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Ratios of torques of antagonist muscle groups in female soccer players

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Purpose: An increase in the value of the hamstring-to-quadriceps (*H*/*Q*) ratio with an increase in angular velocity may effectively prevent injuries of the back of the thigh. Previous studies have found that the conventional H/Q ratio was unaltered along with an increasing angular velocity in females. Therefore, this study aimed to investigate the relationships between the conventional H/Q ratio and angular velocity in a group of female soccer players. *Methods*: The study was carried out on a group of 16 female soccer players (age: 20.7 ± 3.9 years, body height: 166.1 ± 5.8 cm, body mass: 58.4 ± 6.2 kg, training experience: 8.8 ± 4.1 years). Measurements of peak torque of extensors and flexors of the knee joint under static conditions and under isokinetic conditions (at angular velocities of 30°/s, 60°/s, 90°/s and 120°/s) were carried out using a Biodex dynamometer. *Results*: There was a statistically significant increase in the conventional *H*/*Q* ratio with an increase in angular velocity. These differences occurred between measurements at angular velocities of 0°/s and 30°/s, and 30°/s and 60°/s. *Conclusions*: As previously found for males, an increase in conventional H/Q ratio with increased angular velocity was also present in this group of female players. This phenomenon should reduce the number of injuries of the muscles of back of the thigh. Coaches should pay attention to increasing the level of strength in the group of knee joint flexor muscles so as to make the value of the *H*/*Q* ratio appropriately high and increasing with increasing angular velocity.

Key words: *asymmetry, knee joint, hamstring-to-quadriceps ratio*

1. Introduction

Female soccer players are four to six times more prone to injuries of lower limbs than their male peers [10]. Regardless of gender, injuries are most frequent in the muscles of the back of the thigh and occur mainly without contact [9], [20]. This is caused by the explosive nature of such activities as kicking (shots), rapid starts, sprints or jumps [10], [14]. This type of injury may be caused by excessive asymmetry of antagonist muscle groups in the lower limbs. For example, an injury might occur during quick extension of the lower limb in the knee joint (e.g., during kicking the ball) when the group of antagonist muscles does not counteract with effective eccentric activity to slow down or stop the movement [4], [17].

One of the measures that might prevent injuries in lower limbs is to control the ratio of the torques produced by extensor and flexor muscle groups in the knee joint. This is achieved by manipulating the hamstring-to-quadriceps (*H*/*Q*) ratio [2], [6], [11]. The commonly used conventional *H*/*Q* ratio represents the ratio of concentric hamstrings peak torque during lower limb flexion to concentric quadriceps peak torque during lower limb extension [8]. The functional *H*/*Q* ratio, by contrast, is a measure of the isokinetic eccentric peak torque of the hamstrings relative to the isokinetic concentric peak torque of the quadriceps during lower limb extension at equivalent angular velocities [1]. The standards for evaluation of the relation between torques measured under static and isokinetic conditions (conventional *H*/*Q* ratio) were proposed by Wit et al. [23]. Percentage standards of the conventional *H*/*Q* ratio for

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measurements under isokinetic conditions were developed taking into account that the proportion of torques in the extensor and flexor muscle groups was independent of angular velocity. The lack of correlation between angular velocity and the conventional *H*/*Q* ratio was demonstrated by Wit et al. [23], [24].

The most recent scientific reports, however, have described cases where the value of the *H*/*Q* ratio (both conventional and functional) changed with angular velocity [4], [11], [12], [19]. It is expected to see increased functional *H*/*Q* ratio with increasing angular velocity, resulting purely from physiological factors. Eccentric contractions indeed do increase or maintain the torque value at increasing angular velocity, whereas concentric contractions decrease torque value at increasing angular velocity [12]. But an increase in the conventional *H*/*Q* ratio has mainly been observed with an increase in angular velocity for male subjects. By contrast, this tendency has not been found in female groups [11].

