ISOKINETIC PERFORMANCE IN ELITE VOLLEYBALL AND BASKETBALL PLAYERS

Belgin Bamaç[1], Tuncay Çolak[1], Aydın Özbek[1], Serap Çolak[2], Yezdan Cinel[2] and Özlem Yenigün[2]

[1]Kocaeli University, Faculty of Medicine, Department of Anatomy, Kocaeli, Turkey
[2]Kocaeli University, School of Physical Education and Sport, Kocaeli, Turkey

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Abstract:

The aim of this study was to determine and compare the maximal voluntary peak torque of the hamstring and quadriceps muscles, and the torque ratio between these muscles in volleyball and basketball players across a spectrum of speeds in their dominant legs. Twenty male volleyball players, 20 male basketball players, and 20 controls were evaluated using an isokinetic dynamometer at angular velocities of 60º, 180º and 300°s^{-1}. No significant quadriceps and hamstring muscles concentric peak torque was found between volleyball and basketball players with the exception of quadriceps at 300°s^{-1} (volleyball: 139.9±0.7 Nm, basketball: 117.2±1.9 Nm). The mean hamstring/quadriceps muscles (H/Q) ratios at 60°s^{-1} were similar to each other. No significant differences were found between volleyball and basketball players for H/Q muscles ratio at 180°s^{-1}. Volleyball players demonstrated higher differences compared to the basketball players and control groups only at 300°s^{-1} (p=.001 and p=.000, respectively). Our data suggest that the sport's demands seem to influence isokinetic concentric H/Q ratio.

Key words: *basketball, concentric strength, isokinetic, dynamometer, hamstring muscles, quadriceps, volleyball*

Introduction

Muscular imbalance between the agonist and antagonistic muscles has been suggested as a possible cause of sports-related injuries (Grace, 1985; Aagaard et al., 1997; Söderman, Alfredson, Pietila, & Werner, 2001; Devan, Pescatello, Faghri, & Anderson, 2004; Magalhaes, Oliviera, Ascensao, & Soares, 2004). One of the most commonly used methods to assess muscle strength balance between antagonist/agonist muscles is isokinetic testing (Calmes & Minaire, 1995). Isokinetic testing can be used to evaluate quadriceps and hamstring muscle strength, providing a determination of the magnitude of torque generated and subsequently, the hamstring to quadriceps (H/Q) muscles strength ratio. The H/Q isokinetic peak torque ratio has been used to assess the functional ability of the knee and muscle balance (Holmes & Alderink, 1984; Grace, 1985; Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1995). It has been expressed as concentric hamstring to quadriceps muscles strength (Aagaard et al., 1997; Rosene, Fogarty & Mahaffey, 2001; Söderman et al., 2001) and recently as eccentric hamstring to concentric quadriceps muscles strength (Aagaard, Simonsen, Magnusson, Larsson, & Dhyre-Poulsen, 1998; Coombs & Garbutt, 2002). The H/Q muscles ratio may reflect a predisposition to injury (Knapik, Bauman, Jones, Haris, & Vaughan, 1991; Aagaard et al., 1997; Devan et al., 2004). In a study of 146 female soccer players, Söderman et al. (2001) demonstrated that concentric action is related to a higher risk of traumatic leg injuries. When the knee is injured, the H/Q muscles ratio is often used as a rehabilitative goal due to the importance of the flexor-extensor strength balance in overall knee stabilization (Holm, Ludvingsen, & Sten, 1994).

It is known that the sport's specific demands could have an important role in an athlete's profile (Magalhaes et al., 2004), and the ratio between maximal antagonist/agonist torques are related to several specific sports demands (Calmes & Minaire, 1995). Specific training adaptations that produce similar H/Q muscles ratios among different sports have been reported before (Zakas, Mandroukas, Vamvakoudis, Christoulas, & Aggelopoulou, 1995; Rosene et al. 2001). However, Read & Bellamy (1990) found significant differences in the H/Q muscles ratios among tennis, squash, and track athletes. Magalhaes et al. (2004) noted differences in the H/Q muscles ratio among soccer and volleyball players. In each case, the authors attributed the findings to training adaptations acquired by the subjects for their respective sports (Rosene et al., 2001).

