

Research article

## Lower limb strength in professional soccer players: profile, asymmetry, and training age

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### Abstract

Kicking and cutting skills in soccer are clearly unilateral, require asymmetrical motor patterns and lead to the development of asymmetrical adaptations in the musculoskeletal function of the lower limbs. Assuming that these adaptations constitute a chronicity-dependent process, this study examined the effects of professional training age (PTA) on the composite strength profile of the knee and ankle joint in soccer players. One hundred soccer players (n=100) with short (5-7 years), intermediate (8-10 years) and long (>11 years) PTA were tested bilaterally for isokinetic concentric and eccentric strength of the knee and ankle muscles. Knee flexion-extension was tested concentrically at 60°, 180° and 300 °/sec and eccentrically at 60° and 180 °/sec. Ankle dorsal and plantar flexions were tested at 60 °/sec for both the concentric and eccentric mode of action. Bilaterally averaged muscle strength [(R+L)/2] increased significantly from short training age to intermediate and stabilized afterwards. These strength adaptations were mainly observed at the concentric function of knee extensors at 60°/sec (p = 0.023), knee flexors at 60°/sec (p = 0.042) and 180°/sec (p = 0.036), and ankle plantar flexors at 60°/sec (p = 0.044). A linear trend of increase in isokinetic strength with PTA level was observed for the eccentric strength of knee flexors at 60°/sec (p = 0.02) and 180°/sec (p = 0.03). Directional (R/L) asymmetries decreased with PTA, with this being mainly expressed in the concentric function of knee flexors at 180°/sec (p = 0.04) and at 300 °/sec (p = 0.03). These findings confirm the hypothesis of asymmetry in the strength adaptations that take place at the knee and ankle joint of soccer players mainly along with short and intermediate PTA. Players with a longer PTA seem to adopt a more balanced use of their lower extremities to cope with previously developed musculoskeletal asymmetries and possibly reduce injury risk. This has certain implications regarding proper training and injury prevention in relation to professional experience in soccer.

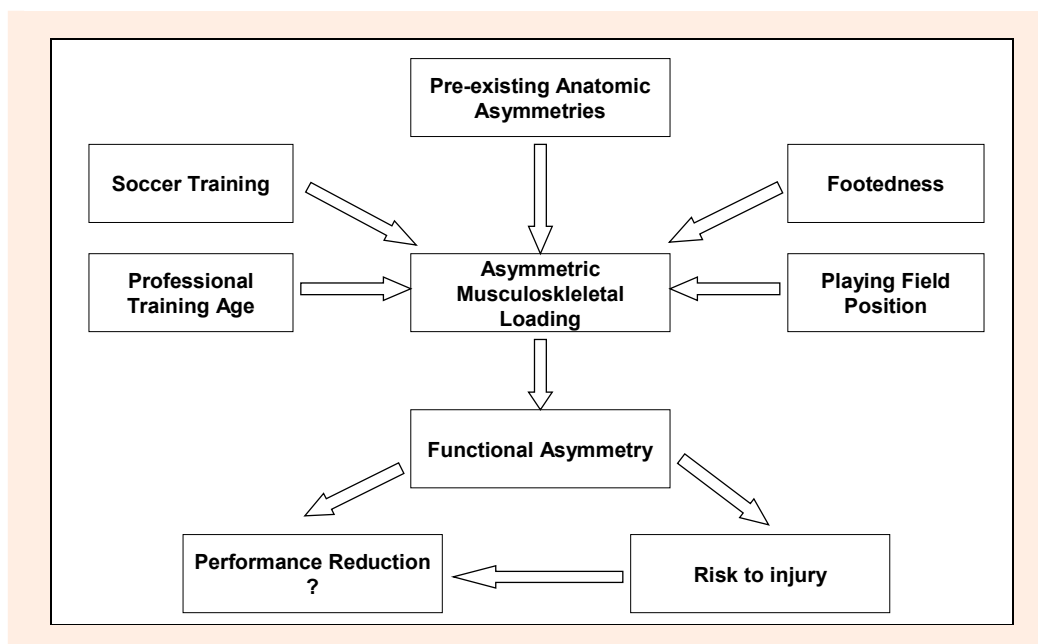
**Key words:** Soccer, isokinetic strength, asymmetries, training-age.

### Introduction

Strength deficits between the two limbs (strength asymmetries) or between agonist-antagonist muscle groups (reciprocal strength ratio imbalances) have been reported in sports with asymmetric kinetic patterns like soccer (Arnason et al., 2004; Dauty et al., 2003) and volleyball (Markou and Vagenas, 2006) as well as in sports with symmetric motor patterns like running (Vagenas and Hoshizaki, 1991; 1992) and cycling (Smak et al., 1999). In soccer, strength asymmetries have been implicated

with injuries to the lower limbs (Tsepis et al., 2004; 2006) as muscle strength is crucial for performance and injury prevention (Bangsbo, 1994). The players are forced to use their lower limbs unilaterally in almost all kicking and cutting skills (Reilly, 1996) and this alters the strength balance between the two extremities or between antagonistic muscle groups (Fousekis et al., 2009). With the majority of soccer injuries occurring at the lower extremities (Le Gall et al., 2006) the development of muscle strength symmetry and balanced ratio in the function of knee flexors and extensors can decrease the incidence rate of soccer injuries (Croisier et al., 2008). Studies show that soccer players possess various muscle strength asymmetries, mainly attributed to preferred sidedness in executing most of the unilateral soccer skills (Chin et al., 1994; Ergun et al., 2004; Masuda et al., 2005; McLean and Tumilty; 1993). On the contrary, whereas others, failed to confirm significance in the degree of bilateral leg strength asymmetry found in soccer players as well (Capranica et al., 1992; Rochongar et al., 1988; Zakas, 2006). This contradiction necessitates further study and clarification of the problem of strength asymmetry in soccer players, as a result of pre-existing limb preference (footedness). It was hypothesized that consistent asymmetrical workloads and functional adaptations gradually induce asymmetries in the myodynamic characteristics of the player. In turn, soccer-specific kinetic adaptations and strength asymmetries are suspect to interacting with some critical exogenous factors of soccer performance such as professional training age (Amato et al., 2001; Gerodimos et al., 2003) and playing position (Davis et al., 1992; Wisloff et al., 1998). These factors may influence the degree of pre-existing anatomic and functional asymmetries thus leading to soccer injury as proposed in the theoretical model of asymmetry depicted in Figure 1.

