MUSCULAR STRENGTH AND STRENGTH ASYMMETRIES OF HIGH ELITE FEMALE SOCCER PLAYERS

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Abstract

The aim of the study was to determine the profile of muscular strength and strength asymmetries of national female soccer players (n = 17, age = 24.19 ± 3.66 years, body height = 168.37 ± 6.76 cm, body mass = 62.13 ± 6.05 kg). The muscular strength of the lower limbs was assessed using a Cybex Humac Norm isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). The maximum peak muscle torque of the knee extensors (PTE) and flexors (PTF) of the preferred (PL) and non-preferred leg (NL) during concentric contraction were measured at three angular velocities of movement (60, 120, 180, 240 and 300 °·s⁻¹). The muscular strength of PTE and PTF significantly decreased with increasing angular velocity (p<0.01). The female players produced insignificant muscle strength differences between the PL and NL at all angular velocities. The difference between PTE and PTF was ~ 43.2 % at the lowest velocity and ~ 32.8 % at the highest velocity. Speed of muscle contraction had a significant effect on the ipsilateral ratio (H:Q ratio) in female players (PL: F6,69,25.8 = 7.61, p = 0.00, η² = 0.32, NL: F2,37,37.9 = 14.50, p = 0.00, η² = 0.48). Concerning the Q:Q ratio, contraction velocity only insignificantly affected its size F3,79,44.5 = 0.38, p = 0.82, η² = 0.02. The bilateral ratio of knee flexors (H:H) did not significantly change under the contraction velocity (F4,64 = 2.86, p = 0.03, η² = 0.15). The comparison of bilateral ratio of knee extensors vs. knee flexors was significant (p<0.01) at the velocities of 180, 240 and 300 °·s⁻¹. It appears that the bilateral ratio of knee extensors is stable with respect to speed of muscle contraction while the ratio of knee flexors is sensitive to increasing movement velocity above 180°·s⁻¹. Our study indicated that almost 50 % of female players have at least one strength asymmetry (bilateral knee flexor) regardless of their limb’s preferences. Maladaptive effects in terms of different kinds of body strength asymmetries represent a potential risk of a player’s injury; therefore the detected asymmetries should be systematically monitored and compensated using specific exercises.

Key words: female football, strength imbalances, injurie risk prevention, elite female athletes

Introduction

Success in soccer requires a high level of physical fitness aimed to its usage according to demands of the game in all aspects (fitness, technical, tactical and psychological) throughout the game. Williams and Reilly (2000) reported a number of components determining success in soccer, namely SUPS (speed, understanding, personality, skill), and TIPS (talent, intelligence, personality, speed). Studies examining physiological profiles of soccer players showed several key points of physical fitness in elite soccer players: aerobic and anaerobic capacity, repeated sprint ability, power strength, speed, agility and quickness, body composition (Cometti, Maffiuletti, Pousson, Chatard, & Maffulli, 2001; Mohr, Ellingsgaard, Andersson, Bangsbo, & Krustrop, 2003; Mohr, Krustrop, & Bangsbo, 2003; Mujika, Santisteban, Impellizzeri, & Castagna, 2009; Williams & Reilly, 2000). Speed is a crucial component of soccer performance. Based on research we know that speed has a significant correlation with isokinetic strength of knee extensors and flexors (Lehance, Binet, Bury, & Croisier, 2009). As a factor contributing to success in soccer, the quadriceps muscle plays a role in sprinting, jumping and ball-kicking; hamstring contributes to knee flexion, which is a major factor in stride power (Lehance et al., 2009). Women’s soccer was the topic of a number of studies dealing with the following issues: speed, agility and quickness (Polman, Walsh, Bloomfield, & Nesti, 2004), injury risk factors (Brophy, Silvers, Gonzales, & Mandelbaum, 2010; Ostenberg & Roos, 2000), the comparison with male soccer players from the following points of view: aerobic capacity (Mohr, Ellingsgaard, et al., 2003), injury occurrence (Ostenberg & Roos, 2000), physical performance according to positional characteristics (Vescovi, Brown, & Murray, 2006), isokinetic strength of lower limbs (Jenkins et al., 2013) and comparison of fitness determinants of success between men and women (Mujika et al., 2009). In soccer, the players are forced to switch between high demanding skills which require strength, power, coordination and agility, with these qualities being symmetrically distributed to the lower extremities for maximal body balance and skill efficiency (Fousekis, Tsepis, & Vagenas, 2010). Results of some studies indicated that long-term participation in soccer leads to development of various degrees and modes of functional asymmetry (Fousekis et al., 2010). The asymmetrical loads imposed on the musculoskeletal structure along with the long-term adaptations predispose the soccer players to alternation of the
kinematic patterns and induce strength-related asymmetries. Ostenberg and Roos (2000) in their prospective study reported that during one season there were 65 injuries overall in 123 players. The injury rate was 14.3 per 1000 game hours and 3.7 per 100 practice hours. The most frequently injured was the knee (26%). Isokinetic testing is a useful tool for coaches, trainers and clinicians to provide information regarding muscle balance around the knee. The comparison of strength parameters between elite and sub-elite soccer players revealed a significantly higher level of muscle strength (mainly knee flexors) and H:Q ratio (Maly, Zahalka, & Mala, 2014). A bilateral deficit between the limbs (Q:Q, H:H) was not significant between the monitored groups. However, strength and functional asymmetries are often caused by unilateral and uncompensated load of the body and result in maladaptive effects (Maly, Zahalka, & Mala, 2010); however, they were not found in very young soccer players (Maly, Zahalka, Mala, & Teplan, 2013).

