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Lower-extremity strength ratios of professional Greek soccer players
A follow-up study during in-season

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OBJECTIVE **Assessment of the differences in isokinetic concentric strength of the knee extensors and flexors in soccer players measured before the end of the season (April) in the years 2013 and 2014.** METHOD **Measurements were made in the April of 2013 and 2014 in 13 professional soccer players of hamstring (H) and quadriceps (Q) peak torque-ratio (PT), and total work (TW) at two testing speeds (60º·s^{-1} and 180º·s^{-1}), expressed as per-kg body weight (Nm·kg^{-1}), and peak muscle torque (PT) (Nm), using an IsoMed 2000-dynamometer chair. Repeated measures analysis (based on general linear modeling) was used to assess the differences.** RESULTS **Between 2013 and 2014 a positive Δ-change was observed in mean match playing time (+35%, p=0.001), but less time had been spent during training sessions on isokinetic strength training. Correlation analysis according to the different velocities showed significantly negative correlation in 2013 between the playing time and TWQ at 60ºs^{-1} and at 180ºs^{-1} between TWQ and age (p<0.05). PT was lower for the players in 2014 than in 2013 at 60ºs^{-1}: Q (Nm)–(-32.0, p=0.002) v 60ºs^{-1} Q (Nm kg^{-1})–(-0.40, p=0.002), as was the percentage of ratio (%)–(-13.1, p<0.001) and TWH (-93, p=0.043). In 2014, positive correlation was found of 60ºs^{-1} PTH (Nm), 60ºs^{-1} PTH (Nm·kg) and 180ºs^{-1} PTQ (Nm) measurements with the playing-time (p<0.05). In 2014 Angular velocity of 180ºs^{-1} PT was lower in 2014 at H-(Nm) (-9.8, p=0.008), ratio (%) (-21.1, p<0.001) and in TWH (-144, p=0.045).** CONCLUSIONS **The limited time spent on individual training sessions in the second year of testing, because of higher mean match-play time and the optional nature of the isokinetic concentric strength training, appeared to affect negatively the maximum torque of the knee and thus increase the risk for severe injuries.**

Δείκτες ισχύος κάτω άκρων επαγγελματιών αθλητών ποδοσφαίρισης: Επαναληπτική παρακολούθηση στη διάρκεια της αγωνιστικής περιόδου

Περίληψη στο τέλος του άρθρου

Key words

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Soccer playing is characterized by intermittent physical activity with sequences of actions, including running, sprinting, jump duels and kicking, which require a variety of skills, all dependent on lower limb strength.[1,2] Injuries constitute the most common reason for soccer player unavailability for training sessions and matches, and are reported to account for 20–37% of all time loss at men's professional level.[3–5] A rate of 7 to 8 injuries in the lower extremities per 1,000 hours of soccer playing is documented.[5] One study reported[6] that 17% of all soccer injuries are located in the thighs, and that hamstring (H) strain is the most common type of strain in the thighs, accounting for 12% of the total, with a higher incidence than quadriceps (Q) strain (5%).[5,6] Although H injuries are often multifactorial in origin, epidemiological evidence suggests that poor eccentric muscular strength and muscle strength imbalance play a central role in acute focal muscle injuries.[7] Strength deficits between the two limbs (strength asymmetries) and between agonist-antagonist muscle groups (reciprocal strength ratio imbalance) have been reported in soccer players. This is because they are forced to use their limbs unilaterally in all kicking and cutting skills, which alters the balance of strength between the two limbs and between antagonist muscle groups.[8]

Isokinetic dynamometry is commonly used to evaluate muscle strength imbalance between knee flexors and extensors in soccer players. The main limitations of isokinetic testing are the constant angular velocity during an open-chain movement and the often single-joint motor task investigated. These are not characteristics of sports movements, in which the angular velocities vary constantly and multi-joint motor tasks are common.[9] In addition, asymmetry between the preferred (dominant) and the non-preferred (non-dominant) limb may also increase the potential risk for knee injuries.[10] Studies of thigh muscle strength in Greek professional soccer players[2,8,11–13] have documented Q and H strength at angular velocities ranging from 60°/second (60°s^{-1}) to 300°/second (300°s^{-1}). In the largest study of preseason thigh muscle strength profiles of professional European and American soccer players, approximately half of the players had H strength imbalance.[14]

The aim of the present study was to examine possible differences between the isokinetic strength profiles (Q concentric, H concentric, total work [Joule], % ratio) near the end of two consecutive seasons, according to the playing time in the season.