The effects of PTA on total muscle strength asymmetry have not been studied sufficiently, even though the development of muscle strength is a long term process. So far no study examined the potential effects of PTA on the development of strength asymmetries in soccer players. Relevant studies analyzed peak torque of the knee muscles in players of different ages and found that lower extremity muscle strength increases with age (Amato et al., 2001; Gerodimos et al., 2003; Gur et al., 1999; Kellis et al., 2001; Rochongar et al., 1988; Voutselas et al., 2007). Two studies reported a significant effect of chronological (Gur et al., 1999) or professional training age (Voutselas et al., 2007) mainly on the reciprocal



**Figure 1.** Theoretical model of factors associated with functional asymmetry in soccer.

strength ratio of the knee muscles and showed that older soccer players tend to possess significantly higher knee strength ratios in their dominant extremity compared to younger players.

On the other hand other studies showed no significant relationship between age and strength capacities of the knee flexor and extensor muscles (Rochongar et al., 1988; Kellis et al., 2001) and this suggests further investigation of the problem, as the relevant studies do not all make the same bilateral comparisons and in several cases do not account for the potential effects of footedness on the produced results. Yet, some studies tested only concentric muscle action (Rochongar et al., 1988; Voutselas et al., 2007) and others tested both concentric and eccentric muscle actions (Gur et al., 1999), whereas almost all of them were limited to the examination of the knee joint (Amato et al., 2001; Gerodimos et al., 2003; Gur et al., 1999; Kellis et al., 2001; Rochongar et al., 1988; Voutselas et al., 2007). These methodological variations make relevant results at least partially incomparable and imply the need for a comprehensive methodological approach involving knee and ankle joints as well as several representative speeds of isokinetic testing.

The present study aimed primarily at describing the isokinetic muscle strength profile of the knee and ankle joint in professional soccer players with different training ages. Secondly, it aimed at examining the existence and degree of possible training age-related strength asymmetries in the lower extremities of the players. This would improve our knowledge of the mechanisms responsible for the lateral strength adaptations and their potential effects on the myodynamic structure of the lower extremities of the player.

## Methods

The sample consisted of 115 professional soccer players voluntarily recruited among four professional teams (3<sup>rd</sup> national soccer division). The players had approximately

the same training regime (6-7 training sessions per week with one strength training session every two weeks), no injury at least five (5) months before the evaluation, and at least five (5) years of training at the professional level. After an initial evaluation according to Fuller et al. (2006), 104 players were retained for further study. Informed written consent was obtained from each player and the study was approved by postgraduate studies committee of the Department of Physical Education and Sport Science, University of Athens. Based on the results of the isokinetic myodynamic assessment four (4) players were excluded from further analysis as they exhibited excessive asymmetry ( $\geq 30\%$ ) between right and left side, possibly due to either unreported serious injury or excessive measurement error.

Each player's footedness was assessed according to Markou and Vagenas (2006). Using foot preference 74 players were grouped as right-footed, 16 as left-footed and 10 as mixed footed. The players were also grouped according to their PTA into 5-7 years (34 players), 8-10 years (30 players) and >10 years (36 players). Maximum isokinetic strength of the knee flexors and extensors and of the ankle dorsal and plantar flexors was then assessed on both lower extremities using a Biodex-System 3 (Biodex Corp., Shirley, NY). Testing speeds for the knee were set at 60°/sec, 180°/sec and 300°/sec for concentric muscle action and at 60°/sec and 180°/sec for eccentric. The ankle joint was tested at the 60°/sec for both concentric and eccentric muscle action. These testing speeds have been widely used for muscle strength assessment in soccer players (Masuda et al., 2005; Zakas, 2006). Selecting low (60°/sec), medium (180°/sec) and high (300°/sec) isokinetic testing speeds is essential for optimal strength evaluation, given that in slow muscle action the vast majority of motor units are recruited, while faster testing velocities enrich the force-velocity spectrum of the acting muscles (Baltzopoulos and Brodie, 1989). On the other hand, the eccentric type of testing was considered necessary as it simulates joint function appropriate for optimal

joint stability during the braking phase of various soccer skills (Arnason et al., 2007).

The testing order for joint (knee, ankle) and muscle group (flexors, extensors) was randomized. Five maximal effort trials were performed and recorded for each limb in each experimental condition according to the procedural guidelines (Biodex, 2009). The player was tested in a seated position (90° hip angle) with the body maximally stabilized by straps around the thigh, the waist, and the chest with arms firmly crossed on the chest. For the knee flexion and extension measurements the axis of rotation of the dynamometer was aligned with the lateral femoral epicondyle and for the ankle dorsal-plantar flexion measurements with the fibular lateral condyle. The range of motion of the isokinetic testing was set at 0° (full extension) to 90° for the knee and approximately 0° to 50°-55° for the ankle. During ankle joint testing the knee was strapped at full extension for better stabilization and maximal involvement (facilitation) of the gastrocnemius, which is the key muscle for power generation at the ankle joint. Prior to isokinetic assessment each player was given a 10-15 min warm-up consisting of mild pedalling on an ergometric bicycle and ballistic (dynamic) muscle stretching exercises of very short duration (4-5 secs). The familiarization protocol comprised of three (3) submaximal and two (2) maximal isokinetic actions. Five consecutive maximum effort trials were then performed by each player. A five (5) minutes rest was given after each angular speed testing and a 30 minutes rest was given between testing of the two joints (Masuda et al., 2005).

