MUSCULAR STRENGTH AND STRENGTH ASYMMETRIES IN ELITE AND SUB-ELITE PROFESSIONAL SOCCER PLAYERS

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Abstract

Purpose: The purpose of research was to compare strength parameters of lower limbs (knee extensors and flexors) and their asymmetries (bilateral and unilateral) in elite and sub-elite professional soccer players. Material and method: The screened sample was composed of two professional soccer teams. The first team (Team 1 – elite professional players, n = 28, age = 24.31 ± 4.79 years) was a leader of the first Czech league the second team (Team 2 – sub-elite professional players, n = 24, age = 26.19 ± 3.67 years) was a leader of the second Czech league. Maximum peak torque (PT) and derived parameters (bilateral ratio [Q:Q and H:H] and unilateral ratio [H:Q]) were evaluated using Cybex isokinetic dynamometer at three angular velocities (60, 180, 300 °·s⁻¹) for the dominant (DL) and non-dominant leg (NL) during the knee flexion (KF) and extension (KE) in concentric contraction. The four-way mixed-design ANOVA, Student’s t-test and Cohen “d” index of effect size were used for statistical analyses. Results: The factor of P (performance) revealed a significant effect on the level of isokinetic strength of lower limbs in soccer players (F(1.596) = 91.74, p < 0.01, η² = 0.14). The factors of L (laterality) did not significantly influence the level of thigh muscular strength of lower extremities in soccer players (F(1.596) = 2.47, p > 0.05, η² = 0.01). The factor of the tested muscle group (KE, KF) showed a significant effect on the compared bilateral differences (F(1.288) = 11.13, p < 0.01, η² = 0.04). Post-hoc tests also showed significantly higher (p < 0.01) values of the bilateral deficit in KE compared to KE. A significant effect was also found in the unilateral ratio of the lower limbs (H:Q) on the basis of comparison of the performance criterion (F(1.288) = 15.51, p < 0.01, η² = 0.05) and angular velocity of movement (F(2.288) = 5.56, p < 0.01, η² = 0.04). The unilateral ratio (H:Q) was significantly higher in both the dominant and non-dominant limbs in favour of the higher performance Team 1 in comparison to Team 2 (H:Q ratio dominant limb: F(1.144) = 5.87, p < 0.05, η² = 0.04; non-dominant limb: F(1.144) = 11.21, p < 0.01, η² = 0.07). Discussions and conclusions: The results of the study suggest that more than 50 % of players have at least one strength asymmetry regardless of their performance level. Elite professional players have much greater muscular strength of KE and KF, especially at higher angular velocity. Concerning sub-elite players, we found a lower unilateral H:Q ratio. The results of the study point to worse preparedness of KF (performance and prevention perspective) in the sub-elite players. 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: knee extensor, knee flexor, strength asymmetries, football, injury, testing