MATERIAL AND METHOD

Subjects

The study participants were 13 elite level professional soccer players (mean age: 26.2 years, mean body weight: 78.5 kg, mean height: 181.5 cm). The study was approved by the institutional ethics board. An informed consent form was signed by each participating athlete. All the subjects were injury-free and had completed at least 6 years' participation in the top division of Greek championship (Super League). None of the participants had ever suffered a major knee injury or severe Q or H muscle injury. Of the 13 players who took part in the study, 7 were midfielders, 5 were defenders, and one was a forward.

Experimental protocol

The objective of this study was to evaluate the isokinetic H and Q strength profile of 13 male professional football players before the end of the season (i.e., in April) in the years 2013 and 2014 and to identify whether any player had H strength imbalance. In the year 2013, all the participants had followed a specific isokinetic strength training program twice per week during the in-season period. This consisted of 4 sets of six repetitions at 60°s^{-1} and 4 sets of six extension-flexion repetitions at 180°s^{-1} for both limbs. All the strength tests included a rest of 90 seconds between sets and 180 seconds between limbs. In 2014 the isokinetic strength training program was optional during the in-season period. For the testing, concentric (60°s^{-1} and 180°s^{-1}) H and Q isokinetic strength was measured with an IsoMed 2000 dynamometer (D&R Ferstl GmbH, Hemau, Germany). The primary variables studied were bilateral concentric H and Q peak torque ratio (PT), concentric H-Q PT ratio, and total work (TW). The choice of primary variables was based on a ratio proposed by Croisier and colleagues.[15] Strength imbalance was considered any two of the criteria: bilateral concentric H PT ratio <0.86, concentric H-Q ratio <0.47, mixed ratio <0.80.[16]

Procedure

All the measurements for both years (2013 and 2014) were made in the month of April during the in-season training period. Isokinetic strength measurements were conducted for both legs. PT of the knee extensors and flexors was determined at two different angular velocities (60°·s^{-1}and 180°·s^{-1}) and expressed as per kg body weight (Nm·kg^{-1}) and as peak muscle torque (Nm).

These angular velocities have been used widely for lower body muscle strength assessment in soccer players.[1,2,8,10,11,13,15] All the measurement sessions were conducted at the same time of the day (±1 h) and by the same investigator, in an attempt to reduce possible effects of diurnal influences and examiner variability. Prior to testing, each subject completed a general warm-up phase consisting of 10 minutes cycling on a stationary cycle ergometer (Monark 894 Eα) with a pedal rate of 70 rpm, followed by several stretching exercises of the lower extremity muscles.

Immediately after the warm-up phase, each subject was seated comfortably on the adjustable IsoMed 2000-dynamometer chair with the hip joint at about 75° (0°=full extension) and the popliteal fossa of the tested leg at the frontal edge of the seat. Straps and pads were adjusted at the shoulders, chest, hip, and right femur in order to minimize body movements and to optimally isolate the movement of the knee joint. Further stabilization of the upper body was achieved by instructing subject to hold on to the side handles situated lateral to the hips. The mechanical axis of the dynamometer was aligned with the axis of rotation of the knee, utilizing the lateral femoral epicondyle as a bony reference. The distal shin pad of the dynamometer lever arm was attached 2–3 cm proximal to the lateral malleolus at a position of 90° knee flexion, using a strap. Individual settings were recorded and saved by the integrated IsoMed 2000 software, to ensure similar conditions for each of the testing sessions. The IsoMed 2000 dynamometer has shown high reproducibility in the measuring of PT during concentric and eccentric knee extension.[17]

After stabilization, the weight of the tested leg resting in a relaxed state at terminal extension was measured and gravity adjustment was made using the integrated software. Range of motion (ROM) was set to 10°–90° of knee flexion, with a fast acceleration setting at the beginning and a hard deceleration cushion at the end of the movement. A threshold force requirement of 50N was chosen in an attempt to minimize possible force oscillation.