Volleyball and basketball are two games with different technical skills and different training and playing procedures. Quadriceps and hamstring muscle groups are involved in several important motor abilities such as running and jumping in volleyball and basketball. The aim of this study was to determine and to compare the maximal voluntary peak torques of the hamstring and quadriceps muscles, and the torque ratio between these muscles in volleyball and basketball players for their dominant legs.

Methods

Subjects

The study group consisted of 20 male volleyball players (age: 19.55±.5 years; weight: 79.4±2.1 kg; height: 185.2±1.6 cm) and 20 male basketball (age: 23.6±.7 years, weight: 84.7±2.9 kg, height: 188.2±1.9 cm). They had been active in high-peformance volleyball and basketball (second highest division in the country). The control group consisted of 20 non-active males (age: 21.1± .4 years; weight: 65.1±1.5 kg; height: 174.3±.4 cm). They were derived from a random selection of students from the School of Medicine and had not been participating in any kinds of sports activity. Body weight and height were measured using standardized equipment.

Each subject was informed of the testing procedures, and then their written informed consent was obtained. The project was approved by the Ethical Research Committee of Kocaeli University.

Before the initiation of the study, the subjects were asked to indicate on a questionnaire whether they had any musculoskeletal pain, discomfort, or known injury in a lower extremity. Inclusion criteria were (a) having no history of any lower extremity injury in the preceding year before volunteering to participate in the study, (b) having no history of knee ligament sprain or knee surgery.

Isokinetic Testing

Maximal gravity corrected concentric peak torque was obtained for the knee extensors (quadriceps) and flexors (hamstrings) during isokinetic knee joint movement at angular velocities of 60, 180 and 300 degrees $x^{s(-1)}$. The two parameters studied in this investigation were the peak torque (PT) and hamstring/quadriceps muscles (H/Q) ratio. Muscle torques of the quadriceps and hamstring muscle groups were measured with a Biodex dynamometer (System 3 Dynamometer; Biodex Medical System, Inc, Shirley, NY). Only the dominant leg was evaluated. Leg dominance was identified by asking which leg was habitually used for kicking a ball.

The first author's primary responsibility was isokinetic testing instruction. Throughout the study, all tests were done by the same investigator.

Before the testing procedure, all the participants performed conditioning exercises and stretching of the lower extremities to warm up. The subjects were seated on the dynamometer chair and secured to the apparatus with straps across the chest and thigh with a 60º hip angle. The dynamometer axis of rotation was aligned with the knee joint, set at 0-90º. The first author instructed the athlete to extend and flex the knee at full force throughout the test. The subjects were allowed to view the Biodex computer monitor, and standardized verbal instructions and encouragement were provided.

The subjects were allowed three submaximal contractions of the quadriceps and hamstring muscle groups at the beginning of the test to acquaint themselves with the test condition. Then, they were given five maximal contractions at $60°s^{-1}$, 10 maximal contractions at $180°s^{-1}$, and 15 maximal contractions at $300°s^{-1}$ for each test condition. The highest peak torque found during all the repetitions was recorded for data analysis. Between each velocity test, the subjects were allowed to rest for one minute. The most frequently reported strength ratio of the muscles of the knee has been the concentric hamstring-quadriceps muscles ratio (Hcon/Qcon) (Coombs & Garbutt, 2002). The hamstring/quadriceps muscles strength ratio was calculated by dividing the maximal knee flexor (hamstring muscle) moment by the maximal knee extensor (quadriceps) moment measured at identical angular velocity in concentric mode.

Peak torque (Nm) values of the quadriceps and hamstring muscles concentric torque and the ratio between concentric hamstring and quadriceps muscles peak torque values were used in the statistical analyses.