Introduction

Strength is an important component of specific physical fitness in soccer. Testing of lower limbs strength is very important because muscle groups (quadriiceps, 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. Long-term preferred and uncompensated load of one side of the body may lead to asymmetry and dominance of one leg, what can be a result of pre-existing limb preference (footedness). The isokinetic strength assessment should become an integral part of a player’s diagnostics before the preparatory period aimed at detection of the level of strength predispositions as well as knee extensor and flexor asymmetries (Croisier, Ganteaume, & Ferret, 2005; Orchard, Marsden, Lord, & Garlick, 1997). It also is accepted and clinically important for assessment of deficit and muscle imbalances in athletes (Cometti, Maffiuletti, Pousson, Chatard, & Maffulli, 2001). Morgan and Oberlander (2001) suggest that approximately 75 % of injuries in soccer occur to the lower limbs. It seems that a high level of the ratio of hamstring and quadriiceps muscle strength is an essential parameter of identification of increased risk of injury (Fousekis, Tsepis, Poulmedis, Athanasopoulos, & Vagenas, 2011; Fousekis, Tsepis, & Vagenas, 2010). It has been documented that strength asymmetry across the body can be linked to increased prevalence of injury (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008) and impaired performance in athletes (Young, James, & Montgomery, 2002). Results of the study by Fousekis et al. (2010) suggest that long-term training in soccer causes strength asymmetries of different characters and degrees. Out of 100 professional players tested, only 11 % did not show strength asymmetry in 14 examined parameters. In contrast, up to 20 % showed 4 to 7 strength asymmetries. Previous investigators have shown significant differences in muscle strength, vertical jump, sprint and endurance performance between soccer teams of different competition levels (Brewer & Davis, 1991; Cometti et al., 2001; Gissis, Papadopoulos, Kalapotharakos, Komsis, & Manolopoulos, 2006; Haugen, Tonnesen, & Seiler, 2006; Montgomery, 2002). Previous researchers also have shown differences in movement patterns and injury risk in soccer players with different footedness (Morgan, & Oberlander, 2001; Maly, Maly, Plicka, & Zahalka, 2015; Muly, 2009).
Also Malý, Zahálka, and Malá (2011) reported insignificant differences in knee extensor and flexor strength between more and less successful professional players. Moreover, it seems that there is a lack of information that would compare bilateral asymmetries of muscular strength of lower limbs in professional players from the perspective of their performance level. Players of higher performance level undergo greater physical effort during the match as well as training workout volume in comparison to players of lower performance level. On the contrary, conditions of professional top performance players (doctors, physiotherapists, sport massage therapists, fitness coaches, sport equipment, nutrition and control of their fitness state) are usually better in comparison to players of lower level. To sum up, the question is whether elite players have greater muscular strength of lower limbs and whether there occur more strength asymmetries, caused by greater load, than in sub-elite players. It was hypothesized that elite professional soccer players have a higher level of muscular strength (knee extensor, knee flexor) and bilateral asymmetries than sub-elite professional players. We also assume a higher unilateral ratio (H:Q ratio) in elite players than in sub-elite players.

Methods

Study sample
The screened sample was composed of two professional soccer teams. The first team (Team 1 – elite professional players, n = 28, age = 24.31 ± 4.79 years, body height = 182.57 ± 4.91 cm, body mass = 77.43 ± 6.41 kg) was a leader of the first Czech league and in comparison with the second team (Team 2 – sub-elite professional players, n = 24, age = 26.19 ± 3.67 years, body height = 183.29 ± 9.37 cm, body mass = 79.15 ± 9.09 kg) was at a higher performance level because Team 2 was a leader of the second Czech league. All players had a professional status (they were under a professional agreement). In terms of periodization, testing was carried out at the beginning of the preparatory 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 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 dominant (DL) and non-dominant leg (NL) during concentric contraction were measured at three angular velocities of movement (60, 180 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 °”). 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 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 3 sets@10 repetitions, forward lunges 3 sets@10 repetitions) and static stretching of lower limb muscles (6 minutes) – individually approach. The testing protocol consisted of three attempts at knee flexion and extension at the monitored velocities (from the lowest to the highest velocity). The procedure from the lowest to the highest velocity was standardised and recommended by Wilhite, Cohen, and Wilhite (1992). 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 passive rest of 1 minute in length (Rahnama, Lees, & Bambaecichi, 2005). Reliability of PT at velocities 60, 120 and 180°·s⁻¹ was higher than 0.90 (Impelizzeri, Bizzini, Rampini, Cereda, & Maffiuletti, 2008). 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 *posthoc* test. The effect size coefficient was assessed using “Partial Eta Squared - $\eta^2$”. The comparison of peak torque (PT), 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 *posthoc* (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

The factor of P (performance) showed a significant effect on the level of isokinetic strength of lower limbs in soccer players ($F_{(1.596)} = 91.74$, $p < 0.01$, $\eta^2 = 0.14$). With increasing angular velocity, significant changes in PT appeared ($F_{(2.596)} = 1381.05$, $p < 0.01$, $\eta^2 = 0.83$) in both teams. The factor of L (laterality) did not significantly influence the level of thigh muscular strength of lower extremities in soccer players ($F_{(1.596)} = 2.47$, $p > 0.05$, $\eta^2 = 0.01$).