Concentric maximum strength of the knee extensor muscle group of the dominant and non-dominant knees was tested at angular velocities of 60°·s^{-1} and 180°·s^{-1}. The order of testing was random for each subject and kept the same for the other sessions. All tests were conducted as discrete movements in a single direction (i.e., non-reciprocal) with a 2-minute rest between tests. Prior to each test, each subject performed 4–5 sub-maximal practice trials as a specific warm-up and to become acquainted with the requirements of the test. Between the warm-up and testing, there was a rest period of 1 minute, which was used to instruct the subject "(...) to push as fast and hard as possible against the shin pad, from the beginning up to the end of the movement (...)" in the subsequent test. The test protocol included one set of six consecutive maximal concentric flexion and extension contractions. A rest period of 180s was allowed between series of the two angular velocities. Single repetitions were introduced by repeating these instructions and giving the verbal countdown "(...) concentrate, 3–2–1–go (...)". Throughout repetitions, additional strong verbal encouragement and visual online feedback were provided to ensure maximum effort.

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences software (IBM SPSS Statistics for Windows, IBM Corp, Armonk, NY), version 23.0. Distributions of the descriptive characteristics of the 13 professional soccer players were estimated. The difference between playing time in the two years was tested by the non-parametric Wilcoxon signed rank test. The correlation coefficients between isokinetic measurements were estimated for each year, 2013 and 2014. Differences in isokinetic measurements between the two years were explored using general linear modeling and repeated measures analysis. The age of the players, their weight, the *Δ*-changes in the time (in minutes) playing in matches during each season and the side of the leg (right/left) were used as covariates. All the analyses were based on 26 measurements. No significant difference was found between the two legs (right vs left) in any of the isokinetic measurements (Mann-Whitney test, $p \geq 0.01$, results not shown). Repeated measures analysis was used to estimate the changes in 26 measurements of H-Q PT ratio at the two angular velocities between 2013 and 2014. The covariates used were the age, weight, *Δ*-change in time (minutes) playing in matches during the two seasons and the leg (right/left). Effect sizes based on eta-squared (η^2) and observed power were estimated at 0.289 and 0.795 at the angular velocity of $60^o s^{-1}$ or 0.420 and 0.960 in $180^o s^{-1}$.

RESULTS

Table 1 shows the descriptive characteristics of the 13 professional soccer players participating in the study. Between 2013 and 2014, a significant difference (*Δ*-change) was found in mean match-playing time (777 vs 1,231 m, p=0.001). This difference was close to 35%. No significant difference was observed between the years on angular velocity examined for side-to-side asymmetry (results not shown).

Significant negative correlation was found in 2013 of the measurements at the speed of $60^o s^{-1}$ with total work-quadriceps (TWQ), and the measurements at the speed of $180^o s^{-1}$ TWQ with the age of the player (tab. 2) ($p < 0.05$).

Table 1. Descriptive characteristics of the 13 professional soccer players, participating in the study.

		Mean (standard deviation) ***[median]***
Age *(years)*		26.2 (4.9)
Body weight *(kg)*		78.5 (6.5)
Body height *(cm)*		181.5 (5.6)
Match playing time *(minutes)* during the season:	2013	777 (526) *[507]*
	2014	1,231 (1,070) *[973]*
	Δ-change	454 (603) *[466]**
	Δ-change (%)	35.2 (81.9) *[65.8]*

Age, weight and height were recorded at the end of the first year of measurements (2013)
Wilcoxon signed rank test: *p=0.001

Significant positive correlation was found in 2014 of the measurements at $60^o s^{-1}$ and PT-hamstring (Nm) [PTH-(Nm)], $60^o s^{-1}$ PTH-(N·kg) and of measurements at $180^o s^{-1}$ to PTQ (Nm) with the playing time in matches during the season ($p < 0.05$). For both years, positive correlation was demonstrated between all measurements of PT and TW ($p < 0.001$) (tab. 2).