Average peak torque (Nm) values were calculated for each set of five isokinetic testing repetitions per body side, joint, muscle group, testing speed and muscular contraction modes. Bilaterally averaged peak torque values were calculated for each subject according to the pooled bilateral estimate (R+L)/2. Asymmetry in peak torque values was calculated as directional (left vs. right, L-R), absolute (|Left vs. Right|, |L-R|) and fluctuating (dominant vs. non-dominant, D-ND) according to Vagenas and Hoshizaki (1992), Markou and Vagenas (2006), and Tsepis et al (2004). In addition, for each isokinetic speed of testing the reciprocal strength (flexion/extension) ratio was assessed by both the conventional (concentric knee flexion/concentric knee extension) and the functional (eccentric knee flexion/concentric knee extension) type. The calculation of both types of reciprocal strength ratios secured the best representation of the knee potential for dynamic stabiliza-

tion during forceful activities (Aagaard et al., 1998).

The statistics included descriptive analysis and analysis of variance (ANOVA) with (a) all possible single degree of freedom comparisons after Bonferonni corrections, and (b) trend analysis to locate possible significant ordering between the three consecutive levels of PTA, using SPSS V17. Statistical significances were tested at the  $\alpha = 0.05$  probability level.

## Results

The relative frequency (%) of the players in the 3x3 contingency of footedness by professional training age (PTA) level is given in Table 1. Seventy four percent (74%) of the players were right-footed, 16% left-footed and 10% possessed mixed footedness. The players were about equally distributed among the three PTA groups (36%, 30%, and 34%, respectively). According to chi-square analysis the inter-dependence between the two categorical variables was not significant ( $p > 0.05$ ).

**Table 1. Relative frequency (%) of soccer players according to professional training age (PTA) and footedness (N=100).**

Prof. Training Age*	Footedness			Total
	Left	Right	Mixed	
5-7 years	26	4	6	36
8-10 years	22	5	3	30
≥11 years	26	7	1	34
Total	74	16	10	100

\* PTA with Footedness ( $\chi^2 = 4.33$ ,  $df = 4$ ,  $p = 0.363$ ).

The physical and isokinetic strength characteristics of the players are displayed in Table 2 and 3, respectively. The three footedness groups presented significant differences in chronological and professional training age ( $p < 0.05$ ) but not in height and weight ( $p > 0.05$ ). Soccer players with mixed footedness had significantly higher chronological age than both right-footed players ( $p = 0.01$ ) and left footed players ( $p = 0.008$ ), and significantly higher PTA than right footed players ( $p = 0.028$ ). As expected the group of players with long PTA had significantly higher chronological and professional training age than the intermediate ( $p < 0.001$ ) and short ( $p < 0.001$ ) group. No significant differences were found among the three PTA groups in height and weight ( $p > 0.05$ ).

ANOVA on the bilaterally averaged isokinetic strength values revealed significant differences among the three PTA groups (Table 4). An overall quadratic trend was observed in most of the knee extension

**Table 2. Mean ( $\pm$ SD) values for age, height, weight and PTA by footedness and PTA level in professional soccer players (N=100).**

		N	Age (years)	Height (m)	Weight (kg)	PTA
		100	23.6 (4.2)	1.78 (.06)	73.34 (5.94)	8.71 (2.81)
Footedness	Right	74	24.4 (3.7) *	1.78 (.06)	73.75 (6.26)	8.44 (2.63) *
	Left	16	23.5 (4.4) *	1.77 (.04)	71.72 (3.47)	8.50 (2.82)
	Mixed	10	28.5 (5.3)	1.76 (.06)	72.90 (6.60)	10.90 (3.44)
PTA (years)	5-7	36	20.8 (.83) *	1.77 (.06)	71.97 (5.67)	5.82 (.71) *
	8-10	30	24.3 (.97) *	1.77 (.06)	73.06 (6.73)	8.41 (.56)
	>10	34	29.6 (2.86)	1.79 (.05)	74.90 (5.20)	11.74 (1.11) *

\*  $p < 0.05$ . ANOVA for Footedness: \*Age ( $F = 5.330$ ,  $p = 0.006$ ), Height ( $F = 0.695$ ,  $p = 0.502$ ), Weight ( $F = 0.790$ ,  $p = 0.457$ ), \*PTA ( $F = 3.560$ ,  $p = 0.032$ ). ANOVA for PTA: \*Age ( $F = 208.75$ ,  $p = 0.000$ ), Height ( $F = 1.1147$ ,  $p = 0.322$ ), Weight ( $F = 2.194$ ,  $p = 0.117$ ), \*PTA ( $F = 164.529$ ,  $p = 0.000$ ).

**Table 3.** Mean ( $\pm$ SD) isokinetic peak torque and reciprocal strength ratios values per crossed combination of joint, motion, type of contraction, PTA and body side in professional soccer players (N=100).

Joint (motion)	Type of contraction (testing speed)	Professional Training Age (PTA)							
		5-7 years (N=34)		8-10 years (N=30)		$\geq 11$ years (N=36)			
		Right	Left	Right	Left	Right	Left		
Knee	Extension	Con 60	236 (32)	227 (34)	251 (42)	245 (36)	240 (34)	235 (34)	
		Con 180	165 (23)	161 (22)	173 (29)	173 (6)	170 (26)	167 (24)	
		Con 300	133 (17)	132 (19)	137 (23)	137 (18)	137 (21)	135 (18)	
	Flexion	Ecc 60	310 (60)	299 (55)	325 (53)	314 (52)	318 (66)	306 (74)	
		Ecc 180	282 (53)	285 (65)	303 (44)	299 (44)	295 (64)	293 (67)	
		Con 60	133 (25)	126 (24)	141 (24)	140 (26)	140 (22)	138 (20)	
	Ankle	Dorsal flexion	Con 180	103 (18)	96 (17)	110 (16)	106 (19)	107 (17)	105 (15)
			Con 300	92 (17)	87 (16)	99 (13)	98 (15)	93 (15)	95 (18)
		Plantar Flexion	Ecc 60	184 (42)	183 (43)	189 (44)	193 (39)	203 (32)	200 (46)
Ecc 180			180 (38)	179 (36)	190 (36)	187 (45)	194 (39)	194 (38)	
Knee Strength Ratios		Conv. ratio	Con 60	24 (5)	23 (5)	25 (5)	24 (5)	23 (6)	22 (5)
			Ecc 60	50 (8)	50 (10)	50 (9)	52 (9)	49 (8)	48 (8)
Con 60	111 (22)		109 (19)	120 (22)	121 (23)	121 (25)	119 (25)		
Knee Strength Ratios	Funct. ratio	Ecc 60	212 (46)	207 (37)	218 (38)	215 (36)	216 (42)	204 (41)	
		60 deg/sec	.56 (.80)	.55 (.10)	.56 (.80)	.58 (.70)	.58 (.80)	.59 (.10)	
	180 deg/sec	.62 (.10)	.59 (.10)	.64 (.60)	.61 (.90)	.63 (.80)	.63 (.90)		
	300 deg/sec	.69 (.90)	.66 (.60)	.72 (.60)	.69 (.10)	.68 (.10)	.71 (.70)		
	60 deg/sec	.78 (.10)	.80 (.10)	.76 (.10)	.84 (.10)	.86 (.10)	.85 (.10)		
	180 deg/sec	1.09 (.20)	1.11 (.20)	1.10 (.20)	1.09 (.20)	1.14 (.20)	1.17 (.20)		