Analysis of variance did not show any significant effect of P (performance) and velocity (V) on the bilateral deficit of lower limbs (performance: $F_{(1.288)} = 2.17$, $p > 0.05$, $\eta^2 = 0.01$; velocity: $F_{(2.288)} = 0.18$, $p > 0.05$, $\eta^2 = 0.00$). The factor of the tested muscle group (KE, KF) revealed a significant effect on the compared bilateral differences ($F_{(1.288)} = 11.13$, $p < 0.01$, $\eta^2 = 0.04$). Posthoc tests also showed significantly higher ($p < 0.01$) values of the bilateral deficit in knee flexors compared to knee extensors. An insignificant effect of P (performance) factor on the size of bilateral deficit of knee extensor muscular strength (Q:Q ratio) ($F_{(1.144)} = 0.05$, $p > 0.05$, $\eta^2 = 0.00$) and knee flexor strength (H:H ratio) was detected ($F_{(1.144)} = 2.60$, $p > 0.05$, $\eta^2 = 0.02$).

A significant effect was found in the unilateral ratio of the lower limbs (H:Q) on the basis of comparison of the performance criterion ($F_{(1.288)} = 15.51$, $p < 0.01$, $\eta^2 = 0.05$) and angular velocity of movement ($F_{(2.288)} = 5.56$, $p < 0.01$, $\eta^2 = 0.04$). Posthoc tests showed a significantly higher H:Q ratio ($p < 0.01$) at velocity of 300°·s⁻¹ in comparison to velocity of 60°·s⁻¹. The unilateral ratio (H:Q) of the knee was significantly higher in both the dominant and non-dominant limbs in favour of the higher performance team (T1) in comparison to Team 2 (H:Q ratio dominant limb: $F_{(1.144)}=5.87$, $p<0.05$, $\eta^2=0.04$; non-dominant limb: $F_{(1.144)}=11.21$, $p<0.01$, $\eta^2=0.07$).

<table>
<thead>
<tr>
<th>Table 1 The isokinetic strength parameters and their statistical comparison.</th>
<th>AV ($\text{°} \cdot \text{s}^{-1}$)</th>
<th>Team 1 Mean(SD)</th>
<th>Team 2 Mean(SD)</th>
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<th>Effect Size</th>
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<td>2.09(0.19)</td>
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<td>1.53(0.15)</td>
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<td>H:Q (%)</td>
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<td>63.15(9.38)</td>
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<td>62.17(8.13)</td>
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<td>PT (N·m·kg⁻¹)</td>
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<td>3.21(0.34)</td>
<td>3.01(0.26)</td>
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<td>PT (N·m·kg⁻¹)</td>
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<td>H:Q (%)</td>
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<td>58.13(7.05)</td>
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<td>Q:Q (%)</td>
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<td>6.50(5.57)</td>
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<tr>
<td>180</td>
<td>6.23(4.21)</td>
<td>6.42(4.79)</td>
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<td>300</td>
<td>9.19(6.38)</td>
<td>10.54(8.25)</td>
<td>1.34</td>
<td>-0.18</td>
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</table>

AV – angular velocity, SD – standard deviation, ES – effect size, PT – peak torque of extensors, PT – peak torque of flexors, H:Q – hamstring to quadriceps ratio, Q:Q – quadriceps to quadriceps ratio, H:H – hamstring to hamstring ratio, *— significant difference at $p < 0.05$, **— significant difference at $p < 0.01$. 