Statistical analyses

The SPSS package (SPSS for Windows, version 11.0, SPSS, Chicago, IL, USA) for personal computers was used for the statistical analyses. The mean and standard deviation values were calculated for all the parameters used.

The means of the variables for all three groups were compared. The variables compatible with the normal distribution were evaluated by one-way analyses of variance (ANOVAs), and those that were not were evaluated by Kruskal-Wallis ANOVA. In the one-way ANOVA the Tukey honestly significant difference (HSD) was used as a *post-hoc* test. The group with a difference in Kruskal-Wallis ANOVA was identified by the Mann-Whitney U test.

Results

We used the mean peak strength of flexion and extension at concentric contractions at speeds of 60°s^{-1}, 180°s^{-1}, and 300°s^{-1} in the knee of all the athletes and controls (Table 1). In all the test velocities, both quadriceps and hamstring muscles concentric peak torque were significantly higher in volleyball and basketball players than in the controls. There were no significant differences between the volleyball and basketball players with respect to quadriceps and hamstring muscles concentric peak torque at 60°s^{-1} and 180°s^{-1} . However, a high level of concentric knee extension strength was observed for the volleyball players compared to the basketball players at 300°s^{-1} (p=.002).

The mean H/Q muscles ratios at 60°s^{-1} were similar to each other (Table 2). The values of the ratio of H/Q muscles were .46±.41; .49±.14, and .45±.11 in 60°s^{-1} for the volleyball players, basketball players and the controls, respectively.

The volleyball players presented lower H/Q muscles ratio at the speed of 180°s^{-1}. The mean H/Q muscles ratios for volleyball players, basketball players and controls were .51±.16; .58±.12 and .59±.14, respectively. In the 180°s^{-1} test, the H/Q muscles ratios revealed significant differences between the volleyball players and the controls (p=.025). However, no significant differences were found between the basketball players and the controls (p=.953). The H/Q muscles ratios also revealed no significant differences between the volleyball and basketball players at 180°s^{-1} (p=.051), (Table 2).

The data concerning H/Q muscles ratio between the volleyball players and basketball players showed significant differences only at 300°s^{-1}, volleyball players having a higher difference compared with the basketball players and the controls (p=.001 and p=.000, respectively). However, there were no statistically significant differences between the basketball players and the controls (p=.758). The mean H/Q muscles ratios for the volleyball players, basketball players and the controls were .56±.31, .71±.1, and .69±.18, respectively (Table 2).

Table 1. Hamstring and quadriceps muscles peak torques (Nm) evaluated at different angular velocities (values are means and standard deviations).

Velocity °s^{-1}		Volleyball (N=20)	p* value	Basketball (N=20)	p* value	Controls (N=20)
60	H	127.4±.4*	.000	124.6±1.5*	.000	79.9±.6
	Q	247.3±.6*	.000	246.5±.5*	.000	174.3±.9
180	H	88.1±.8*	.000	93.8±.7*	.000	71.0±.4
	Q	172.5±.7*	.000	159.6±1.2*	.000	115.1±.9
300	H	82.8±1.2*	.000	94.1±0.2*	.000	70.0±.1
	Q	139.9±.7*Δ	.000	117.2±1.9*Δ	.000	93.1±.2

* Significant differences (volleyball players vs controls and basketball players vs controls).
H: hamstring muscles, Q: quadriceps.
Δ Significant differences between volleyball and basketball players(p=.002).

Table 2. The mean H/Q muscles ratios

Velocity °s^{-1}	p* value	Volleyball (N=20)	pΔ value	Basketball (N=20)	p+ value	Controls (N=20)
60	>.05	.46±.41	>.05	.49±.14	>.05	.45±.11
180	.051	.51±.16	.025	.58±.12	.953	.59±.14
300	.001	.56±.31	.000	.71±.1	.758	.69±.18

* P value for differences between volleyball players and basketball players.
Δ P value for differences between volleyball players and controls.
\+ P value for differences between basketball players and controls.