Wit et al. [23] adopted the values of 57–75% for isokinetic conditions and 34–61% for static conditions as standard levels of the conventional *H*/*Q* ratio. However, values greater than 80% should not negatively affect health nor increase injury risk, compared to values lower than the standard. An increase in the strength of the flexors of the knee joint compared to extensors (even up to the proportion of 1:1), is recommended for athletes after previous injuries of the lower limbs [4]. Schiltz et al. [18] examined a group of basketball players after injuries of the lower limbs and found larger values of the conventional *H*/*Q* ratio compared to the group without previous injuries. Furthermore, Kim and Hong [13] demonstrated that athletes who practiced football or basketball and had conventional *H*/*Q* ratios over 60% suffered fewer non-contact injuries of the lower limbs. Therefore, it is essential that the conventional *H*/*Q* ratio should be sufficiently high (over 60%). An increase in conventional *H*/*Q* ratio with an increase in angular velocity is thus very beneficial and likely to protect an athlete during sports competition, when movements are performed at peak velocity. An appropriate ratio between the strength of agonist and antagonist muscle groups also improves movement efficiency [21].

An increase in conventional *H*/*Q* ratio (equivalent to reduced asymmetry in antagonist muscle groups of the knee joint) with increased angular velocity is likely to effectively prevent injuries of the back of the thigh (including those that occur without contact). Therefore, the study aimed to investigate relationships between the conventional *H*/*Q* ratio and angular velocity in a group of female soccer players. The authors attempted to answer the question whether, in accordance with some previous reports, the conventional *H*/*Q* ratio would remain unaltered with the increase in angular velocity in a group of female soccer players.

2. Materials and methods

The study was carried out on a group of 16 female soccer players from the KS AZS Wrocław soccer club (national level). The study group was characterized by the following mean (±SD) values: body height 166.1 ± 5.8 cm, body mass 58.4 ± 6.2 kg, age 20.7 ± 3.9 years. Training experience was 8.8±4.1 years. The measurements were performed in the Biomechanical Analyses Laboratory (with PN-EN ISO 9001:2009 certification) of the University School of Physical Education in Wrocław, Poland. Before the tests, each participant was familiarized with the research goals (the tested subjects were already familiarized with the measuring equipment during their training cycle), informed about the purpose of the study and provided written consent for the tests. The study design was approved by the Senate's Research Bioethics Committee, and the procedures complied with the Declaration of Helsinki regarding human experimentation.

Measurements of peak torques of extensors and flexors of the knee joint under static conditions (at 75° and 30°, respectively; 0° at the knee joint was considered to be a full extension) and isokinetic conditions (at angular velocities ω of: 30°/s, 60°/s, 90°/s and 120°/s) were done using a Biodex System 4 Pro dynamometer. Angular velocities, at which the measurements were performed, were intentionally kept relatively low to avoid measurement errors typical to this type of equipment [25]. Biodex 4 Pro is a measuring system for assessing the level of muscle torque and consists of a computer with software, chair and dynamometer. The subject, after sitting on the test armchair, was immobilized with stabilizing belts on the chest and thighs in order to stabilize the neighbouring body segments. Such positioning was aimed at elimination of the effect of other muscle groups on the value of muscular forces in the area of the knee joints. The rotational axis of the measurement head was adjusted individually to each subject so that it was in line with the transverse axis of the knee joint, located 2.5 cm over the joint's gap. Measurements were done for the right and left lower limb separately and the isokinetic range of movement was 90°. One trial included three full cycles of extension and flexion. For each lower extremity two trials (for each angular velocity) were carried out, and the trial with the

higher value (a single highest value found within the three extension-flexion cycles) of the peak torque was selected for further analysis. The sequence of measurements was randomized. The peak torque value was chosen only from those torque values that corresponded to angular velocity equal to the set value that defined the measuring conditions, so the transients were thus excluded. Furthermore, the value of the joint angle for peak torque was recorded.

Asymmetry of torques of agonist and antagonist muscle groups actuating the knee joint was evaluated as the conventional hamstring-to-quadriceps ratio (*H*/*Q* ratio) using the method described by Wit et al. [23]:

$$\text{H/Q ratio} = \frac{M_f}{M_e} \cdot 100\%$$

where M_f denotes the concentric peak torque value of knee joint flexors, and M_e is the concentric peak torque value of extensors of the same joint.