Date: 28
Discussion

Isokinetic strength parameters
The players’ performance level had a significant effect on thigh muscle strength in the compared groups. The greatest differences were observed in the comparison of knee flexor strength; moreover, there were differences between the compared teams at all tested angular velocities. These differences were found in both dominant and non-dominant limb. The differences between the compared groups at individual angular velocities were as follows (dominant leg: 11.11 %, 12.58 % and 13.16 %, non-dominant leg: 10.26 %, 16.55 % and 11.11 %). Cometti et al. (2001) reported significant differences in knee flexor strength between professional and amateur players, i.e. players of the second division. The knee flexor muscles play an important part during ball-striking in slowing down the extension of the leg but also during dynamic phases without the ball such as rapid acceleration (Lehance, Binet, Bury, & Croisier, 2009). One of the causes of better results of knee flexor strength is the fact that elite soccer players underwent a strength training controlled by a specialised fitness coach two-times a week while sub-elite professional soccer players only had one strength training session during a week plan. 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). The level of muscular strength of knee flexors in our players (both teams) was higher in comparison to young professional players (age 18.9 years) at all compared velocities (Daneshjoo, Rahnama, Mokhtar, & Yusof, 2013). In comparison to young elite players (U18 category) (Lehnert, Urban, Herbert, Procházka, & Psotta, 2011), elite soccer players achieved greater muscular strength of knee flexors at the lowest velocity (60°·s⁻¹) but at higher velocities our players achieved worse results. Also sub-elite professional soccer players achieved worse results in knee flexor strength in all tested velocities. Papaevangelou, Metaxas, Riganas, Mandroukas, and Vamvakoudis (2012) present insignificant differences in knee flexor strength between professional players and players of U21 category (the same club) at three angular velocities (60, 180 and 300 °·s⁻¹). The study and comparison of available literature indicate the need for more detailed analysis of results with respect to the following factors: number of strength training sessions within a micro-cycle, type of strength exercises, volume and intensity, type of the protocol used (holding the side bars vs. arms crossed on the chest) etc. Knee extensor strength at the lowest velocity was 3.18 ± 0.42 N-m·kg⁻¹ for dominant leg and 3.21 ± 0.34 N-m·kg⁻¹ for the non-dominant leg in the elite professional players while in the sub-elite professional players, the value for the dominant leg was 3.05 ± 0.26 N-m·kg⁻¹ and for the non-dominant leg: 3.01 ± 0.26 N-m·kg⁻¹. Knee extensor muscle strength in the dominant leg at the lowest velocity was not significantly different between the groups (p>0.05). Concerning other compared velocities, elite professional players achieved significantly higher values for both the dominant and non-dominant leg than sub-elite professional players. Menzel et al. (2013) reported higher values of knee extensor PTₑ₆₀ in professional players (n = 46) for the dominant leg 3.36 ± 0.51 N-m·kg⁻¹ and non-dominant leg 3.43 ± 0.57 N-m·kg⁻¹ in comparison to our teams. The difference between the limbs makes 2.05 % in favour of the non-dominant leg. The difference in our research is 0.94 % in Team 1 (in favour of the non-dominant limb) and 1.31 % Team 2 (in favour of the dominant limb). Also at a higher velocity (180 °·s⁻¹), Brazilian elite players achieved better results for the dominant leg by 3.00 % (compared to Team 1) and by 10.30 % (compared to Team 2) and for the non-dominant leg by 3.83 % (compared to Team 1) and 11.91 % (compared to Team 2). At the highest angular velocity (300°·s⁻¹), our players from both groups achieved worse results in comparison to values presented by Menzel et al. (2013). Knee extensor performance in the dominant leg was better by 3.45 % (compared to Team 1) and 12.07 % (compared to Team 2) and in the non-dominant leg 2.34 % (compared to Team 1) and 9.94 % (compared to Team 2). Our players (both teams) achieved better results in knee extensor muscle strength in comparison to professional players from the study by (Lehance et al., 2009). In the case of knee flexors, our players (Team 1) had a higher level (dominant leg: 11.22 %, non-dominant-leg: 7.69 %) and players from Team 2 produced the same force by the dominant leg 1.76 N-m·kg⁻¹ and lower strength (2.78 %) by the non-dominant leg (1.75 vs. 1.80 N-m·kg⁻¹). Rahnama, Reilly, Lees, and Graham-Smith (2003) reported the value PTₑ₆₀ = 3.10 ± 0.50 N-m·kg⁻¹ for amateur players (n = 13). Lower value of PTₑ₆₀ = 3.06 ± 0.44 N-m·kg⁻¹ is mentioned only by Lehance et al. (2009) in elite junior players (1st Belgian league) or PTₑ₆₀ = 2.98 ± 0.35 N-m·kg⁻¹ in professional players. Tournoy, Chollet, Leroy, Leger, and Beuret-Blanquart (2000) state an even lower value PTₑ₆₀ = 2.06 ± 0.08 N-m·kg⁻¹ in French amateur players (n = 21). Papaevangelou et al. (2012) reported insignificant differences in knee extensor strength between professional players and players of U21 category (the same club) at three angular velocities (60, 180 and 300 °·s⁻¹). Malý et al. (2011) reported insignificant differences in extensor strength between more and less successful soccer players. Cometti et al. (2001) presents insignificant differences in knee extensors between elite, sub-elite and amateur French soccer players in concentric contraction and even a higher value in favour of amateur players in eccentric contraction. Metaxas et al. (2009) did not find any difference in knee extensor strength at various angular velocities (60, 180, 300 °·s⁻¹) between 1st, 2nd, 3rd and 4th division. Oberg, Molier, Gillquist, and Ekstrand (1986) reported differences in concentric peak torque of the quadriceps muscles between the highest and lowest Swedish soccer division. They concluded that high-level soccer players had greater strength because training intensity...
increases with increasing level of competition. In our case, we deal with a professional team which dominated in domestic competition and qualified for 2nd round of qualification of Champions League. Many studies consider „high-elite“ players those playing the highest national competition or having the status of a professional player. Therefore, there may appear methodological problems with a comparison of the monitored groups and generalization of results.