Discussion and conclusions

The results reported here showed that there were significant differences between the volleyball and basketball players at 300°s^{-1}, although no significant differences were found at 60°s^{-1} and 180°s^{-1} for the H/Q muscles ratio. Some studies have found differences in H/Q muscles ratio between different types of sports (Read & Bellamy, 1990; Magalhaes et al., 2004) unlike others (Holm et al., 1994; Rosene et al., 2001). The authors attributed the findings to training adaptations in each case. Magalhaes et al. (2004) found that at 90°s^{-1}, volleyball players presented lower H/Q muscles ratio than did soccer players. They suggested that this low H/Q muscles ratio found in volleyball players could contribute to enhanced knee injury susceptibility, with particular emphasis on the tensional stress on the anterior cruciate ligament (ACL) due to decreased joint stabilizing strength.

The hamstring muscles play a key function in maintaining knee joint stability (Coombs & Garbutt, 2002). It has been suggested that the role of the hamstring muscles during leg extension is to assist the anterior cruciate ligament in preventing anterior tibial drawer forces. Tensile stress on the ACL is significantly reduced when the hamstring and the quadriceps muscles are co-active during extension, compared to when quadriceps are active alone (More et al., 1993). The H/Q muscles ratio may reflect a predisposition to injury (Knapik et al., 1991; Croce, Pitetti, Horvat, & Miller, 1996; Söderman et al., 2001). This predisposition may result from decreased antagonist hamstring muscles co-activation during extension loads (Barata et al., 1998). There seems to be little consensus of a normative value for conventional H/Q muscles ratio although .6 appears to have gained some general acceptance (Coombs & Garbutt, 2002) and is frequently used as an injury prevention and rehabilitation tool (Kannus, 1994; Coombs & Garbutt, 2002).

In this research, we found that a highly developed quadriceps muscle contributes to decreased antagonist hamstring muscles co-activation in volleyball players. The mean quadriceps peak torque was found to be significantly higher than in the basketball players and in the controls as shown in Table 1. The volleyball players also presented a lower H/Q muscles ratio than the basketball players and the controls at 300°s^{-1} due to exacerbated quadriceps strength when related to hamstring muscles strength. This functional imbalance could be a specific volleyball adaptation or/and insufficient hamstrings compensatory strength training. Although the sports represented in our study (volleyball and basketball) require similar movements (running, jumping, acceleration and deceleration) different training skills may be responsible for the differences in the H/Q muscles ratios among the sports examined.

The relationship between lower H/Q muscles ratio and knee injury risk has been demonstrated through the studies of Söderman et al. (2001) in soccer players, Knapik et al. (1991) in collegiate athletes, and Devan et al. (2004) in hockey, soccer, and basketball players. In volleyball, generally the knee injuries are caused by frequent jumps with loss of balance and a consequent one-footed landing (Ferreti, Papandrea, & Conteduca, 1990; Kovacs et al., 1999). Quadriceps activity was higher for single-footed landings while hamstring muscles activity did not change (Tillman, Criss, Brunt, & Hass, 2004). Reduced function of the antagonist hamstring muscles due to activities that emphasize loads on the knee extensors may result in muscular imbalances between the hamstring muscles and quadriceps; thereby, possibly predisposing athletes to injury (Barata et al., 1998). The data presented in this study, despite the absence of differences in H/Q muscles ratio at 60°s^{-1} and 180°s^{-1}, in cotrast to those at 300°s^{-1}, might suggest that volleyball players are more prone to injury than basketball players. Although volleyball and basketball require similar movements, Tillmann et al. (2004) stated that identifying jumping and landing techniques varies from sport to sport and from person to person. De Vita & Skelly (1992) reported that landing technique has significant implications on the kinematics of the patterns of the lower extremity muscle activation. In order to decrease the risk of injury as a result of muscular imbalance, attention must be given to proper muscle balance between hamstring and quadriceps muscles. We recommend that male volleyball players put additional effort into hamstring muscles exercises that could increase the H/Q muscles ratio.