Several studies dealt also with isokinetic strength of lower extremities in female soccer players (Jenkins et al., 2013; Mercer, Gleeson, & Wren, 2003; Soderman, Bergstrom, Lorentzon, & Alfredson, 2000) but not at the level of the national team. The one of strength asymmetry manifestations is the occurrence of muscle imbalances, which may limit individual's physical fitness, cause muscle pain, increase the risk of muscle injuries and consequently decrease the level of performance. From the scientific point of view, the size of isokinetic lower extremity strength, bilateral and ipsilateral ratios in elite national level female soccer players has so far not been well described in relation to laterality of limbs. Its objectification and possibilities of their improvement, or compensation of strength differences using targeted intervention programmes is the current scientific problem.

Methods

Study sample
The screened sample consisted of national female soccer teams (n=17, age=24.19±3.66 years, body height = 168.37 ± 6.76 cm, body mass = 62.13 ± 6.05 kg). Concerning the playing positions, the following players were assessed: 2 goalkeepers, 3 attackers, 6 midfielders and 6 defenders. Testing took place in the national soccer training camp during the competitive period. Participants recruited were not injured or rehabilitating from injury at time of testing.

Assessment of strength indicators
The muscular strength of the lower limbs was assessed using a Norm isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). The maximum peak muscle torque of the knee extensors (PT_E) and flexors (PT_F) of the preferred (PL) and non-preferred leg (NL) during concentric contraction were measured at three angular velocities of movement (60, 120, 180, 240 and 300 °·s⁻¹).

Limb dominance was defined by determining which foot each participant preferred to use to kick a ball. The tested subject sat on the seat of the dynamometer, which was ergonomically set with the arm of the dynamometer based on the instructions and individual somatic characteristics of the participant. The axis of the dynamometer arm rotation was visually adjusted to the axis of knee rotation with a laser point. PT was controlled and modified by gravitational influence at each velocity. The motion range was 90° (maximum extension was marked and set as “anatomic zero ° 0°”). The participant’s trunk and thigh of the tested limb were fixed by means of the dynamometer’s fixing straps so that movement was confined to a single joint movement only (knee extension – flexion).

The participant held the side handles of the device during the measurement. Before measurement, all tested subjects completed a short warm-up (dynamic half squats 4 sets@15 repetitions, forward lunges 4 sets@10 repetitions) and static stretching of lower limb muscles (6 minutes) – individual approach. The testing protocol consisted of three attempts at knee flexion and extension at the monitored velocities (from the lowest to the highest velocity). Before testing at each velocity, the participants completed 4 training trials at submaximal intensity. This procedure is in accordance with methodological recommendations for testing isokinetic strength on an isokinetic dynamometer in youths (De ste Croix, Deighan, & Armstrong, 2003). Between the tested velocities, there was a break with inactive rest of 1 minute in length (Rahnama, Lees, & Bambacecchi, 2005). Visual feedback and verbal stimulation were given during the testing. We also took into account the factor of gravitation of the isokinetic dynamometer arm and lower extremity segment, which was calculated by the dynamometer and compensated during the particular measurement. The research was approved by the Ethical Committee of the Faculty of Physical Education and Sports at Charles University in Prague. Measurements were carried out in accordance with the ethical standards of Declaration of Helsinki and ethical standards in sport and exercise science research (Harriss & Atkinson, 2011).