**Bilateral asymmetries**

Results of our study revealed significantly higher values of the bilateral deficit in knee flexors compared to extensors. From the perspective of a comparison of the performance level, lower-level players had significantly greater strength asymmetry in knee extensors as well as flexors (Table 1). However, posthoc tests in individual angular velocities did not show any statistical differences but in the case of knee flexors there were differences up to 28.85 % (angular velocity of 180 °·s⁻¹). In the case of elite professional players, the bilateral deficit ranged between 5.89 – 9.19 % and in sub-elite players it ranged between 6.42 – 10.92 %. do Carmo et al. (2013) reported in professional Brazilian players (n = 164) knee extensor strength asymmetry 7.75 % and knee flexor asymmetry 8.10 %.

Limb dominance (laterality) did not have any significant effect on isokinetic muscular strength of lower limbs in the tested groups. When interpreting bilateral deficit results, it is necessary to assess them in terms of their dominance. Significant differences between the DL and NL during concentric contraction at a velocity of 60 °·s⁻¹ in adult elite athletes (Q:Q = 10.53 ± 9.44 %, H:H = 10.30 ± 5.69 %) were published by Jones and Bampouras (2010). Bilateral deficit higher than 10 % was detected between muscular strength of knee flexors in favour of the non-dominant limb in soccer players (Rahnama et al., 2005). Inter-individual assessment in elite professional players (n = 26) showed that in the case of knee extensors there was, at least at one of the tested velocities, strength asymmetry higher than 10 % in 13 players (50 %) and in knee flexors it was found in 16 players (62 %). In the group of sub-elite professional players (n = 24), 13 players (54 %) had strength asymmetry higher than 10 % in knee extensors and flexors. Rahnama et al. (2005) suggest that up to 68 % of soccer players had muscle asymmetries in extensors or flexors between the extremities higher than 10 % in at least one of the measurements of muscle strength.