The significance of differences between measurements was evaluated with ANOVA for repeated measures and Bonferroni *post hoc* test with the use of Statistica 10 software package. The significance level was set at $p = 0.05$.

3. Results

In Tables 1 and 2 the values of torques of extensors and flexors of the knee joints found for the female soccer players are presented. A statistically significant ($p < 0.05$) increase in the conventional *H*/*Q* ratio with the increase of angular velocity at the knee joint was observed in the group studied. The significant differences in conventional *H*/*Q* ratio were between angular velocities of 0 and 30°/s and between angular velocities of 30°/s and 60°/s. These differences occurred for the right leg, left leg and summed across both lower limbs. The above relationships are illustrated in Fig. 1.

Table 1. Mean values (±SD) of peak torque of the knee joint extensors (M_e) in female soccer players

ω (°/sec)	Static conditions	30	60	90	120
Right lower limb (Nm)	218.1 ± 45.3	165.6 ± 24.6	146.5 ± 21.6	132.1 ± 18.6	121.3 ± 18.3
Left lower limb (Nm)	222.7 ± 46.8	173.3 ± 35.1	150 ± 25.6	134.3 ± 24.6	123.3 ± 21.9
Total of lower limbs (Nm)	440.8 ± 89.4	338.9 ± 56.9	296.5 ± 45.7	266.3 ± 41.4	244.6 ± 39.4

Table 2. Mean values (±SD) of peak torque of the knee joint flexors (M_f) in female soccer players

ω (°/sec)	Static conditions	30	60	90	120
Right lower limb (Nm)	101.5 ± 19.4	85.4 ± 20	82.8 ± 16.4	76.2 ± 15.3	70.6 ± 16.9
Left lower limb (Nm)	90.9 ± 18.2	84.4 ± 18.1	80.8 ± 15.5	75.7 ± 15.4	68.5 ± 16.3
Total of lower limbs (Nm)	192.5 ± 36	169.8 ± 36.6	163.6 ± 30.8	151.9 ± 29.4	139 ± 32.7

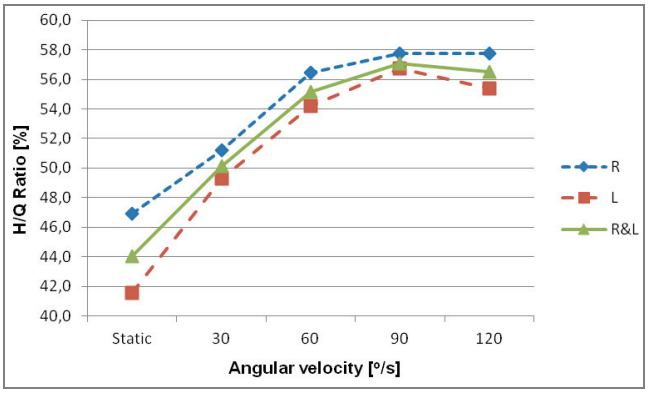

Fig. 1. Value of the conventional *H*/*Q* ratio as a function of angular velocity for right (R), left (L) and both lower limbs (R & L)

4. Discussion

The values of conventional *H*/*Q* ratios, we measured under static conditions, were near to recommended standards for the conventional *H*/*Q* ratio developed by Wit et al. [23]. Furthermore, the conventional *H*/*Q* ratios measured under isokinetic conditions for all the selected angular velocities indicated extensors relatively stronger than flexors in both lower limbs. Excessively high values of torques of extensors of the knee joint, compared to flexors, may increase the risk of non-contact injury within the rear muscle group of the thigh. Therefore, coaches should pay more attention to improvement of strength in the muscle group of knee joint flexors [6], [9]. Positive effects on the value (increase) of the conventional *H*/*Q* ratio have been observed during plyometric training [10]. Disproportion in torque of agonist and antagonist muscle groups has been observed in male soccer players [5], [16]. However, there are groups of soccer players for which the value of conventional *H*/*Q* ratio remains within the recommended standard [4].