Statistical analysis
The four-way mixed-design ANOVA with three between subject effects (performance (P), laterality (L), muscle group (MG) and one within subject effect (angular speed)) was used for evaluation of dependent variables: peak torque, unilateral and bilateral strength ratios. To evaluate equality of error variances, Levene’s test was used. Multiple comparisons of means of the monitored groups were carried out using Bonferroni’s post hoc test. The effect size coefficient was assessed using “Partial Eta Squared - η²P.” The comparison of peak torque (PT_E), unilateral ratios (H:Q) and bilateral ratios (Q:Q, H:H) between teams were carried out using the Student’s t-test for independent variables. The probability of type I error (alpha) was set at 0.05 in all statistical analyses.
The probability of type II error (beta) was controlled using post hoc (retrospective) analysis and it was set at 0.2 (conventional value). Moreover, effect size between the means of the screened groups was assessed using Cohen's coefficient of effect size \(d\). It was calculated as the difference of the means of the compared parameters and divided by a “pooled” standard deviation (Thomas & Nelson, 2001). The coefficient was assessed as follows: \(d = 0.20 – small\) effect, \(d = 0.50 – medium\) effect and \(d = 0.80 – large\) effect (Cohen, 1992). Statistical analysis was performed using IBM® SPSS® v21 (Statistical Package for Social Science, Inc., Chicago, IL, 2012).

**Results**

Muscle strength of knee extensors and flexors significantly decreased with increasing angular velocity (Table 1a,b; Figure 1,2). In terms of the bilateral deficit, female players produced insignificant muscle strength differences between the preferred and non-preferred leg at all angular velocities. The difference between knee extensors and flexors was ~ 43.2 % at the lowest velocity and ~ 32.8 % at the highest velocity. Speed of muscle contraction had a significant effect on the ipsilateral ratio (H:Q ratio) in female players (preferred leg: \(F_{1.69,25.8} = 7.61, p = 0.00, \eta^2 = 0.32\), non-preferred leg: \(F_{2.37,37.9} = 14.50, p = 0.00, \eta^2 = 0.48\). The lowest H:Q ratio was detected at the lowest velocity 60°·s\(^{-1}\). Based on Bonferroni’s post hoc test we found out that from the velocity of 180°·s\(^{-1}\) on, the dependence between H:Q ratio and higher movement velocity was not significant (Table 3). Moreover, no significant difference in H:Q ratio between the preferred and non-preferred leg was found (Table 3). The most interesting results were revealed in the bilateral ratio (Q:Q and H:H ratio). Concerning the Q:Q ratio, contraction velocity only insignificantly affected its size \(F_{2.79,44.6} = 0.38, p = 0.82, \eta^2 = 0.02\) (Table 4). The level of the Q:Q ratio ranged between 5.59 – 7.24 % at different velocities. The bilateral ratio of knee flexors (H:H ratio) did not significantly change under the contraction velocity (\(F_{1.64} = 2.86, p = 0.03, \eta^2 = 0.15\). The comparison of bilateral ratio of knee extensors vs. knee flexors was significant (\(p < 0.01\)) at the velocities of 180, 240 and 300 °·s\(^{-1}\). It appears that the bilateral ratio of knee extensors is stable with respect to speed of muscle contraction while the ratio of knee flexors is sensitive to increasing movement velocity above 180°·s\(^{-1}\).
Figure 1. a) Peak muscle torque of knee extensors (PT_E) in absolute values, b) Peak muscle torque of knee flexors (PT_F) in absolute values (N·m·kg⁻¹)

Table 3. Ipsilateral ratio between peak muscle torque of knee flexors and extensors in the preferred and non-preferred lower extremities (H:Q ratio)