Table 3 presents the comparison and *Δ*-changes at different angular velocities and TW between the two years. PT was significantly lower in the players in 2014 at $60^o s^{-1}$-Q (Nm) (-32.0, p=0.002), $60^o s^{-1}$-Q (Nm kg^{-1}) (-0.40, p=0.002), for the percentage of ratio (%) (-13.1, $p < 0.001$) and for TWH (-93, p=0.043). At the angular velocity of $180^o s^{-1}$, PT was significantly lower in 2014 for H-(Nm) (-9.8, p=0.008), ratio (%) (-21.1, $p < 0.001$) and TWH (-144, p=0.045). No significant difference was found between the two legs in any of these parameters (results not shown in table, $p > 0.01$).

Figure 1 presents the difference in H:Q ratio measured at the two angular velocities between the two periods. The change in H:Q ratio between the years 2013 and 2014 was significant only at the speed of $180^o s^{-1}$ (+77.7% vs +134.2%, respectively, $p < 0.001$).

DISCUSSION

This study points out notable differences in measurements between the two study years 2013 and 2014: (a) The soccer players in 2014 had significantly greater participation time (by close to 35%) in terms of mean match-play time than in 2013, (b) significant negative correlation was found in 2013 of the measurements at the speed of $60^o s^{-1}$ with TWQ, and at $180^o s^{-1}$ of TWQ with age, and significant positive correlation was found in 2014 of the measurements of the $60^o s^{-1}$ PTH (Nm), $60^o s^{-1}$ PTH (N kg) and $180^o s^{-1}$ PTQ

Table 2. Correlations of isokinetic measurements* of 13 selected professional soccer players, made in the years 2013 and 2014.

Isokinetic measure-ments	Year	Age	Time playing in matches during the seasons	$60^{o}\cdot s^{-1}$, peak torque, H (Nm)	$60^{o}\cdot s^{-1}$, peak torque, Q (Nm)	$60^{o}\cdot s^{-1}$, peak torque, H (N·kg)	$60^{o}\cdot s^{-1}$, peak torque, Q (N·kg)	$60^{o}\cdot s^{-1}$, total work, H	$60^{o}\cdot s^{-1}$, total work, Q	$180^{o}\cdot s^{-1}$, peak torque, H (Nm)	$180^{o}\cdot s^{-1}$, peak torque, Q (Nm)	$180^{o}\cdot s^{-1}$, peak torque, H (N·kg)	$180^{o}\cdot s^{-1}$, peak torque, Qt(N·kg)	$180^{o}\cdot s^{-1}$, Total work, H
		r-Pearson												
$60^{o}\cdot s^{-1}$, peak torque, H (Nm)	2013	-0.260	0.151											
	2014	0.005	0.463†											
$60^{o}s^{-1}$, peak torque, Q (Nm)	2013	-0.265	0.076	0.775‡										
	2014	-0.216	0.086	0.681‡										
$60^{o}s^{-1}$, peak torque, H (N·kg)	2013	-0.308	0.153	0.881‡	0.617‡									
	2014	0.046	0.440†	0.946‡	0.554‡									
$60^{o}s^{-1}$, peak torque, Q (N·kg)	2013	-0.341	0.037	0.615‡	0.905‡	0.654‡								
	2014	-0.249	0.019	0.638‡	0.941‡	0.617‡								
$60^{o}s^{-1}$, total work, H	2013	-0.171	0.059	0.835‡	0.540‡	0.777‡	0.438†							
	2014	-0.197	0.011	0.691‡	0.648‡	0.616‡	0.621‡							
$60^{o}s^{-1}$, total work, Q	2013	-0.396†	-0.157	0.668‡	0.727‡	0.618‡	0.715‡	0.613‡						
	2014	0.098	-0.098	0.439†	0.681‡	0.351	0.644‡	0.569‡						
$180^{o}s^{-1}$, peak torque, H (Nm)	2013	0.054	0.277	0.853‡	0.798‡	0.597‡	0.547‡	0.678‡	0.561‡					
	2014	-0.258	0.252	0.502‡	0.732‡	0.253	0.530‡	0.487†	0.421†					
$180^{o}s^{-1}$, peak torque, Q (Nm)	2013	-0.158	0.154	0.707‡	0.782‡	0.500‡	0.617‡	0.483†	0.657‡	0.827‡				
	2014	-0.213	0.448†	0.490†	0.566‡	0.340	0.440†	0.194	0.284	0.730‡				
$180^{o}s^{-1}$, peak torque, H (N·kg)	2013	0.097	0.362	0.810‡	0.742‡	0.743‡	0.650‡	0.702‡	0.580‡	0.906‡	0.748‡			
	2014	-0.350	0.222	0.500‡	0.750‡	0.357	0.680‡	0.500‡	0.416†	0.908‡	0.700‡			
$180^{o}s^{-1}$, peak torque, Q (N·kg)	2013	-0.218	0.144	0.537‡	0.657‡	0.539‡	0.687‡	0.368	0.653‡	0.580‡	0.889‡	0.675‡		
	2014	-0.229	0.384	0.383	0.379	0.423†	0.453†	0.057	0.153	0.342	0.821‡	0.534‡		
$180^{o}s^{-1}$, total work, H	2013	-0.131	0.120	0.824‡	0.648‡	0.791‡	0.581‡	0.846‡	0.611‡	0.745‡	0.592‡	0.811‡	0.523‡	
	2014	-0.512‡	-0.141	0.305	0.725‡	0.114	0.621‡	0.573‡	0.500‡	0.818‡	0.475†	0.817‡	0.213	
$180^{o}s^{-1}$, total work, Q	2013	-0.389†	0.090	0.718‡	0.703‡	0.691‡	0.688‡	0.629‡	0.856‡	0.579‡	0.618‡	0.614‡	0.609‡	0.698‡
	2014	-0.227	-0.079	0.364	0.748‡	0.212	0.661‡	0.401†	0.756‡	0.636‡	0.430†	0.612‡	0.215	0.704‡