Comparison of the value of the conventional *H*/*Q* ratio in soccer players with those found for other disciplines is difficult due to the use of different an-

gular velocities during measurement. In a group of female judo contestants evaluated by Wit et al. [24], the conventional *H*/*Q* ratios were within the standard or favoring flexors depending on angular velocity (from 100°/s to 300°/s). Furthermore, a group of basketball players studied by Buśko [3] achieved *H*/*Q* ratios (measured under static conditions) that suggested a strong advantage of flexors. The opposite was found in a study by Drid et al. [7] of female judo contestants who were characterized by a substantial advantage of extensors. Therefore, specific laboratory measurements of muscle torques offer opportunities for diagnosis of irregularities which might lead to injuries [15].

The study showed that an increase in the conventional *H*/*Q* ratio along with an increase in angular velocity may also occur in female groups, contrary to previous reports [11]. This should reduce the number of injuries in the muscles of the back of the thigh among female players. Due to different training regimes, athletes of different sports are unique, so that relationships known for the general population do not necessarily apply to them [11]. The increase in the conventional *H*/*Q* ratio along with increase in angular velocity observed in this group of female soccer players may suggest a substantial masculinization of lower limbs in this group, with properties similar to those observed in male lower limbs [22]. Soccer is a sport with a predominance of explosive movements that require substantial speed and strength abilities [14].

The relationship between the conventional *H*/*Q* ratio and angular velocity results in the curves presented in Fig. 2. The slope of the curve for torques of extensors of the knee joint with respect to angular velocity is greater than the slope of the curve for flexors of the knee joint. Therefore, an increase in angular velocity causes peak torque in the extensors to decrease more rapidly, compared to the flexor group. The knee extensor torque decrements between consecutive angular velocities were significantly larger than those of the knee flexors. Within either muscle group, the torques developed at consecutive angular velocities differed significantly. Furthermore, decreasing torque at the knee joint is accompanied by changes in the joint angle at which the peak torque is reached. The value of this angle decreases for the extensor muscles (Fig. 3), and increases for flexors (Fig. 4). Therefore, the values of peak torque for extensors and flexors of the knee joint during explosive movements of the lower limb, which are performed at a substantial angular velocity, are nearly balanced and occur at similar value of the knee joint angle, which allows for effective braking of the movement.

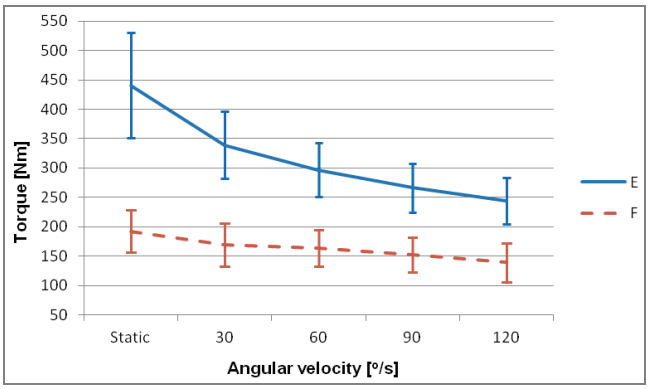

Fig. 2. Mean (±SD) values of torque (total of both lower limbs) as a function of angular velocity for extensors (E) and flexors (F) of the knee joint

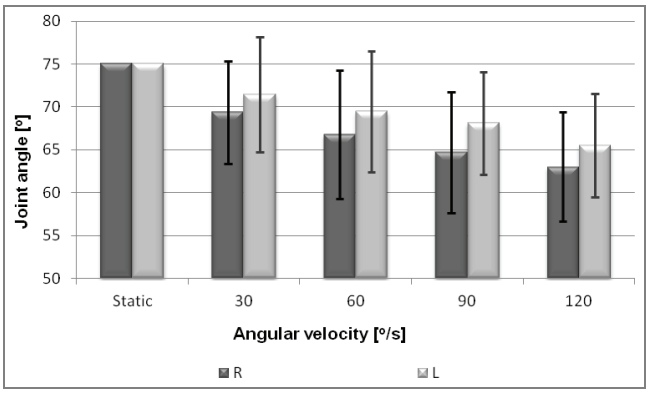

Fig. 3. Joint angle at which peak torque of knee joint extensors is developed as a function of angular velocity for right (R) and left (L) lower limb