Con = Concentric, Ecc = Eccentric, Conv = Conventional concentric knee ratio (Concentric Knee Flexion/Concentric Knee Extension), Funct = Functional knee ratio (Eccentric Knee Flexion/ Concentric Knee Extension).

measurements, while a gross linear trend was observed for the average strength in most of the knee flexion measurements (Figure 2). A significant quadratic trend ( $p < 0.05$ ) was found in the 60°/sec of concentric knee extension and ankle dorsal flexion. A significant linear trend ( $p < 0.05$ ) was also found in the 60°/sec and in the 180°/sec of concentric and eccentric action of the knee flexors. Players with intermediate PTA had highest average isokinetic strength values, while

players with short PTA had lowest average strength values. These strength adaptations were better observed at 60°/sec ( $p < 0.05$ ) for concentric knee extension and at 60°/sec ( $p < 0.05$ ) and 180°/sec ( $p < 0.05$ ) for concentric knee flexion. For the ankle joint, strength differences were not significant except for concentric plantar flexion ( $p < 0.05$ ).

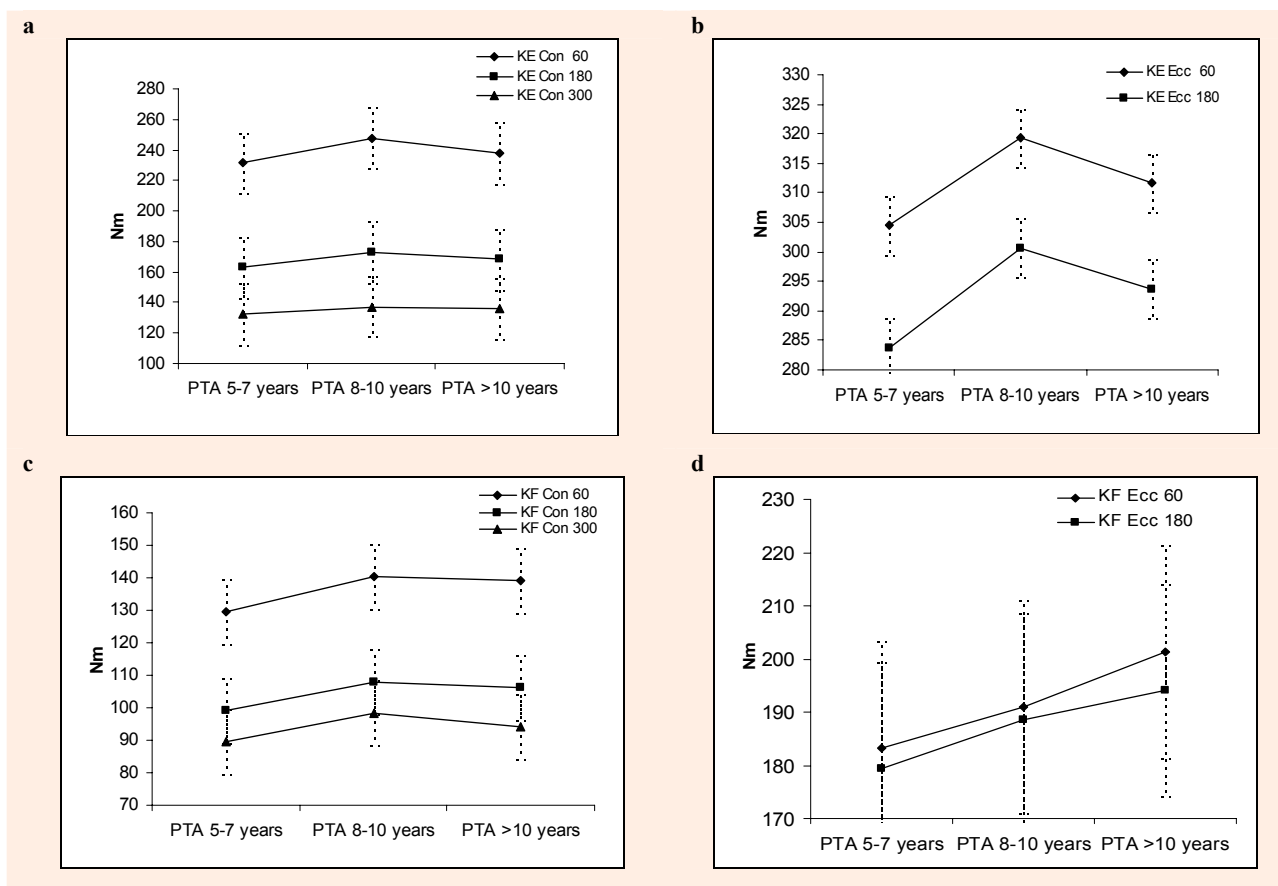
A gross linear trend was also apparent for most average knee strength ratios, with statistical significance

**Table 4.** Bilaterally averaged values for isokinetic peak torque (Nm) and reciprocal strength ratios and ANOVA results for the differences between the three PTA groups in professional soccer players (N=100).