We found no differences in the H/Q muscles ratio between the basketball and volleyball players at 60°$s^{-1}$and 180°s^{-1}. Zakas et al. (1995) reported no significant differences in the H/Q muscles ratio among different divisions of basketball and soccer players at 60°s^{-1} and 180°s^{-1}. Rosene et al. (2001) also reported no differences in the H/Q muscles ratios among athletes in volleyball, soccer, basketball, and softball players at 60, 120 and 180°s^{-1}. Significant differences of isokinetic data at 300°s^{-1} may be attributed to the findings regarding training adaptations acquired by the volleyball players under increased velocity.

In the 180°s^{-1} and 300°s^{-1} tests, the mean H/Q muscles ratio values were significantly decreased in the volleyball players compared with the controls. However, there were no significant differences between the basketball players and the controls. These findings reinforce the specificity as regards the demands of each sport. Basketball players seem to have more balanced hamstring-quadriceps muscle groups than volleyball players do.

In conclusion, our findings indicate that volleyball players present an H/Q muscles ratio below the usual clinically recommended ratios (Coombs & Garbutt, 2002) at all the tested velocities. This hamstring/quadriceps muscles imbalance can be seen as an injury risk for volleyball players. They could benefit from specific strength training of hamstring muscles.

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PARAMETRI IZOKINETIČKE IZVEDBE POKRETA KOD VRHUNSKIH ODBOJKAŠA I KOŠARKAŠA

Sažetak

Uvod

Odbojka i košarka dvije su sportske igre koje zahtijevaju različite tehničke vještine igrača, kao i različite trenažne postupke te načine igranja. Mišići opružači (*m. quadriceps*) i pregibači (*m. biceps femoris, m. semitendinosus, m. semimembranosus*) potkoljenice uključeni su u očitovanje nekih motoričkih sposobnosti koje su važne za uspjeh i u odbojci i u košarci. Cilj ovog istraživanja bilo je utvrđivanje i uspoređivanje maksimalnog voljnog okretnog momenta mišića opružača i mišića pregibača potkoljenice te omjera okretnog momenta između navedenih mišića dominantne noge kod odbojkaša i košarkaša.

Metode

Eksperimentalna grupa sastojala se od 20 odbojkaša (dob: 19,55 ± ,5 god., težina: 79,4 ± 2,1 kg, visina: 185,2 ± 1,6 cm) i 20 košarkaša (dob: 23,6 ± ,7 god., težina: 84,7 ± 2,9 kg, visina: 188,2 ± 1,9 cm). Ispitanici obje grupe bili su kvalitetni odbojkaši i košarkaši (druga nacionalna liga). Kontrolna grupa sastojala se od 20 neaktivnih muškaraca (dob: 21,1 ± ,4 god., težina: 65,1 ± 1,5 kg, visina: 174,3 ± ,4 cm). Maksimalni okretni moment izmjeren je na opružačima (*m. quadriceps*) i pregibačima (*stražnja loža*) potkoljenice pri izokinetičkom pokretu u koljenom zglobu pri kutnim brzinama od 60º, 180º i 300º u sekundi. Proučavala su se dva parametra u ovom istraživanju. Maksimalni okretni moment (eng. *peak torque*; PT) i omjer između maksimalnih okretnih momenata mišića pregibača i opružača potkoljenice (eng. *hamstrings/quadriceps*, H/Q). Okretni momenti sila mišića opružača i pregibača potkoljenice izmjereni su dinamometrom Biodex (System 3 Dynamometer; Biodex Medical System, Inc, Shirley, NY). Istraživanje je provedeno samo na dominantnoj nozi. Ispitanici su sjedili na dinamometrijskoj stolici; kukovi su im bili pod kutom od 60˚ te su trakama, koje su prelazile preko njihovih bedara i prsa, bili pričvršćeni za aparat. Os rotacije na dinamometru bila je poravnata s koljenom ispitanika i postavljena na opseg pokreta od 0 do 90˚. Kako bi se upoznali s uvjetima testiranja, na počeku testa ispitanicima je bilo dopušteno izvesti tri submaksimalne kontrakcije opružačima i pregibačima potkoljenice. Nakon toga, izvodili su po pet maksimalnih kontrakcija pri brzini od 60ºs^{-1}, 10 maksimalnih kontrakcija pri brzini od 180ºs^{-1} i 15 maksimalnih kontrakcija pri brzini od 300ºs^{-1}. Najveći okretni moment koji je zabilježen pri pokušajima unutar svakog testa uzet je za analizu. Omjer snage između pregibača i opružača potkoljenice dobiven je dijeljenjem maksimalnog okretnog momenta pregibača potkoljenice s maksimalnim okretnim momentom opružača potkoljenice izmjerenih pri istim kutnim brzinama u koncentričnom režimu rada. Vrijednosti najvećeg okretnog momenta (Nm) opružača i pregibača potkoljenice u koncentričnom režimu rada te omjeri između maksimalnih okretnih momenata opružača i pregibača potkoljenice u koncentričnom režimu rada koristili su se za statističku analizu.