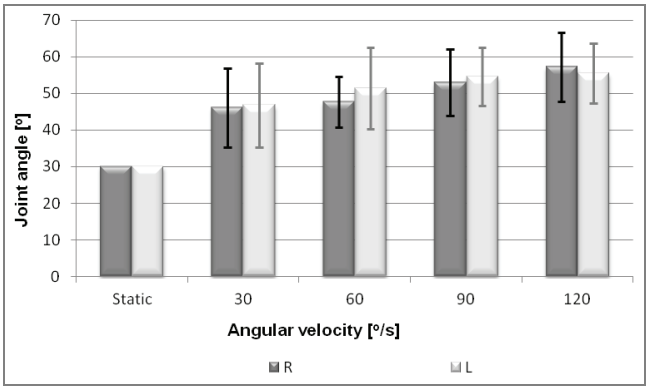

Fig. 4. Joint angle at which peak torque of knee joint flexors is developed, as a function of angular velocity for right (R) and left (L) lower limb

5. Conclusions

1. An increase in the conventional *H*/*Q* ratio with an increase in angular velocity was found in female soccer players, contrary to previous reports. This

should reduce the risk of non-contact injury in the muscles of the back of the thigh in the group studied.

2. Coaches should pay attention to increasing the level of strength in the group of knee joint flexor muscles so as to make the value of the *H*/*Q* ratio appropriately high and increasing with increasing angular velocity.
3. Significant differences in the value of the conventional *H*/*Q* ratio were found between measurements performed under static and isokinetic conditions at the angular velocity of 30°/s and under isokinetic conditions at the angular velocities of 30°/s and 60°/s for the right, left and both lower limbs.
4. With the increase in angular velocity, peak torque in the muscle group of extensors of the knee joint decreased more rapidly than peak torque in the flexor group. This tendency is statistically significant for all selected angular velocities.
5. A decline in the value of muscle torque developed at the knee joint along with an increase in angular velocity was accompanied by changes in the joint angle at which peak torque was reached. The value of this angle decreased for extensors, but it increased for flexors.

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References

[1] AAGAARD P., SIMONSEN E.B., MAGNUSSON S.P., LARSSON B., DYHRE-POULSEN P., *A new concept for isokinetic hamstring:quadriceps muscle strength ratio*, Am. J. Sport. Med., 1998, 26(2), 231–237.

[2] AKAGI R., TOHDOH Y., TAKAHASHI H., *Strength and size ratios between reciprocal muscle groups in the thigh and lower leg of male collegiate soccer players*, Clin. Physiol. Funct. I., 2014, 34(2), 121–125.

[3] BUŚKO K., *Training-induced changes in the topography of muscle torques and maximal muscle torques in basketball players*, Biol. Sport, 2012, 29(1), 77–83.

[4] CHEUNG R.T.H., SMITH A.W., WONG D.P., *H:Q ratios and bilateral leg strength in college field and court sports players*, J. Hum. Kinet., 2012, 33, 63–71.

[5] DANESHJOO A., RAHNAMA N., MOKHTAR A.H., YUSOF A., *Bilateral and unilateral asymmetries of isokinetic strength and flexibility in male young professional soccer players*, J. Hum. Kinet., 2013, 36, 45–53.

[6] DERVIŠEVIĆ E., HADŽIĆ V., *Quadriceps and hamstrings strength in team sports: basketball, football and volleyball*, Isokinet. Exerc. Sci., 2012, 20(4), 293–300.

[7] DRID P., OSTOJIC S.M., VUJKOV S., PURKOVIC S., TRIVIC T., STOJANOVIC M., *Physiological adaptations of a specific muscle-imbalance reduction training programme in the elite female judokas*, Arch. Budo., 2011, 7(2), 61–64.

[8] DVIR Z., EGER G., HALPERIN N., SHKLAR A., *Thigh muscle activity and anterior cruciate ligament insufficiency*, Clin. Biomech., 1989, 4(2), 87–91.

[9] HÄGGLUND M., WALDÉN M., EKSTRAND J., *Injuries among male and female elite football players*, Scand. J. Med. Sci. Spor., 2009, 19(6), 819–827.