Joint (motion)	Type of contraction (testing speed)	Professional Training Age (PTA)			ANOVA (linear)		ANOVA (quadratic)		ANOVA (omnibus)			
		5-7 years (N=34)	8-10 years (N=30)	$\geq 11$ years (N=36)	F	p	F	p	F	p		
		Knee	Extension	Con 60	231.35	247.85	237.65	.67	.20	3.25	<b>.04</b>	3.16
Con 180	162.9			172.8	168.2	.92	.16	1.95	.08	1.41	.12	
Con 300	132.45			137.2	135.9	.66	.20	.60	.22	.75	.23	
Flexion	Ecc 60		304.45	319.25	311.65	.29	.29	.86	.17	.57	.28	
	Ecc 180		283.75	300.7	293.7	.60	.21	1.02	.15	.80	.22	
	Con 60		129.5	140.5	139.1	3.27	<b>.04</b>	1.85	.08	2.53	<b>.04</b>	
Ankle	Dorsal flexion		Con 180	99.35	107.95	106.15	3.21	<b>.04</b>	2.28	.06	2.71	<b>.03</b>
			Con 300	89.5	98.4	94.25	1.80	.09	2.20	.07	1.44	.12
	Plantar Flexion		Ecc 60	183.3	190.95	201.3	3.77	<b>.02</b>	.18	.33	1.96	.07
		Ecc 180	179.35	188.45	194.05	3.16	<b>.03</b>	.06	.40	1.61	.10	
	Knee Strength Ratios	Conv. ratio	Con 60	23.05	24.555	22.4	.32	.28	3.13	<b>.04</b>	1.74	.09
			Ecc 60	49.65	50.55	48.45	.30	.29	.80	.18	.56	.28
Con 60	109.8		120.7	119.9	3.87	<b>.02</b>	1.17	.14	2.49	<b>.04</b>		
Knee Strength Ratios	Funct. ratio	Ecc 60	209.3	216.15	210	.00	.49	.52	.23	.26	.38	
		60 deg/sec	.555	.570	.585	2.04	.07	.00	.48	1.02	.18	
	180 deg/sec	.605	.625	.630	1.52	.11	.20	.32	.86	.21		
	300 deg/sec	.675	.705	.695	.77	.19	1.19	.13	.96	.19		
	60 deg/sec	.790	.800	.855	2.77	<b>.05</b>	.62	.21	1.69	.09		
	180 deg/sec	1.100	1.095	1.155	1.60	.10	.55	.22	1.09	.16		

Con = Concentric, Ecc = Eccentric, Conv = Conventional concentric knee ratio (Concentric Knee Flexion/Concentric Knee Extension), Funct = Functional knee ratio (Eccentric Knee Flexion/ Concentric Knee Extension).





**Figure 2.** Graphical depiction of trends in bilaterally averaged isokinetic strength among the three groups of professional training age (N=100). **a)** Bilaterally averaged knee extensors concentric strength and **b)** eccentric strength, **c)** bilaterally Averaged knee flexors concentric strength and **d)** eccentric strength.

not being secured for conventional ( $p = 0.07$ ) and being at the limit for functional ( $p = 0.05$ ) ratios at the 60°/sec.

### Isokinetic strength asymmetries

ANOVA on directional asymmetries revealed a significant linear trend ( $p < 0.05$ ) in the 180°/sec and 300°/sec of concentric knee flexion, where players with long PTA had lowest strength asymmetries, while players with short PTA had highest strength asymmetries. A significant quadratic trend ( $p < 0.05$ ) was found in the 60°/sec of eccentric knee flexion. Players with intermediate PTA had highest directional strength asymmetries, while players with short and long PTA had lower strength asymmetries. No significant trends in directional asymmetries (R-L) were found in the other measurements.

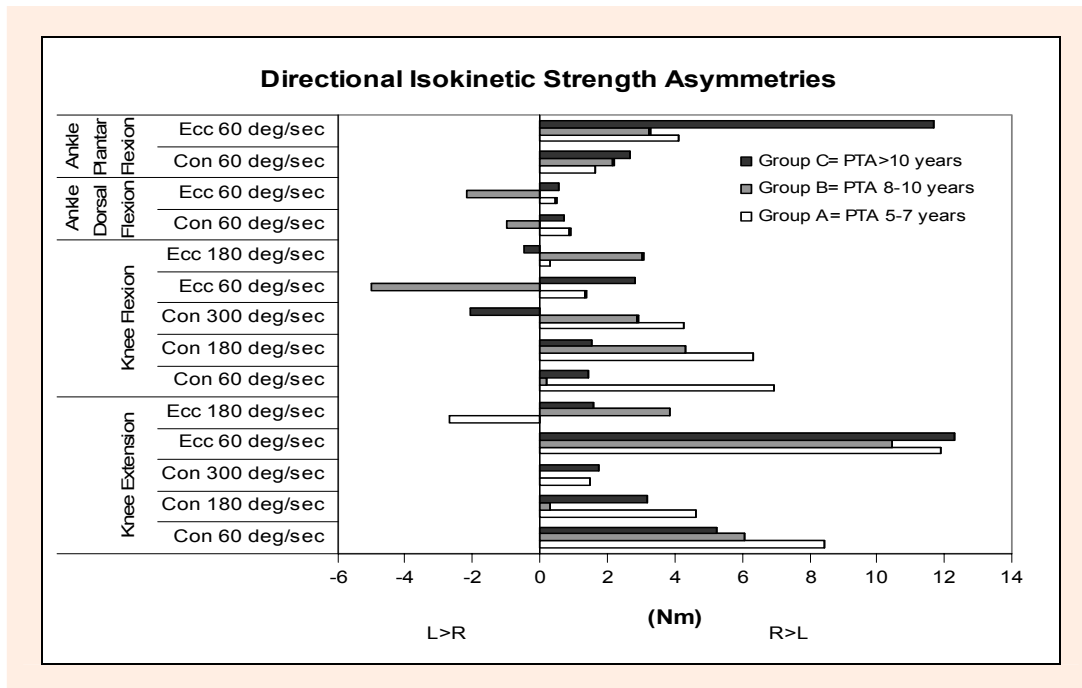
Univariate follow-up analysis of the directional asymmetries (R-L) revealed that in the majority of the measurements the right foot of the players tended to produce significantly higher isokinetic peak torque values than the left (Figure 3). This finding was more evident in players with short PTA at 60°/sec of concentric and eccentric knee extension ( $p < 0.05$ ) and at 60°/sec and 180°/sec of concentric knee flexion ( $p < 0.05$ ). In players with intermediate PTA, knee flexors presented a significant eccentric muscle strength superiority of the left foot for measurements at the 60°/sec ( $p < 0.05$ ). The ankle joint presented more symmetric results in all groups of players with a general trend of no significant directional strength deficits. The only exception was the significant

