was observed at 70%.

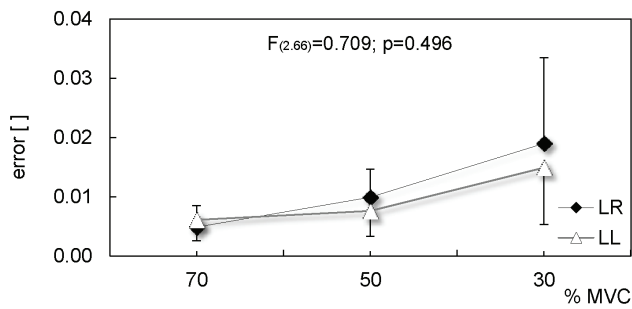


Fig. 3. Mean values \pm SD of error for reproducing predefined muscle force in a trial with visual control

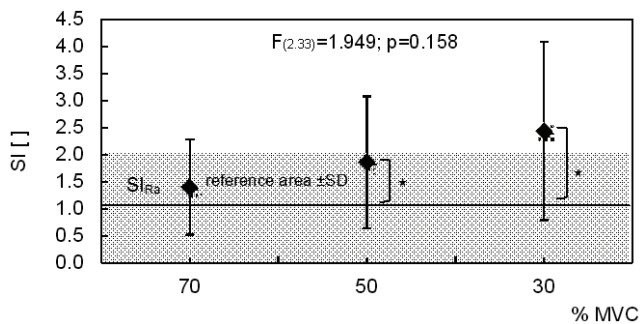


Fig. 4. The mean values \pm SD of SI obtained during individual trials to reproduce 70%, 50%, and 30% of MVC and the area of reference values ($p < 0.05 - *$)

Figure 4 presents the calculated SI in a trial with visual control, related to the reference value obtained during the maximum measurement. By controlling force levels with feedback, the football players were able to reproduce the predefined values with regard to the reference values \pm SD for 70% and 50% for both the right and left limbs. In these cases, it was observed that the mean values of symmetry index did not

exceed the area that had been considered as acceptable. SI for the value of 30% was outside the reference area. However, comparative analysis demonstrated significant asymmetry in reproducing 50% and 30% of MVC with respect to SI_{Ra} at $p < 0.05$.

It should be noted that the graph shows the absolute values of symmetry index. By analyzing individual SI values, it was found that greater asymmetry when reproducing predefined values was directed toward the non-dominant limb (left). The values of symmetry index in those cases were negative. such a situation occurred in all three trials when reproducing 70%, 50%, and 30% of MVC.

The results of reproducing predefined levels of force without visual control

The main trial aimed to assess the symmetry of proprioceptive sense in a trial without visual control. Table 3 presents the results graded according to the order of reproduction but also according to predefined levels (70%, 50%, and 30% of MVC). Predefined values are in Table 2.

When analyzing the accuracy of reproduction, participants in this trial were characterized by a lower level of sense of a predefined value than in a trial with visual control. It was further observed that in almost all trials the football players made bigger mistakes in reproducing with their left limbs.

Taking into account the predefined factors such as limb and the level of predefined value, analysis was conducted to verify the significance of differences and their impact on proprioceptive senses. There was no significant interaction between the examined factors ($F_{(4,132)} = 0.672$; $p = 0.613$). It can be concluded that

Table 3. The mean values \pm SD of torque obtained while reproducing predefined levels (70%, 50%, and 30% of MVC) in successive trials (I, II, and III) for the right and left limb and the relative error (er) calculated from the logarithmic values

	70%					
	I		II		III	
	$\bar{x} \pm SD$	er	$\bar{x} \pm SD$	er	$\bar{x} \pm SD$	er
L_R	110.6 \pm 21.95	0.028	109.7 \pm 20.78	0.029	107.1 \pm 17.55	0.029
L_L	109.8 \pm 29.52	0.037	106.7 \pm 30.36	0.041	107.3 \pm 27.2	0.040
	50%					
	I		II		III	
	$\bar{x} \pm SD$	er	$\bar{x} \pm SD$	er	$\bar{x} \pm SD$	er
L_R	82.8 \pm 13.52	0.026	81.6 \pm 14.41	0.026	74.0 \pm 27.21	0.039
L_L	78.4 \pm 19.76	0.035	77.7 \pm 21.95	0.045	78.0 \pm 18.77	0.038
	30%					
	I		II		III	
	$\bar{x} \pm SD$	er	$\bar{x} \pm SD$	er	$\bar{x} \pm SD$	er
L_R	57.2 \pm 12.94	0.036	49.8 \pm 12.44	0.045	54.9 \pm 14.32	0.056
L_L	51.2 \pm 13.97	0.044	52.7 \pm 18.34	0.043	49.7 \pm 13.41	0.044