H: Hamstring, Q: Quadriceps
*Analysis was performed on 26 observations made on 13 players in both legs (right/left); † $p<0.05$; ‡ $p<0.001$

(Nm) with the playing time, and (c) significant changes were observed at the different angular velocities between 2013 and 2014: PT was significantly lower in 2014 at $60^{o}s^{-1}$-Q (Nm), 60 $^{o}s^{-1}$-Q (Nm kg^{-1}), and for TWH, while at the angular velocity of $180^{o}s^{-1}$ PT was significantly lower in 2014 for H (Nm) and for TWH.

The results of the current study indicate that PT, percentage of ratio (%) and TW at both angular velocities showed significant change in the second year of evaluation. These changes in this group of players could have been influenced by the cumulative amount of match playing time during the second year of the championship season (2014). In both seasons, the players performed each week one session of aerobic high-intensity training (high-intensity interval training and small-sided games), one session of functional strength training (plyometric training, resistive sprints, agility drills), one session of other sprint ability exercises (with and without changes of direction) and one session of isokinetic measurement, which for the second year was optional. It is possible that the limited time of individual

Table 3. Comparison of isokinetic measurements* of 13 professional soccer players, made in the years 2013 and 2014.

Angular velocity				Year of measurement 2013	Year of measurement 2014	Δ-change	p-value
				Mean (standard deviation)			
$60^o \cdot s^{-1}$	Peak torque	Hamstring	Nm	188.8 (4.9)	175.7 (8.7)	-13.1	0.076
		Quadriceps	Nm	279.0 (8.7)	247.0 (11.5)	-32.0	0.002
		Hamstring	$Nm \cdot kg^{-1}$	2.40 (0.06)	2.24 (0.11)	-0.16	0.097
		Quadriceps	$Nm \cdot kg^{-1}$	3.54 (0.11)	3.14 (0.15)	-0.40	0.002
		Ratio	%	84.5 (2.5)	71.4 (3.1)	-13.1	<0.001
	Total work	Hamstring		1,149 (40)	1,056 (43)	-93	0.043
		Quadriceps		1,405 (43)	1,404 (56)	-1	0.976
$180^o \cdot s^{-1}$	*Peak torque*	Hamstring	Nm	157.9 (3.6)	148.2 (3.3)	-9.8	0.008
		Quadriceps	Nm	204.3 (5.5)	195.7 (4.5)	-8.6	0.096
		Hamstring	$Nm \cdot kg^{-1}$	2.01 (0.05)	1.88 (0.04)	-0.13	0.009
		Quadriceps	$Nm \cdot kg^{-1}$	2.60 (0.07)	2.50 (0.06)	-0.10	0.103
		Ratio	%	91.2 (2.5)	70.1 (2.6)	-21.1	<0.001
		Hamstring	$\%60^o \cdot s^{-1}$	109.0 (2.9)	119.9 (10.1)	+10.9	0.273
		Quadriceps	$\%60^o \cdot s^{-1}$	73.9 (1.7)	85.1 (6.7)	+11.2	0.110
	Total work	Hamstring		1,536 (48)	1,392 (58)	-144	0.045
		Quadriceps		1,658 (48)	1,724 (64)	+66	0.291