directional superiority of the right foot in players with long PTA in eccentric plantar flexion of the foot ( $p < 0.05$ ).

Trend analysis of the fluctuating asymmetries (D-ND) revealed similar quantitative and qualitative trends but with no statistical significance (Figure 4). Nevertheless, univariate analysis (paired t-tests with Bonferroni correction) showed that the dominant extremity in players with short PTA was significantly stronger than the non-dominant at the 180°/sec of eccentric knee flexion ( $p < 0.05$ ). The same finding was observed for dominant knee flexion in players with intermediate PTA at 180°/sec of eccentric action ( $p < 0.05$ ). Inter-group comparisons via ANOVA showed that the dominant knee extensors of intermediate PTA players were significantly stronger than those of the short PTA players at the 60°/sec of concentric action ( $p < 0.05$ ).

No significant differences were observed between the three PTA groups in terms of absolute (L-R) asymmetries (Figure 5). As an exception to this trend, players with long PTA had significantly higher absolute asymmetries than players with intermediate PTA in eccentric plantar flexion at 60°/sec ( $p < 0.05$ ).

The analysis of directional asymmetries in knee reciprocal strength ratios showed that, as a trend, in the majority of measurements the right foot of players with short and intermediate PTA had better conventional knee strength ratios than the left one, while the left knee had greater functional strength ratios than the right (Figure 6).



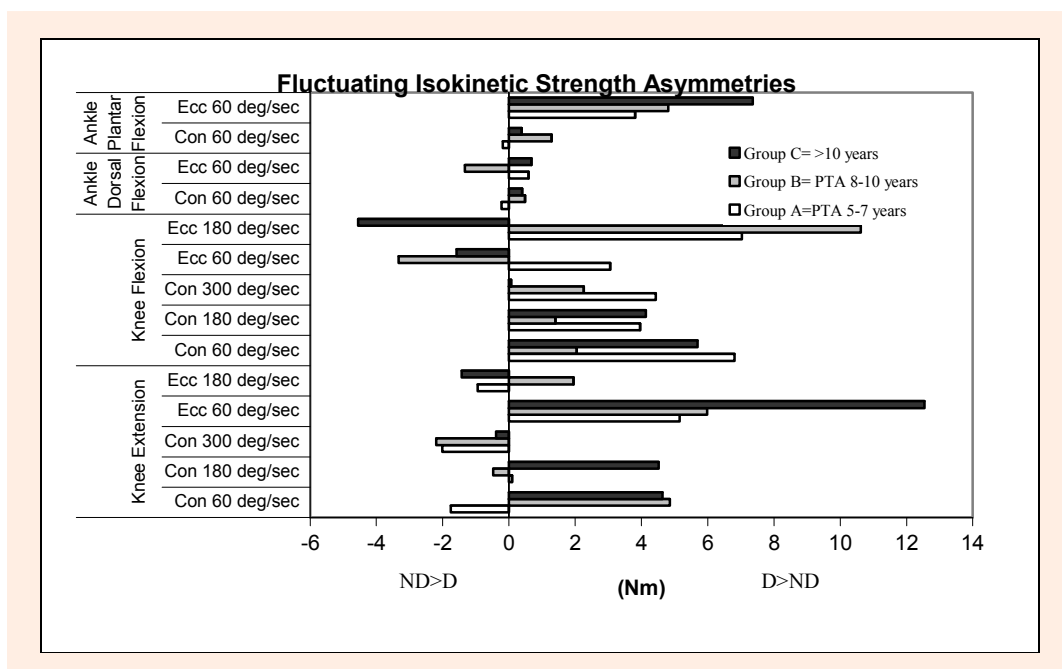
**Figure 3.** Graphical depiction of the Directional (L-R) asymmetries in peak isokinetic torque (Nm) for the three groups of professional training age (N=100) .

This superiority of the left foot over the right one was statistically significant only at the 60°/sec of functional ratio ( $p < 0.05$ ) and only in players with intermediate PTA. On the other hand players with long PTA did not present any significant asymmetry in the conventional or functional type of ratios ( $p > 0.05$ ). Regarding fluctuating asymmetries (D-ND), the dominant knee of players with short PTA had significantly greater conventional knee strength ratio ( $p < 0.05$ ) than the non-dominant at testing speeds of 60°/sec and 300°/sec. Players with intermediate and long PTA did not present imbalanced (asymmetrical) values between the preferred and non-preferred extremity