<table>
<thead>
<tr>
<th>Velocity (°·s⁻¹)</th>
<th>Preferred extremity Mean (SD)</th>
<th>Non-preferred extremity Mean (SD)</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>58.71(11.78)ᵗ🕒ystals</td>
<td>58.24(6.38)ᵗ🕒ystals</td>
<td>0.18</td>
<td>N.S.</td>
<td>0.05</td>
</tr>
<tr>
<td>120</td>
<td>64.53(14.45)ᵗ</td>
<td>64.94(7.50)ᵗ</td>
<td>0.12</td>
<td>N.S.</td>
<td>0.04</td>
</tr>
<tr>
<td>180</td>
<td>66.65(16.83)ᵗ</td>
<td>70.00(10.37)ᵗ</td>
<td>0.83</td>
<td>N.S.</td>
<td>0.24</td>
</tr>
<tr>
<td>240</td>
<td>69.59(16.98)ᵗ</td>
<td>71.06(12.28)ᵗ</td>
<td>5.70</td>
<td>N.S.</td>
<td>0.1</td>
</tr>
<tr>
<td>300</td>
<td>67.59(18.24)ᵗ</td>
<td>70.94(14.93)ᵗ</td>
<td>6.61</td>
<td>N.S.</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*—significant difference between velocities 60 and 120°·s⁻¹, †—significant difference between velocities 60 and 180°·s⁻¹, ‡—significant difference between velocities 60 and 240°·s⁻¹, §—significant difference between velocities 60 and 300°·s⁻¹, ¶—significant difference between velocities 120 and 180°·s⁻¹, ‖—significant difference between velocities 120 and 240°·s⁻¹, N.S.—nonsignificant difference, d—Cohen’s coefficient of effect size

Table 4 Bilateral ratio between peak muscle torque of knee extensors (Q:Q) and flexors (H:H)

<table>
<thead>
<tr>
<th>Velocity (°·s⁻¹)</th>
<th>Knee extension Mean (SD)</th>
<th>Knee flexion Mean (SD)</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>7.24(4.21)</td>
<td>10.18(8.66)</td>
<td>1.08</td>
<td>N.S.</td>
<td>0.43</td>
</tr>
<tr>
<td>120</td>
<td>6.88(4.29)</td>
<td>10.41(7.22)</td>
<td>1.62</td>
<td>N.S.</td>
<td>0.59</td>
</tr>
<tr>
<td>180</td>
<td>6.65(4.44)</td>
<td>12.65(9.01)</td>
<td>3.31</td>
<td>p&lt;0.01</td>
<td>0.84</td>
</tr>
<tr>
<td>240</td>
<td>5.59(3.73)</td>
<td>11.47(7.49)</td>
<td>3.58</td>
<td>p&lt;0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>300</td>
<td>6.71(4.79)</td>
<td>16.24(8.74)</td>
<td>4.18</td>
<td>p&lt;0.01</td>
<td>1.35</td>
</tr>
</tbody>
</table>

F 0.377 2.86
P p>0.05 p<0.05
Eta 0.023 0.152

*—nonsignificant difference, d—Cohen’s coefficient of effect size

**Discussion**

Strength is an important component of specific physical fitness in soccer. Testing of lower limb strength is very important because muscle groups (quadriceps, hamstring, calves) must generate and absorb high forces during acceleration, deceleration, jumping, kicking, turning, tackling, changes of direction and other movement activities during the soccer match. The level of knee muscle strength significantly decreased with increasing movement velocity. These results were also presented in the men’s category (Lehnert, Xaverova, & De Ste Croix, 2014; Maly, Zahalka, & Mala, 2011; Maly et al., 2014).

In case that the muscle is contracting against a high external load, force is high but velocity is low. This relation between force and contraction velocity is known as the Hill’s curve (Hill, 1938). It is based on the principle that the maximum time necessary for contact between actin and myosin filaments decreases with higher velocity of concentric activity (Huxley’s model). Therefore, the length of the contact phase reduces in the overall cycle. Cross-bridge forms between actin and myosin have to be re-released immediately after their connection so there is not sufficient time for power production.
reported a lower value of peak muscle division). Our female players achieved similar higher than Turkish female players (75.40±12.48 N·m)(Andrade et al., 2012) and, controversially, comparison to elite Brazilian female players (83±