Rezultati

Koristili smo prosjek najveće snage zabilježene pri koncentričnim kontrakcijama mišića pregibača i opružača potkoljenice pri kutnim brzinama od 60ºs^{-1}, 180ºs^{-1} i 300ºs^{-1} u koljenom zglobu kod svih ispitanika iz eksperimentalnih i kontrolne skupine. Pri svim kutnim brzinama, obje mjerene mišićne skupine i kod odbojkaša i kod košarkaša imale su statistički značajno veći okretni moment sile pri koncentričnim kontrakcijama od ispitanika iz kontrolne skupine. Nisu zabilježene značajne razlike između odbojkaša i košarkaša u rezultatima maksimalnog okretnog momenta pri koncentričnim kontrakcijama mišića opružača i pregibača potkoljenice pri kutnim brzinama od 60ºs^{-1} i 180ºs^{-1}. Ipak, kod odbojkaša je opažena veća razina jakosti pri koncentričnom pokretu ispružanja potkoljenice pri brzini od 300ºs^{-1} (p=,002) u odnosu na košarkaše.

Prosječne vrijednosti omjera okretnog momenta mišića pregibača i opružača potkoljenice pri kutnoj brzini od 60ºs^{-1} bile su vrlo slične u skupinama ispitanika. Zabilježene vrijednosti bile su 0,46 ± 0,41; 0,49 ± 0,14 i 0,45 ± 0,11 pri kutnoj brzini od 60ºs^{-1} za odbojkaše, košarkaše, odnosno za ispitanike iz kontrolne skupine.

Kod odbojkaša je zabilježen niži omjer maksimalnog okretnog momenta pregibača i opružača potkoljenice pri kutnoj brzini od 180ºs^{-1}. Zabilježene prosječne vrijednosti bile su 0,51 ± 0,16; 0,58 ± 0,12 i 0,59 ± 0,14 za odbojkaše, košarkaše, odnosno ispitanike iz kontrolne skupne. U testu pri kutnoj brzini od 180ºs^{-1} omjeri maksimalnih okretnih momenata otkrili su značajne razlike između odbojkaša i kontrolne skupine (p=,025). Ipak, nije zabilježena značajna razlika između košarkaša i kontrolne skupine (p=,953). Isto tako, nije zabilježena značajna razlika u omjerima maksimalnih okretnih momenata između odbojkaša i košarkaša pri 180ºs^{-1} (p=,051).