Muscle bilateral asymmetries were found in at least one measurement in 50 % of players at a velocity of 60 °·s⁻¹ and in 75 % of players at a velocity 300 °·s⁻¹ (Malý, Zahálka, & Malá, 2010). Therefore, it is necessary to individually assess the bilateral ratio as high variability of results at all velocities (60,180 and 300 °·s⁻¹) in concentric contraction was found in the group assessment. More muscle imbalances were observed in knee flexors.

The bilateral ratio between muscle strength of knee extensors during concentric contraction is not significantly dependent on angular velocity (Malý et al., 2010). 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 %. Dauty, Potiron-Josse, and Rochcongar (2003) indicate that in the case of muscle strength asymmetries of knee flexors lower than 10 % we can exclude muscle injury of the particular muscle groups or after the injury the muscles have fully recovered and muscle strength can be fully produced. 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 4 players in both groups. All asymmetries were identified in knee flexors. In the case of one sub-elite professional player, his anterior cruciate ligament (ACL) tore without someone else’s fault (no contact) after two months from testing. The bilateral deficit of knee flexors of this player ranged between 14 – 19 % in disfavour of the injured limb while Q:Q ratio was only between 2 – 6 %. Bilateral (right vs. left) or unilateral (agonist – antagonist) comparison of muscle group strength may reveal potentially weak points, which increase the risk of injury of the athlete (Knapik et al., 1991; Lin et al., 2010). Ie Gall, Carling, Williams, and Reilly (2010) reported insignificant differences of knee flexor muscle strength (angular velocity of 60 and 240 °·s⁻¹) between international professional and amateur soccer players in three age categories, namely U14, U15 and U16. On the basis of these results we may assume that asymmetries which occur at higher age are caused by specific soccer uncompensated load which manifests as a maladaptation effect – strength asymmetry.

**Unilateral asymmetries**

A significant effect was found in the unilateral ratio of the lower limbs (H:Q) on the basis of comparison of the performance criterion when elite professional players achieved a higher H:Q ratio at all compared velocities for both the dominant and non-dominant leg. Along with increasing angular velocity also the level of H:Q elevated in both teams. Higher-performance players, in our study, achieved H:Q ratio 0.63 ± 0.09 at the lowest velocity and 0.65 ± 0.14 at the highest velocity for the dominant leg and 0.61 ± 0.07 and 0.65 ± 0.08 for the non-dominant leg. The second group achieved lower values (dominant leg: 0.58 ± 0.07 and 0.64 ± 0.08, non-dominant leg: 0.58 ± 0.06 and 0.61 ± 0.07). Our results are not consistent with the results of the previous study (Malý et al., 2011) when the authors found insignificant differences in H:Q ratio between more and less successful soccer teams. The reason may be the comparison of teams from one competition on the basis of their placement in the chart. However, the authors carried out the measurements only at two angular velocities, namely at 60 and 180 °·s⁻¹.
Cometti et al. (2001) reported significantly higher H:Q ratio in higher-performance players (1st league) in comparison to 2nd league players only at the lowest movement velocity of 60 °.s⁻¹ (p < 0.05). In our study, we detected significant differences at velocities of 60 and 180 °.s⁻¹ and insignificant at the velocity of 300 °.s⁻¹.