the mistakes made by the players with both the right and left limb were at similar levels in the 70%, 50%, and 30% trials of MVC. They were observed in all completed series (I, II, and III). No impact was found on the factor of repeatability. Participants in successive sequences reproduced a predefined percentage of MVC at similar levels. The sportswomen found obtaining the value of 30% of MVC the most difficult in all the sequences. They reproduced the value of 70% of MVC the most accurately.

Further analysis concerned the assessment of the symmetry of proprioception. Figure 5 shows the results of the SI and the reference area considered acceptable.

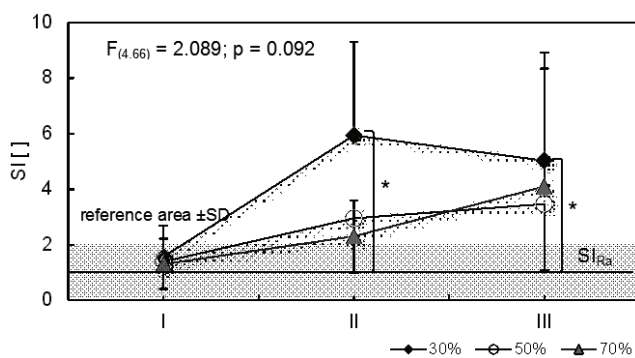


Fig. 5. The mean values of SI for each level of reproduction of MVC obtained for sequences I, II, and III ($p < 0.05 - *$)

In both trial II and trial III, it was demonstrated that the symmetry index SI significantly differed from the values considered acceptable (SI_{Ra}) and indicated by other authors as a norm (Zifchock et al. [35]). For that reason, two analyses were carried out: the repeated measures analysis of variance (ANOVA) in order to verify the influence of fatigue and the level of reproduced values, and a comparative analysis of the SI with the reference values. The factors considered had no significant impact on the symmetry of sense among the players ($F_{(4,66)} = 2.089$; $p = 0.092$). However, by comparing the obtained results with the reference values, significant differences were found in the SI at $p < 0.05$. The largest asymmetry occurred when reproducing the lowest values of MVC (30%) in all the successive sequences, as well as for higher values in trial III ($p < 0.05$). The asymmetry of proprioceptive sense was mainly directed toward the non-dominant limb, as it occurred in the trial performed with visual control. Therefore, it was shown that the participants made greater errors with their left limbs when the obtained values were compared to the reference values.

4. Discussion

Because of its specificity and complexity, football demands of both male and female players not only enormous preparation in terms of fitness, but also a high level of neuromuscular coordination. Failing to follow these requirements can lead to overload and injury of the locomotor system [25]. During a football match, players cover a distance of about 12–15 km, and their heart rate often reaches 170 beats per minute. By analyzing the incidence of injury depending on time a player spent on the field, Hawkins and Fuller [10] demonstrated the significant impact of disturbing homeostasis on protecting a joint against external factors that disrupt its stability. This effect has been observed to a significant extent in the second half of games. The permanently changing conditions of a game cause acyclic movements that require continuous analysis of the situation and proper reaction to occurring stimuli. It seems reasonable, therefore, to conduct training and thus improve both sides, i.e., the right and left limbs, whereas the evaluation of asymmetry may be an indicator for determining risk of injury. However, Zazulak et al. [34], who studied 277 sportspeople, demonstrated that the possibility of predicting injury was determined by a high level of proprioception. In addition, proprioceptive sense plays a vital role in controlling the next movements.