Podaci o omjerima maksimalnih okretnih momenata mišića pregibača i opružača potkoljenice između odbojkaša i košarkaša pokazali su značajne razlike samo u testu koji se izvodio pri kutnoj brzini od 300ºs^{-1} , u kojem su odbojkaši imali veće razlike u odnosu na košarkaše i kontrolnu skupinu (p=,001, odnosno ,000). Međutim, nije zabilježena statistički značajna razlika između košarkaša i kontrolne skupine (p=,758). Prosječne vrijednosti omjera maksimalnog okretnog momenta mišića pregibača i opružača potkoljenice bile su 0,56 ± 0,31, 0,71 ± 0,1 i 0,69 ± 0,18 za odbojkaše, košarkaše, odnosno kontrolnu skupinu.

Rasprava i zaključak

Omjer jakosti mišića natkoljenice (*mišići stražnje lože/kvadriceps*) može ukazivati na sklonost ozljedi. Ta sklonost može biti rezultat smanjene koaktivacije antagonista (*mišića stražnje strane natkoljenice*) prilikom opružanja potkoljenice pod opterećenjem. U ovom istraživanju dokazali smo da dobro razvijen mišić prednje strane natkoljenice (*m. quadriceps*) pridonosi smanjenoj koaktivaciji antagonista (*mišića stražnje strane natkoljenice*) kod odbojkaša. Isto tako, kod odbojkaša je zabilježen manji omjer jakosti mišića prednje i stražnje strane natkoljenice nego kod košarkaša i kontrolne skupine pri testu s kutnom brzinom od $300°s^{-1}$, što je rezultat slabijeg mišića prednje strane natkoljenice (*m. quadriceps*) u odnosu na mišiće stražnje strane natkoljenice. Ta funkcionalna neravnoteža mogla bi biti rezultat specifične odbojkaške adaptacije i/ili nedovoljnog treninga snage usmjerenog na jačanje mišića stražnje strane natkoljenice. Iako sportovi koji su prezentirani u našem istraživanju (odbojka i košarka) zahtijevaju slične kretnje (trčanje, skakanje, ubrzavanja i usporavanja) od svojih igrača, različiti tehnički elementi koji su u strukturi sporta mogli bi biti odgovorni za razlike u omjerima snage između prednje i stražnje strane natkoljenice.

U odbojci su ozljede koljena generalno uzrokovane učestalim skokovima pri kojima dolazi do gubljenja ravnoteže pri doskoku te uzastopnim doskocima na jednu nogu. Aktivnost mišića prednje strane natkoljenice veća je pri jednonožnom doskoku, dok se aktivnost mišića stražnje strane natkoljenice nije mijenjala. Smanjena funkcija mišića stražnje strane natkoljenice kao antagonista zbog aktivnosti kod kojih je naglašeno opterećenje na mišiće opružače potkoljenice mogu rezultirati mišićnom neravnotežom između mišića prednje i stražnje strane natkoljenice, stoga sportaše učiniti sklonima ozljedama koljena. Podaci prezentirani u ovom istraživanju, unatoč izostanku neravnoteže u omjerima snage mišića prednje i stražnje strane natkoljenice u testovima pri brzinama od $60°s^{-1}$ i $180°s^{-1}$, koji su zapravo u suprotnosti s rezultatima testova pri kutnoj brzini od $300°s^{-1}$, mogli bi ukazivati na to da su odbojkaši skloniji ozljedama koljena od košarkaša. Zbog toga populaciji odbojkaša preporučamo dodatni trening snage usmjeren na jačanje mišića stražnje strane natkoljenice koji bi povećao omjer snage mišića prednje i stražnje strane natkoljenice.

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Correspondence to:
Prof. Tuncay Çolak PhD
Kocaeli University, School of Medicine
Department of Anatomy, Umuttepe
41380, Kocaeli, Turkey
Phone: 00 90 262 3037045
Fax: 00 90 262 3222140
E-mail: tuncay_colak73@mynet.com