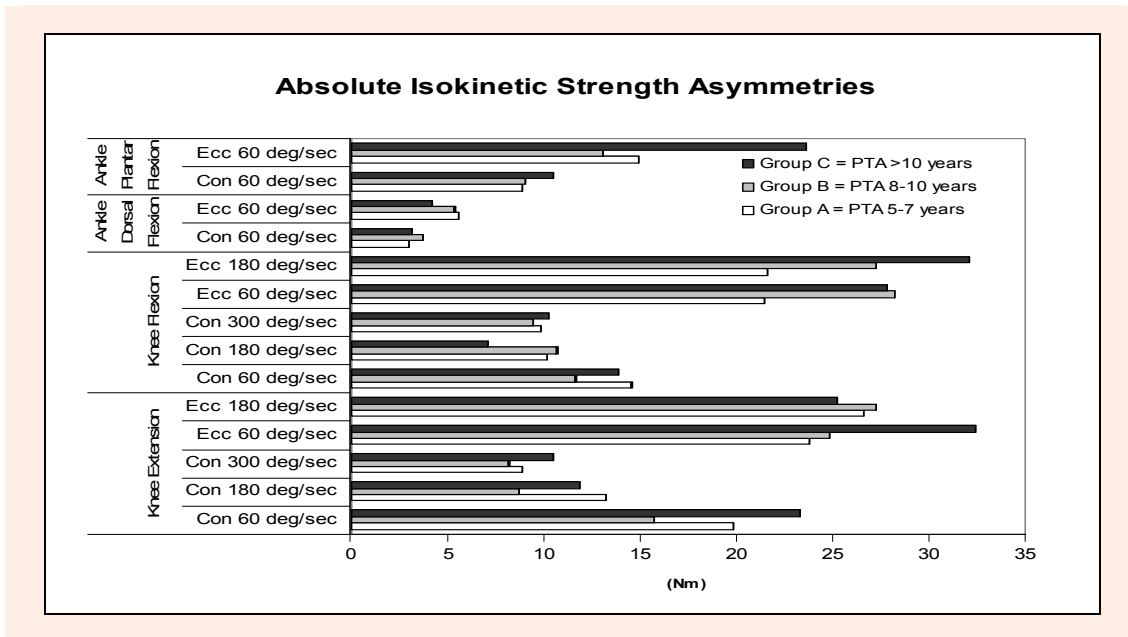
( $p > 0.05$ ). Inter-group comparisons showed that the right knee of players with long PTA had better functional strength ratios ( $p < 0.05$ ) at 60°/sec than players with short and intermediate PTA.

**Discussion**

The present study investigated the muscle strength profile of the lower extremities in three training age groups of professional soccer players by isokinetically assessing bilaterally two joints (Knee-ankle), two types of action (concentric- eccentric) and three testing speeds (60°/sec,



**Figure 4.** Graphical depiction of the Fluctuating (D-ND) asymmetries in peak isokinetic torque (Nm) for the three groups of professional training age (N=100).

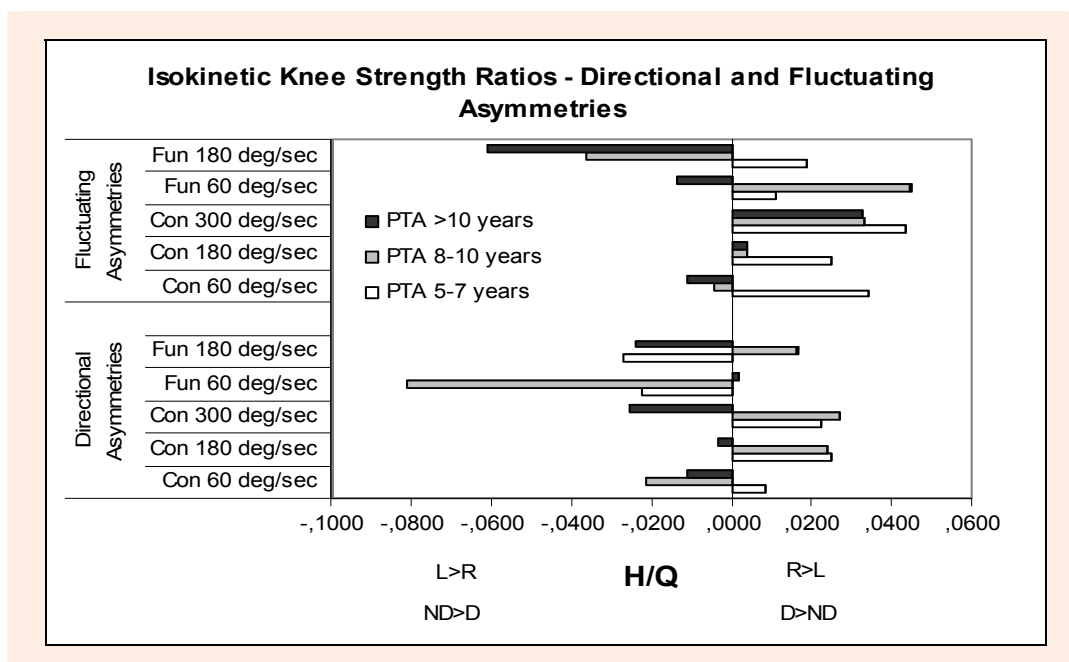


**Figure 5.** Graphical depiction of the Absolute ([L-R]) asymmetries in peak isokinetic torque (Nm) for the three groups of professional training age (N=100).

180°/sec, 300°/sec). The proportions of right, left and mixed footed players in our sample (N=100) are in agreement with those previously reported by relevant epidemiological studies (Mandal et al., 1992; Strauss, 1986).

The findings showed a moderate overall connection between PTA and the composite muscle strength profile of the knee and ankle joint. In general, muscle strength increased from low (5-7 years) to intermediate training age (8-10 years) and stabilized thereafter. Thus, players with intermediate PTA had slightly greater values than players with long PTA in all measurements except for the eccentric measurements of the knee flexors, which increased linearly with PTA. This slight quadratic trend does not confirm previous results suggesting a constant

linear increase in muscle strength with age (Amato et al., 2001; Gur et al., 1999; Kellis et al., 2001; Rochongar et al., 1988), with this dissimilarity being at least partially attributed to methodological variation. For example in previous studies smaller number of players were tested (n = 25) and split in two groups (Gur et al., 1999) or the players tested had an age-range not covering the full chronological range of professional career in soccer (Kellis et al., 2001; Rochongar et al., 1988). Our players represented almost equally the short (5-7 years), intermediate (8-10 years) and long (≥11 years) professional training age. The European Union Football Association (UEFA, 2009) age bracket classification criteria classifies players as either young (≤21 years) or adults (>21 years).