In the case of female soccer players, this is extremely important given their proven excessive laxity of joints [23], weaker development of the tendon-ligament system [9], and significantly more frequent injuries [21]. Another factor affecting the locomotor system in women is its variable resistance to damage, which is associated with decreased collagen synthesis [6], a connective tissue protein exhibiting high tensile strength. The mechanical properties of connective tissue, which transfer the force of working muscles onto the skeleton, depend on collagen [4]. Therefore, reduced amounts of this protein among women in the ovulatory phase may result in frequent injuries during this period of the menstrual cycle [33]. Lebrum et al. [15] reported that hormonal changes in women also affect the body's efficiency of effort, different levels of functioning of the cardiovascular system, thermoregulation, and psychological states.

In this work, the menstrual cycle of the participants was not taken into account, which may have influenced the obtained results; this factor will be included in further research. The main objective was associated with the assessment of asymmetry of pro-

prioceptive sense, which is also an indicator of overload on the one side of the body.

When researching soccer players, Hawkins et al. [11] discovered that the largest number of injuries – those associated with sprained ankles (talocrural joint) – occurred with the dominant limb, which to a greater extent is exposed to shear forces during jumps and kicks. In addition, Bakhtiari [2] in his studies of proprioceptive sense showed that a smaller error in reproducing a predefined angle occurred with the dominant limb; however, in this case the difference with respect to the non-dominant limb was not significant.

Based on the research presented in this paper, there was no statistically significant difference between the values of maximum torque obtained for the right and left limbs. The difference was 3.9% in favor of the non-dominant limb. Perhaps that was due to the standardized measurement conditions (static) and no impact of technique on measurement. Many studies on various sport disciplines have confirmed the results [30]. Therefore, such differences were the reference value for the acceptable asymmetry, which was adopted in the present work.

In the literature addressing the subject, preference in the use of a lower limb is described by taking into account different roles of the lower limb [5]. According to this theory, the dominant limb is the mobilizing limb, while the limb used to provide postural support during the activities performed by the manipulative limb is defined as the non-preferred one [8]. It occurs during a game when football players use their supporting limb to maintain balance so that the preferred limb can perform an accurate kick [12]. In addition, the left limb is more frequently used to perform dynamic activities, while the right limb (dominant) is used in activities requiring precision [5].

Furthermore, other research has documented the greater importance of the role of the visual system compared to the vestibular or proprioceptive systems when maintaining balance and posture control. The result was obtained in the present trial to reproduce a predefined tension with feedback. Errors in reproduction of MVC level did not exceed 2% for either the right or left limbs. However, the sportswomen found reproducing the value of 30% of MVC significantly difficult ($F_{(2,66)} = 13.642$; $p < 0.001$). While analyzing the symmetry of reproducing predefined force levels with respect to the adopted reference values (SI_{Ra}), the asymmetry with regard to 30% and 50% of MVC was shown.

Perhaps this is connected with the size of the motor units. Postural muscles of the body act against gravity. These muscles' motor units are large and

responsible for gradation of force; therefore, it is more difficult to precisely determine smaller force values compared to the larger force values. An even greater difficulty in neuromuscular coordination is observed when there is no information from one of the senses. It is believed that in the absence of visual information, however, position and movement sense is based on the main endings of muscle spindles [13], [32]. Primary spindle endings respond to change of muscle length and to the speed of this change. Secondary endings, however, are not significantly sensitive to change in position and movement, but signal only change in length [20]. Walsh et al. [31] also demonstrated that the sense of muscle fatigue caused by exercising one limb leads to errors by the other limb of body position matching, which was defined by the authors as the sense of effort. This suggests that if muscle fibers affect the sense of position, then an additional signal comes from increased muscle tension necessary to maintain the position [1].

For these reasons, in the authors' own study the female soccer players performed a threefold sequence A, B, C of reproducing 30%, 50%, and 70% of MVC (in various orders of predefined levels) without visual control. The results allowed for assessing the impact of factors such as limb preference, different levels of reproducing MVC, and fatigue on the proprioceptive capabilities of female soccer players. The repeated measures analysis of variance showed no significant interaction between these factors. It was found, however, that in the trial with eyes closed, participants reproduced the predefined level of MVC with a much larger error than in the trial with visual control. In this trial, an important fact was obtaining a greater error in reproducing the lowest values of MVC (30%). However, the impact of fatigue on the accuracy of reproduction was not observed.