velocity (300°·s -1), our female players produced results with 91.9 ± 14.7 N·m. At the highest velocity (240 °·s -1 in elite female players (NCAA first division). This difference makes 6.2% and we believe it was caused by a lower fitness level of Turkish female players ( Turkish university team) in comparison to our female players (national team). A comparison of the dominant and non-dominant leg did not reveal any significant differences in knee extensor strength at any of the tested velocities (p>0.05). Knee flexor strength was lower by 42.23% in comparison to knee extensors. Our female players produced 1.6 times greater value of body weight in both, the dominant and non-dominant leg, at the velocity of 60°·s -1 (Table 2). Expressed in absolute values, strength amounted to 97.82± 16.32 N·m. Elite Brazilian female players produced lower muscle strength 91± 18 N·m(Andrade et al., 2012) and Turkish female players only achieved 78.94± 15.35 N·m (Colak, 2012). At the highest velocity, Brazilian female players achieved greater muscle strength (60± 9 N·m) in comparison to our female players (54± 12 N·m). Turkish female players produced 46± 7 N·m at this velocity. Some results of our study are in accordance with results of other studies; however, some of them are controversial. One of the possible reasons is an unclear definition of players in foreign sources. For instance, the term „elite soccer players” refers to various levels of player’s performance (national representation team, team from the highest national league according to player’s age category, soccer academy, etc.).

Another possible reason of different results can be found in methods of research data obtaining (way of warm-up, testing on the isokinetic dynamometer with arms crossed on the chest or holding the side handles of the device, verbal motivation and visual feedback given, etc.). Generally, there is a lack of studies on really elite female teams (national teams). A sufficient level of knee flexor strength is necessary in terms of performance and injury prevention. The level of knee flexor strength significantly decreased with increasing movement velocity (p<0.01). Crucial moments in individual player’s performance take place at high movement velocity (fast changes of movement direction, switching from offensive to defensive actions and vice versa, shooting, take-off, passing on a longer distance and other). Similarly as for the knee extensors, we did not record any significant differences between the preferred and non-preferred leg. These results are in accordance with study(Maly et al., 2010) who did not find any significant differences in muscle strength between the limbs in elite young soccer players. Despite some shared expressions of strength characteristics from the perspective of gender there are also physiological differences. Compared with the male athletes, the female athletes took significantly longer to generate maximum hamstring muscle torque during isokinetic testing Huston and Wojtys (1996).Elite male and female players regularly (at least twice a year) undergo tests of isokinetic muscle strength and in case of detecting strength asymmetries clinical staff (physiotherapists and fitness coaches) attempt to balance (compensate) this condition.

These facts should be, however, taken into consideration when presenting and comparing results. Our female players produced at the lowest velocity $PT_e = 169.53±26.99$ N·m. Jenkins et al. (2013) reported a lower value of peak muscle torque in knee extensors, $154.1± 24.4$ N·m in elite female players (NCAA first division). This difference means 9.1 %. Ostenberg and Roos (2000) reported $PT_e 87.0 ± 14.7$ N·m in league female players, which, in comparison to our female players, is lower by 48.7%. This difference is enormous and points to a remarkable difference in muscle strength between female players at league and international levels. On the contrary, our results are identical with elite Brazilian female players (n=17) who produced 169± 27 N·m(Andrade et al., 2012) and Turkish female players whose performance was 162.32±22.95 N·m (Colak, 2012).Jenkins et al. (2013) reported the value of peak muscle torque knee extensors $88.8 ± 12.6$ N·m at the velocity of 240 °·s -1 in elite female players (NCAA first division). Our female players achieved similar results with 91.9 ± 14.7 N·m. At the highest velocity (300°·s -1), our female players produced lower muscle strength (80.35± 13.23 N·m) in comparison to elite Brazilian female players (83± 12 N·m)(Andrade et al., 2012) and, controversially, higher than Turkish female players (75.40±12.48 N·m).

Finally, the proportion of combined bridges in the muscle is reduced and the produced strength is lower (Wirth & Schmidtbleicher, 2007). The deficit between strength produced at the lowest velocity (60°·s -1) and the highest velocity (300°·s -1) makes 52.1%. Knee extensor strength was 2.77 N·m·kg -1 for both lower extremities. In comparison to elite male players, this difference is lower by 12.9 %(Maly et al., 2014). The results are expressed as performance per kilogram of participant’s body weight. When comparing absolute values, the difference is significantly higher, namely 30.9 %.