*Analysis was performed of 26 observations on 13 players in both legs (right/left). No significant difference was found between the two legs in any of the above parameters (Mann-Whitney tests, p >0.010; results not shown)

General linear model-repeated measures analysis. Covariates: Age, weight, Δ-change of time (minutes) playing in matches during the seasons and the leg (right/left)

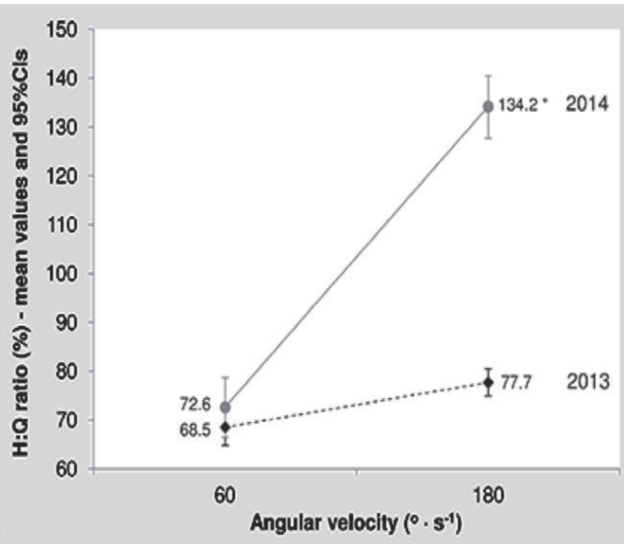

Figure 1. Changes in 26 measurements of Hamstring-to-Quadriceps peak torque ratio (H:Q ratio) at two angular velocities, between 2013 and 2014 (H: Hamstring, Q: Quadriceps, 95% CIs: 95% confidence intervals; general linear model-repeated measures analysis. Covariates: Age, weight, Δ-change of time [minutes] playing in matches during the seasons and the leg [right/left]. Eta squared [η^2] and observed power were estimated at 0.289 and 0.795 at the angular velocity of $60^o \cdot s^{-1}$ or 0.420 and 0.960 in $180^o \cdot s^{-1}$). [*Significant difference between the years was found at the angular velocity of $180^o \cdot s^{-1}$ (p<0.001)].

training in isokinetic strength during the week could affect negatively the maximum torque of the knee. There is a distinct lack of research aimed at better understanding of the correlation between the playing time in matches during the season and the isokinetic strength of the thigh muscles at different angular velocities. One study on a Belgian soccer team[18] observed a 77% increase in the maximum torque of the knee flexors by adding two strength training sessions per week to the annual program, possibly an indication that the H are not routinely stimulated during traditional soccer practice. Based on this observation and on the findings of the present study, it appears that knee flexor and extensor strength decreased in the second year of evaluation for both angular velocities (60^{o-1}, 180^{o-1}). One possible explanation for the low values observed in the present study may be the time of testing. Most studies examining isokinetic strength in soccer players have been conducted at the beginning of the pre-season when players are expected to be weaker.[10,19–21] In the present study, the isokinetic evaluations were conducted near the end of each season (April) and it is likely that testing during the pre-season phase, in which one of the principal purposes is to increase overall muscular strength, would give different results. The muscle symmetry recorded on the knee extensor and flexor muscles of the players in the current study could be the result of the strength training of the lower extremities throughout the two years of the study designed to maintain similar strength on both sides of the body and avoid injuries caused by muscular imbalances.