**Figure 6.** Graphical depiction of the directional (R-L) and fluctuating (D-ND) strength asymmetries in conventional (con) and functional (fun) reciprocal strength ratios (H/Q) for the three groups of professional training age (N=100).

Therefore in our sample the short PTA group is considered as young and the other two groups as adult players.

Our players had low conventional and functional ratio values at slow isokinetic speeds but sufficient at higher speeds. Comparisons with the literature regarding the knee strength ratio, can only be made partly, since only one study of similar design is found in the literature. (Voutselas et al., 2007). Its findings show that the training age of the players has a small effect on the strength balance of knee extensors and flexors of the preferred leg, with the older players being possessing a better conventional ratio in their dominant extremity. In our study, reciprocal knee strength ratios improved along with increased PTA. Players with long PTA had greater values than the other two age groups of players in the majority of conventional and functional isokinetic strength ratios. In particular, their right extremity had a significantly higher functional strength ratio than the other two groups at 60°/sec. This finding is in agreement with the results of Gur et al. (1999), who reported a significantly higher functional ratio at 300°/sec for the dominant knee of adults players compared to young ones, with this being attributed to the training background rather than the effects of the training age per se. On the other hand, Kellis et al. (2001) found no significant effect of chronological age on the functional isokinetic ratio in 158 young soccer players grouped by age.

The directional (R-L), fluctuating (D-ND) and absolute (Max-Min) asymmetries found in this study verify that soccer players tend to be asymmetric in their lower extremities. Players with long PTA presented lower directional strength asymmetries than the other two groups of players in the concentric action of knee flexors, while no significant difference was observed regarding all other measurements. As a trend the right foot tends to produce significantly higher isokinetic peak torque values than the left in the majority of the measurements for both the knee and ankle joint and this can be explained by the high percentage of right-footed players (74.0 %) in the sample. Another explanation can be credited to the different kinetic patterns adopted by that left footed players in general. Left-footed athletes tend to be using both feet almost equally, while right-footed athletes make use mainly of their right foot for most unilateral sport skills and in a more definite manner (Geschwind and Galburda, 1985; Zakas, 2006).

In addition, strength adaptations in favour of the dominant extremity are in general apparent in most strength measurements and PTA groups. This phenomenon was mainly reflected at the slow concentric isokinetic speeds of knee extensors in the present study. The dominant knee extensors of the intermediate PTA players were significantly stronger than the low PTA players at the 60°/sec of concentric evaluation, and this can be attributed to the lateral preference in the use of the lower extremity which probably increases from the short to intermediate PTA.

Contrary to our primary hypothesis that the longer a player is trained under asymmetrical patterns the more asymmetric will get, our adult players and, especially,

players with professional training equal or greater than 11 years possess smaller strength asymmetries and better strength ratios at the knee joint. Especially, the finding that the directional (R-L) strength asymmetries of the players presents a clear decline between intermediate and long PTA level, as evidenced mainly at the concentric function of the hamstrings, seems to be a novel one. Furthermore, higher bilaterally averaged eccentric muscle strength of the knee flexors and better reciprocal strength ratios in players with long PTA as compared with younger players suggest a greater potential for functional joint stability. These results are grossly in line with previous findings suggesting that older players tend to possess a better conventional (Voutselas et al., 2007) or functional (Gur et al., 1999) ratio in their dominant lower extremity. It appears that ultimately a more balanced use of the lower extremities is adopted by soccer players with rather high training experience, possibly as preventative neuromuscular strategy against over-fatiguing and injury. Strength asymmetries were more prevalent in players with short and intermediate training-age probably due to reduced ability to coping with the pre-existing myodynamic asymmetries, as a result of incomplete maturation of their kinetic and neuromuscular patterns

Given the fact that several investigators (Croisier et al., 2008; Devan et al., 2004; Ekstrand and Gillquist, 1983; Knapik et al., 1991; Poulmedis, 1988) identified a relation between strength asymmetries and injuries, these strength adaptations in players with high PTA seems to correlate with lower risk of soccer injuries. In that respect, for example, Poulmedis (1988) suggested that muscle asymmetries and imbalances in the thigh can lead to muscle injuries and increased knee laxity. In addition, significant aetiological factors for soccer injury includes strength deficits in knee extensors and knee joint instability (Ekstrand and Gillquist, 1983), muscle imbalances between extensors and flexors of the knee (Devan et al., 2004) and large eccentric strength asymmetry ( $\geq 15\%$ ) between the lower extremities (Croisier et al., 2008; Knapik et al., 1991). The present study provides a thorough myodynamic profile of a large sample of professional soccer players and can constitute the basis for a more systematic investigation of its connection to injury along with a partial explanation of certain injury predisposing factors in soccer.

## Conclusion

Soccer practicing and competition at the professional level induces critical strength adaptations in the function of the knee and ankle musculature. Bilaterally averaged peak torque values seem to be maximized at the professional training age of 8 to 10 years, whereas a leveling or even slight decline is established in higher ages. Isokinetic strength asymmetries and reciprocal strength ratios imbalances tend to be more prevalent in players with short and intermediate training - age, while players with high professional training experience adopt a more symmetric use of their lower limbs

Further research may focus on prospectively analyzing the possible connection between strength adapta-



tions in soccer players of different professional ages and the development of specific soccer injuries. This will contribute to determining potential injury risk due to professional age - related muscle strength adaptations and it will enable the individualization of specific training and rehabilitation programs in the game.

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### Key points

- Muscle strength increased from the low (5-7 years) to the intermediate professional training age (8-10 years) and stabilized thereafter.
- Soccer practicing and competition at the professional level induces critical strength adaptations (asymmetries) regarding the function of the knee and ankle musculature.
- Soccer players with long professional training age showed a tendency for lower isokinetic strength asymmetries than players with intermediate and short professional training age.

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