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Another possible reason of different results can be found in methods of research data obtaining (way of warm-up, testing on the isokinetic dynamometer with arms crossed on the chest or holding the side handles of the device, verbal motivation and visual feedback given, etc.). Generally, there is a lack of studies on really elite female teams (national teams). A sufficient level of knee flexor strength is necessary in terms of performance and injury prevention. The level of knee flexor strength significantly decreased with increasing movement velocity (p<0.01). Crucial moments in individual player’s performance take place at high movement velocity (fast changes of movement direction, switching from offensive to defensive actions and vice versa, shooting, take-off, passing on a longer distance and other). Similarly as for the knee extensors, we did not record any significant differences between the preferred and non-preferred leg. These results are in accordance with study(Maly et al., 2010) who did not find any significant differences in muscle strength between the limbs in elite young soccer players. Despite some shared expressions of strength characteristics from the perspective of gender there are also physiological differences. Compared with the male athletes, the female athletes took significantly longer to generate maximum hamstring muscle torque during isokinetic testing Huston and Wojtys (1996).Elite male and female players regularly (at least twice a year) undergo tests of isokinetic muscle strength and in case of detecting strength asymmetries clinical staff (physiotherapists and fitness coaches) attempt to balance (compensate) this condition.
Monitoring of ipsilateral ratio between muscle strength of knee flexors and extensors showed a significant effect of velocity on its level. The H:Q ratio raised with increasing angular velocity in both preferred and non-preferred extremity. This result is consistent with the results of the study by (Kong & Burns, 2010). The authors present a significantly different H:Q ratio at velocities of 60°·s⁻¹ vs. 180°·s⁻¹, but insignificant difference when comparing to velocities of 180°·s⁻¹ vs. 240 or 300°·s⁻¹. H:Q ratio of our female players was 0.58 at the velocity of 60°·s⁻¹. The highest values of H:Q ratio were achieved at the medium velocity of 240°·s⁻¹ (preferred leg = 0.70, non-preferred leg = 0.71) (Dauty, Potiron-Josse, & Rochcongar, 2003) reported that H:Q ratio less than 0.6 (60°·s⁻¹) represents a 77.5% probability of hamstring injury occurrence in elite soccer players. The level of H:Q ratio between the preferred and non-preferred leg was not significant. Morgan and Oberlander (2001) reported that approximately 75% of injuries in soccer are in the lower extremities. It appears that a high level of the ratio of hamstring and quadriceps strength is an important parameter in identification of an increased risk of injury (Fried & Lloyd, 1992). Hamstring muscle injury also has a high re-injury rate, which frustrates the injured athletes as well as the clinicians and increases cost of treatment (Liu, Garrett, Moorman, & Yu, 2012). It is considered that knee flexor strength is not sufficiently stimulated by the game (Cometti et al., 2001) or traditional model of soccer players’ training (Botek et al., 2010). Therefore, it is necessary to pay more attention to this muscle group. Results of our study point to significant differences in bilateral deficit of knee flexors at higher movement velocities between the preferred and non-preferred extremity (Table 4).

Furthermore, results of our study revealed significantly higher values of the bilateral deficit in knee flexors compared to extensors. It appears that the bilateral ratio of knee extensors is stable with respect to the speed of muscle contraction, while the ratio of knee flexors is sensitive to increasing movement velocity over 180°·s⁻¹. Bilateral deficit of knee flexors detected between the slowest and fastest movement (60 vs. 300°·s⁻¹) makes 37.3%. Knapik, Bauman, Jones, Harris, and Vaughan (1991) state that the athletes with muscle strength imbalances higher than 15% at a bilateral comparison of extremities had 2.6-times higher frequency of injuries when compared to athletes who had this difference lower than 15%. Fowler and Reilly (1993) state that 20% difference in the bilateral deficit of muscle strength in professional players is a predisposition to injury. We recorded the difference higher than 20% in 8 (almost 50% of total players) players at least at one of the tested velocities. Long-term preferred and uncompensated load of one side of the body may lead to muscle imbalances and dominance of one leg, what can be a result of pre-existing limb preference (footedness) or strength asymmetry. We agree with the recommendation by (Lehance et al., 2009), who mentioned three important reasons for testing isokinetic strength in athletes: to ascertain the absence of muscle strength imbalances between the extremities (or that imbalances are within the limits), to ensure that muscle strength is well balanced between the knee flexors and extensors and finally, that a soccer player with his level of strength abilities meets the standards (norms) according to his age and performance level. Schache, Crossley, Macindoe, Fahner, and Pandy (2011) reported that the bilateral hamstring strength asymmetry significantly increased five days prior the hamstring strain injuries.