The effects of fatigue include decreased muscle force [3], a change in the pattern of muscle activation, and reduced proprioceptive sense in both men and women [23]. Assessing maximum muscle torque before and after the entire experiment did not identify fatigue, either. A slight decrease in force capabilities was observed for the left limb. Maintenance of different levels of MVC for 5 seconds, also repeated nine times with 5-second breaks, probably did not significantly reduce neuromuscular control. However, in order to accurately assess the impact of declines in a sportsperson's ability to efficiently protect against external forces affecting players on a field, further research should include an experiment in which the load will be applied to muscles, thus resulting in their fatigue. Smith et al. [26] have already conducted

a similar type of study; however, they took into consideration the kinesthetic sense. The cited authors demonstrated the influence of muscle fatigue on the sense of limb position. It was observed that during the isometric contractions of varied intensity, position matching error was larger along with increased intensity of muscle contraction. This indicated the significant influence of muscle fatigue on proprioceptive sense, which has also been confirmed by Allen and Proske [1]. After conducting exercises that decreased maximum voluntary contraction (MVC) by 30%, researchers demonstrated significant error in position sense, but not in the range of movement.

The authors' own research includes results about the symmetry of reproducing predefined tension, which proved to be of importance and confirmed the aforementioned results. Only in trial I was the symmetry index within the accepted area of reference; in the remaining trials (II and III), increased asymmetry of proprioceptive sense, mainly directed toward the non-preferential limb (non-dominant), was observed. The impact of the factor of reproduced MVC levels, confirming the results of the authors' own research, was also important. The largest asymmetry occurred in reproducing 30% of MVC. This is probably connected with a foot preference for supporting and precise activities [5].

On the basis of the authors' own research and review of the literature, it has been shown that due to different situations on a field, loading both limbs, especially with coordination exercises that improve proprioception, which increases stability, reduces the risk of conflict of movement in the joints, and plays a significant role in soccer training. Stabilization will be ensured by strengthening the static stabilizers (capsuloligamentous complex) and dynamic stabilizers, which constitute a group of muscles that has their muscle tone regulated by the nervous system. Symmetrical proprioceptive exercises increase the integration of static and dynamic functions of stabilizers of the joints, thus lowering the risk of injury to joints during all movements [17]. Moreover, proprioceptive exercises increase the role of proprioceptive sense in preventing sudden injuries, as it is associated with information conduction velocity. Reflex from mechanoreceptors occurs at a velocity of 70–100 m/s, while the conduction of pain is at 1 m/s [16]. Thus, conscious, protective muscle tension after a stimulus occurs two-three times longer than the stimulation from the ligamentous-muscular reflex [24]. Mandelbaum et al. [18] studied the influence of a neuromuscular and proprioceptive training program on lowering the incidence of ACL injuries in female soccer players. The

program aimed at increasing participants' levels of perception of external forces and increased stabilization of the joint to protect its structures [18].

5. Conclusions

Soccer is becoming an increasingly popular discipline for women.

- The above facts are particularly important for this group due to changes in hormone levels in monthly cycles and different levels of protection of muscle-tendon structures.
- What is also essential is exercise involving both sides and loading both the right and left limbs in order to prevent injuries. Special attention should be paid to develop skills in sensing force of varying levels, which may significantly improve neuromuscular coordination. The paper has shown that the greatest difficulty occurred when the participants tried to reproduce the lowest values of force.
- The values of symmetry index obtained during trials to reproduce the predefined values with visual control were almost always within the area considered as acceptable ($SI_{RF} \pm SD$), while the values of SI obtained during trials with eyes closed significantly exceeded that area. On this basis, it has been concluded that it was much harder to reproduce the predefined values if there was no feedback but only then can we talk about proprioception.
- Attention is drawn to the use of an appropriate measurement tool and the proper methods for diagnosing overload. General tests that compare levels of the right and left limbs cannot always fully show existing threats. Therefore, the symmetry indices, which are much more sensitive to detecting deviations than the statistical tests alone, are worth using in the assessment of overload, as has been shown in the paper.

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