The current study was an in-season evaluation for 2 consecutive years of a group of elite level soccer players, that was incorporated into the training and competition schedule of a professional club.[22] These professional soccer players had limited time available for isokinetic strength training because the coaches had to plan for recovery and preparation for 1–3 matches per week and to focus on tactical and technical training sessions. In this study, the isokinetic strength at the end of the season was lower in the second than in the first year in almost all players. It is likely that players improved and peaked in their isokinetic strength in the middle of the season (January-February-March) and that their strength had decreased at the end of the season (April).

The other main finding of this study was the significant increase in the H:Q ratio at 180° angular velocity in the second year. In soccer practice it is normally considered that the Q muscle group plays an important role in jumping and kicking of the ball, while the H group controls the running activities and stabilizes the knee during turns and tackles.[23–27] It appears that the knee flexor contribution to joint stability becomes increasingly important with increasing limb velocity.[22] In this study, elite soccer players had a higher H:Q ratio in the second year of measurement, but a significant reduction in Q (Nm) by -32% at 60°s^{-1} and in TWH by -93%, whereas TWH at 180°s^{-1} was reduced by -144%. This would imply that isokinetic tests do not reflect the movement of the limbs involved during sprinting, kicking the ball, or jumping.

Certain limitations of this study should be addressed, one of which was the absence of consideration of eccentric muscle action in the isokinetic assessment.[9] New studies have been developed with the purpose of characterizing isokinetic muscular strength according to the players' position on the field, dependent on different physical performance demands.[28] In this study, the performance of the players was not analyzed according to their usual position on the field, because of the small numbers. None of the soccer players in this study had a previous lower limb injury (e.g., anterior cruciate ligament injuries, cartilage tears, or fractured bones) that could have affected their muscle strength results, and no player was severely injured during the two-year period of testing. Other limitations are the small number of players who completed the measurements in both years, and the lack of measurements in the middle of the season. The evaluation of the isokinetic strength was made in this study near the end of the Greek league season, and it is suggested that future studies should include two additional measurements (after post-season and after pre-season).

To the knowledge of the authors, this is the first published report of examination of differences and correlations of the isokinetic strength profiles of the thigh muscles of professional soccer players in two consecutive years of the Greek championship league. The soccer players had participated significantly more, in terms of mean match-play time, in 2014 than in 2013. Correlation analysis according to different angle velocities and playing time in matches showed significant negative association in 2013 between the measurements at 60°s^{-1} and TWQ and at 180°s^{-1} TW-Q with age. The H:Q ratio measured at the two angular velocities showed a significant difference between the two periods only for the 180°s^{-1}. Possibly the limited time of individual training sessions in the second year of measurement, with no indicated frequency in isokinetic concentric strength training through the week, could negatively affect the maximum torque of the knee. It is therefore strongly recommended that strength and conditioning coaches should not only try to maintain the isokinetic concentric strength training sessions (twice per week: 4 sets of six repetitions at 60°s^{-1} and 4 sets of six extension-flexion repetitions at 180°s^{-1} for both lower extremities), but also increase the number of weekly sessions in the annual program of competitive soccer players.

Finally, it can be concluded that even though the players in 2014 had significantly greater participation in terms of mean match-play time, by close to 35%, they showed significant deficit compared to 2013 in the measurements at 60°s^{-1} in TWQ and at 180°s^{-1} of TWQ according to age. The H:Q ratio measured at the two angular velocities between the two periods showed that between the years of 2013 and 2014 there was a significant difference only at 180°s^{-1}. To conclude, it is pointed out that the limited individual training time in the second year of testing, combined with the lack of organized isokinetic strength sessions throughout the week during the season (which during the second study year were optional and infrequent), could affect negatively the maximum torque of the knee, and thus increase the risk for severe injuries.