**Conclusion**

Knee extensor and flexor strength is at a level comparable with elite female players at international level. Nevertheless, we see a lack of information in this field, especially in elite female teams representing national teams of countries. In terms of strength asymmetries, we did not find any significant differences between the preferred and non-preferred leg. The most important finding is the occurrence of bilateral asymmetries in knee flexors at higher angular velocities. Despite regular diagnostics and professional medical support of the team it is a long-term problem and requires an individual approach aimed to compensating muscle imbalances. Our study indicated that almost 50% of female players have at least one strength asymmetry (bilateral knee flexor) regardless of their limb’s preferences. Maladaptive effects in terms of different kinds of body strength asymmetries represent a potential risk of a player’s injury; therefore the detected asymmetries should be systematically monitored and compensated using specific exercises. The results are standardised per kilogram of body weight and therefore may serve for comparative purposes for other researchers as well as a base (criterion) of assessment of elite professional soccer players. In terms of practice, the results may be beneficial for fitness coaches, physiotherapists, doctors and other clinical staff in professional soccer.

**References**


MIŠIĆNA SNAGA I SNAGA ASIMETRIJE KOD ELITNIH IGRAČICA NOGOMETA

Sažetak
Cilj istraživanja bio je utvrditi profil mišićne snage i čvrstoće kod asimetrija nacionalnih nogometašica (N = 17, dob = 24,19 ± 3,66 godina, tjelesne visine = 168,37 ± 6,76 cm, tjelesne mase = 62,13 ± 6,05 kg). mišićna snaga donjih ekstremiteta procijenjena je pomoću Cybex Humac Norm izokinetičkog dinamometra (Cybex NORM®, Humac, CA, SAD). Maksimalni okretni moment vrha mišića koljena ekstensora (PTE) i fleksora (PTF) kod bolje (PL) i slabije noge (NL) tijekom koncentrične kontrakcije mjerene su na tri kutne brzine kretanja (60, 120, 180, 240 i 300 ° • S-1). Mišićna snaga PTE i PTF značajno se smanjila s povećanjem kutne brzine (p <0,01). Kod djevojaka su dobivene beznačajne razlike snage mišića između PL i NL na svim kutnim brzinama. Razlika između PTE i PTF je ~ 43,2% na najnižoj brzini i ~ 32,8% na najvećoj brzini. Brzina kontrakcije mišića je imala značajan utjecaj na ipsilateralni omjer (H: omjer P) kod igračica (PL: F1.69,25.8 = 7.61, p = 0.00, η2 = 0.32, NL: F2.37,37.9 = 14.50, p = 0.00, η2 = 0.48). Što se tiče Q: omjer Q, brzina kontrakcije samo neznatno promijenio pod promjenom brzine kontrakcije (F4,64 = 2,86, p = 0,03, η2 = 0,15). Usporedba bilateralnog omjera ekstensora koljena vs. Fleksora koljena bila je značajna (p <0,01) na brzinama od 180, 240 i 300 ° • S-1. Čini se da je bilateralni odnos ekstensora koljena stabilan u odnosu na brzinu mišićne kontrakcije, a omjer fleksora koljena osjetljiv na povećanje brzine kretanja iznad 180 ° • S-1. Naše istraživanje pokazuje da je gotovo 50% sportašica imalo barem jednu asimetriju snage (bilateralni fleksor koljena) bez obzira na sklonosti svojih ekstremiteta Neadaptivni učinci u smislu asimetrije čvrstoće različitih dijelova tijela predstavljaju potencijalni rizik od ozljeda igrača; Stoga otkrivena asimetrije treba sustavno pratiti i kompenzirati korištenjem određenih vježbi.

Ključne riječi ženski nogomet, neravnoteža snage, prevencija rizika povreda, elitne sportašice

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