**Conclusion**

During the game, strength and power movements are accumulated on both lower extremities. This occurs in an asymmetrical manner and may lead to greater changes of muscle characteristics, strength asymmetries of lower extremities and myodynamic parameters. Our study indicated that more than 50% of players have at least one strength asymmetry regardless of their performance level. Significant differences were found in muscular strength of knee extensors and flexors in favour of elite professional players (especially at higher angular velocities) and greater asymmetries were observed in sub-elite professional players (H:Q ratio). In both groups, the greatest deficiencies were found in knee flexors regardless of the limb dominancy. 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. It also is important to see the results with respect to an individual player’s approach at several grades of angular velocity. 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 ASIMETRIČNOST SNAGE U ELITNIH I NEELITNIH PROFESIONALNIH NOGOMETAŠA

Sažetak
Svrha: Svrha ovog rada bila je usporedba parametara snage donjih ekstremiteta (ekstenzora i fleksora koljena) i njihove asimetrije (bilateralne i unilateralne) kod elitnih i neelitnih profesionalnih nogometaša. Materijal i metode: Komponiran je odabrani uzorak dvije profesionalne nogometne ekipa. Prva momčad (Team 1 – elitni profesionalci, n = 28, god. = 24.31 ± 4.79) bila je vodeća u prvoj češkoj ligi, a druga momčad (Team 2 – neelitni profesionalci, n = 24, god. = 26.19 ± 3.67) bila je vodeća momčad druge čaške lige. Najveći okretni moment (PT) i derivirani parametri (bilateralni odnos [Q:Q i H:H] and unilateralni odnos [H:Q]) bio je evaluiran korištenjem Cybex izokinetičkog dinamometra u tri kutne brzine (60, 180, 300 °·s⁻¹) za dominantnu (DL) i nedominantnu (NL) nogu za vrijeme fleksije (KF) i ekstenzije (KE) koljena u koncentričnim kontarkcijama. Four-way mixed ANOVA, studentov t-test i cohenov “d” index veličine efekta korišteni su za statističku analizu. Rezultati: Faktor P (izvedba) otkrio je značajan učinak na razinu izokinetičke snage donjih ekstremiteta kod nogometaša (F(1.596) = 91.74, p < 0.01, η² = 0.14). Faktori L (lateralnost) nisu pokazali značajan utjecaj na snagu bedrene musculature donjih ekstremiteta nogometaša (F(1.596) = 2.47, p > 0.05, η² = 0.01). Faktor testirane musculature grupa (KE, KF) pokazao je značajan efekt u odnosu na bilateralne razlike (F(1.288) = 11.13, p < 0.01, η² = 0.04). Post-hoc test također je pokazao značajno (p < 0.01) više vrijednosti bilateralnog deficita u KF u usporedbi sa KE. Začajan efekt je također pronađen u unilateralnom odnosu donjih ekstremiteta kod nogometaša (H:Q) na temelju uspoređenih kriterija izvedbe (F(1.288) = 15.51, p < 0.01, η² = 0.05) i brzine kutnog momenta (F(2.288) = 5.56, p < 0.01, η² = 0.04). Unilateralni odnos (H:Q) bio je značajno viši kod obje, dominantne i nedominantne noge u korist bolje izvedbe grupe Team-1 u odnosu na Team-2 (H:Q odnos dominantnih ekstremiteta: F(1.144) = 5.87, p < 0.05, η² = 0.04; nedominantnih ekstremiteta: F(1.144) = 11.21, p < 0.01, η² = 0.07). Rasprava i zaključak: Rezultati istraživanja sugeriraju da više od 50 % igrača ima najmanje jednu asimetriju snage neovisno o njihovoj razini izvedbe. Elitni profesionalci imaju izraženiji deficit snage u KF i KE, posebno kod veće kutne brzine. U vezi neelitnih igrača, pronađen je niži unilateralni H:Q odnos. Rezultati istraživanja pokazuju lošiju pripremu KF (izvedba i preventivna procjena) kod neelitnih nogometaša. Neprikladni učinci u terminima različitih oblika asimetrije tjelesne snage predstavljaju potencijalni rizik povrede igrača; dakle detektirane asimetrije trebaju biti sistematski kompenzirane odgovarajućim ciljanim specifičnim vježbama.

Ključne riječi: koljeno, ekstenzor, fleksor, asimetrija snage, nogomet, povrede, testiranje

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