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ΠΕΡΙΛΗΨΗ

Δείκτες ισχύος κάτω άκρων επαγγελματιών αθλητών ποδοσφαίρισης: Επαναληπτική παρακολούθηση στη διάρκεια της αγωνιστικής περιόδου

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ΣΚΟΠΟΣ Η αξιολόγηση των διαφορών της ισοκινητικής ομόκεντρης ισχύος της κάμψης και της έκτασης γονάτου σε αθλητές ποδοσφαίρισης, πριν από τη λήξη της αγωνιστικής περιόδου (Απρίλιος) μεταξύ των ετών 2013 και 2014. **ΥΛΙΚΟ-ΜΕΘΟΔΟΣ** Σε 13 αθλητές διενεργήθηκε με ισοκινητικό δυναμόμετρο (IsoMed 2000-dynamometer chair) μέτρηση της κάμψης (hamstring, H) και της έκτασης (quadriceps, Q) μέγιστης ροπής (peak torque-ratio, PT) και συνολικού φορτίου (total work, TW) σε δύο ελεγχόμενες γωνιακές ταχύτητες ($60^o \cdot s^{-1}$ και $180^o \cdot s^{-1}$), εκφραζόμενες σε kg σωματικού βάρους ($Nm \cdot kg^{-1}$) και ισχύ μέγιστης μυϊκής ροπής (Nm). Ακολούθησε ανάλυση επαναλαμβανόμενων μετρήσεων βασισμένη σε γενικευμένα γραμμικά μοντέλα για τον έλεγχο διαφορών. **ΑΠΟΤΕΛΕΣΜΑΤΑ** Στο τέλος της διάρκειας των περιόδων 2013 και 2014 βρέθηκε σημαντική αύξηση στον μέσο χρόνο αγωνιστικής συμμετοχής των αθλητών (+35%, p=0,001). Σημαντικά θετική συσχέτιση βρέθηκε το 2013 –κατά τη διάρκεια της περιόδου– μεταξύ των μετρήσεων των $60^o s^{-1}$ συνολικού φορτίου έκτασης (TWQ) και των $180^o s^{-1}$ TWQ με την ηλικία (p<0,05). Η PT το 2014 –πριν από τη λήξη της περιόδου– βρέθηκε χαμηλότερη στην $60^o s^{-1}$ έκταση σε Nm (-32,0, p=0,002) ή στην $60^o s^{-1}$ έκταση σε $Nm \cdot kg^{-1}$ (-0,40, p=0,002), για την ποσοστιαία μεταβολή του δείκτη τους (ratio, %) (-13,1, p<0,001) και στο συνολικό φορτίο κάμψης (TWH) (-93, p=0,043). Επίσης, το 2014 παρατηρήθηκε θετική συσχέτιση της $60^o s^{-1}$ μέγιστης ροπής έκτασης (PT-H) (Nm), της $60^o s^{-1}$ μέγιστης ροπής έκτασης (Nm·kg) και της $180^o s^{-1}$ μέγιστης ροπής κάμψης (PT-Q) (Nm) με τον χρόνο αγωνιστικής συμμετοχής (p<0,05). Η γωνιακή ταχύτητα των $180^o s^{-1}$ μέγιστης ροπής ήταν σημαντικά χαμηλότερη το 2014 στην κάμψη (H) (Nm) (-9,8, p=0,008), στον δείκτη τους (ratio, %) (-21,1, p<0.001) και στο συνολικό φορτίο κάμψης (TWH) (-144, p=0,045). **ΣΥΜΠΕΡΑΣΜΑΤΑ** Ο περιορισμένος χρόνος ατομικής προπόνησης, εξ αιτίας του αυξημένου χρόνου αγωνιστικής συμμετοχής, καθώς και της προαιρετικής ισοκινητικής ομόκεντρης προπόνησης κατά τη διάρκεια της εβδομάδας που εφαρμόστηκε στο δεύτερο έτος μέτρησης, φαίνεται να επιδρά στη μέγιστη ροπή του γονάτου των αθλητών, στοιχείο που ενέχει κίνδυνο για σοβαρούς τραυματισμούς.

Λέξεις ευρετηρίου: Αγωνιστική περίοδος, Αθλητές ποδοσφαίρισης, Γωνιακή ταχύτητα, Δύναμη ποδιών, Ισοκίνηση, Μέγιστη ομόκεντρη δύναμη

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