[10] HEWETT T.E., LINDENFELD T.N., RICCOBENE J.V., NOYES F.R., *The effect of neuromuscular training on the incidence of knee injury in female athletes: a prospective study*, Am. J. Sport. Med., 1999, 27(6), 699–706.

[11] HEWETT T.E., MYER G.D., ZAZULAK B.T., *Hamstrings to quadriceps peak torque ratios diverge between sexes with increasing isokinetic angular velocity*, J. Sci. Med. Sport, 2008, 11(5), 452–459.

[12] JENKINS N.D.M., HAWKEY M.J., COSTA P.B., FIDDLER R.E., THOMPSON B.J., RYAN E.D., SMITH D., SOBOLEWSKI E.J., CONCHOLA E.C., AKEHI K., CRAMER J.T., *Functional hamstrings: quadriceps ratios in elite women's soccer players*, J. Sport. Sci., 2013, 31(6), 612–617.

[13] KIM D., HONG J., *Hamstring to quadriceps strength ratio and noncontact leg injuries: a prospective study during one season*, Isokinet. Exerc. Sci., 2011, 19(1), 1–6.

[14] KOTZAMANIDIS C., CHATZOPOULOS D., MICHAILIDIS C., PAPAIAKOVOU G., PATIKAS D., *The effect of a combined high--intensity strength and speed training program on the running and jumping ability of soccer players*, J. Strength Cond. Res., 2005, 19(2), 369–375.

[15] OLIVEIRA L.F., VERNEQUE D., MENEGALDO L.L., *The influence of aging on the isometric torque sharing patterns among the plantar flexor muscles*, Acta Bioeng. Biomech., 2017, 19(1), 41–45.

[16] PIETRASZEWSKI B., ZAWADZKI J., PIETRASZEWSKA J., BURDUKIEWICZ A., *Body composition and muscle torques of lower limbs*, Biol. Sport, 1997, 14(suppl.7), 104–107.

[17] RUAN M., ZHANG Q., WU X., *Acute effects of static stretching of hamstring on performance and anterior cruciate ligament injury risk during stop-jump and cutting tasks in female athletes*, J. Strength Cond. Res., 2017, 31(5), 1241–1250.

[18] SCHILTZ M., LEHANCE C., MAQUET D., BURY T., CRIELAARD J.-M., CROISIER J.-L., *Explosive strength imbalances in professional basketball players*, J. Athl. Training, 2009, 44(1), 39–47.

[19] STRUZIK A., PIETRASZEWSKI B., *Lower limb torque asymmetry in judo competitors evaluated in isokinetic conditions*, Med. Sport, 2015, 68(4), 639–650.

[20] THELEN D.G., CHUMANOV E.S., HOERTH D.M., BEST T.M., SWANSON S.C., LI L., YOUNG M., HEIDERSCHEIT B.C., *Hamstring muscle kinematics during treadmill sprinting*, Med. Sci. Sport. Exer., 2005, 37(1), 108–114.

[21] TRZASKOMA Z., *Relations between the flexors-to-extensors ratios of lower limbs and trunk, and maximal power output*, Biol. Sport, 1998, 15(suppl.8), 154–160.

[22] WILIŃSKI W., *Gender identity in female football players*, Hum. Mov., 2012, 13(1), 40–47.

[23] WIT A., ELIASZ J., GAJEWSKI J., JANIAK J., JASZCZUK J., TRZASKOMA Z., *Ratio of peak torque of knee flexors and extensors in judo*, [in:] R. Będziński, L. Jankowski, J. Filipiak, P. Modzel (Eds.), Biomechanika '94. XII Szkoła Biomechaniki, Wrocław–Szklarska Poręba, 20–23 października 1994, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, 1994, 321–324.

[24] WIT A., TRZASKOMA Z., ELIASZ J., GAJEWSKI J., JANIAK J., *Peak torque-velocity and power-velocity relationships during the knee joint motion in male and female judoists*, Biol. Sport, 1993, 10(4), 257–266.

[25] ZAWADZKI J., BOBER T., SIEMIEŃSKI A., *Validity analysis of the Biodex System 3 dynamometer under static and isokinetic conditions*, Acta Bioeng. Biomech., 2010, 12(4), 25–32.