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Section I – Kinesiology

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Assessment of Lower Body and Abdominal Strength in Professional Soccer Players

by
Marcos A. Michaelides[1], Koulla M. Parpa[1], Anthos I. Zacharia [1]

The purpose of this study was to evaluate abdominal strength in professional soccer players and compare the findings to their lower body strength. An observational design was used to examine abdominal and lower body strength using two functional performance tests (a lower body isokinetic test and an isometric abdominal test, respectively). One hundred and thirty-two professional male soccer players from Cyprus's first and second divisions participated in this study. Testing included three and twenty-five maximal concentric flexion and extension repetitions at angle speeds of 60°/s (degrees/second) and 300°/s, respectively. On a separate occasion, participants completed two trials on an isometric device (ABTEST Gen. 3 system) for evaluation of abdominal strength. At both isokinetic speeds of 300°/s and 60°/s, abdominal strength had low to moderate significant correlations (p < .05) with quadriceps and hamstring strength. Coefficients of determination (R2) demonstrated that the variability in isokinetic variables accounted for only 14-16% of the variability of abdominal strength. Abdominal strength appears to be high in professional soccer players, but is not dependent on the sports level and/or a playing position. The results of this study demonstrate that abdominal strength and knee joint strength need to be evaluated separately.

Key words: *soccer, fitness testing, isokinetic strength.*

Introduction

Soccer is considered a physically demanding sport that requires a basic element of strength and power (Carling et al., 2009; Kalinowski et al., 2019). To ensure stability of the spine in order to produce force, trunk muscles must have sufficient strength, endurance, and the appropriate recruitment patterns (Brown et al., 2006). The core of the body is commonly referred to as the foundation of all limb movement (Akuthota, 2004); the trunk muscles contract to prepare the body for the postural disturbances provoked by lower body movements (Hodges and Richardson, 1997). This occurs through regulated reactive contractures that increase intra-abdominal pressure, which in turn stabilizes the spine (Essendrop and Schibye, 2004; Hodges et al., 2003). The reactivity of the trunk muscles is a response to the high forces exhibited by the lower body movement onto the spine and is proportional to the inertia of the limbs (Hodges and Richardson, 1997). Furthermore, the level of stability and kinematic response of the trunk depends on the mechanical stability level of the spine and the reflexive activation of the trunk muscles prior to applying force to the body (Cholewicki et al., 1991). Possessing high core stability is crucial for soccer players, who often use their lower limbs, mainly unilaterally, for actions such as kicking, jumping, and dribbling (Reilly et al., 2000). The excessive loading on the trunk in soccer occurs during shooting or fighting for the ball (Dvorak and Junge, 2000).

Video analysis has demonstrated that soccer players are often involved in high intensity activities that require significant levels of lower body strength (Schuth et al., 2016). The frequent unilateral use of the limbs in soccer (Reilly et al., 2000) may result in strength deficits between the two limbs, and thus increase the rate of musculoskeletal injuries in elite soccer players (Croisier et al., 2008; Dauty et al., 2016). Furthermore, Ezechieli et al. (2013) demonstrated

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that soccer specific training did not lead to balanced trunk musculature and core stability, and thus increased the chance of injury, muscle imbalance, and triggered pain syndromes. Groin injuries are among the most common injuries in soccer (Elattar et al., 2016), which could possibly be the result of an imbalance between the comparatively strong hip adductor muscles and the weaker lower abdominal muscles (Anderson et al., 2016). In particular, during soccer related activities, the forceful pull of the adductors against a fixed lower extremity in the presence of relatively under-conditioned abdominal muscles creates a shearing force across the hemipelvis; this results in a muscular overload with subsequent weakening or tearing of the abdominal muscle group (Anderson et al., 2016). Although core fitness (McCall et al., 2014) and lower body strength (Fousekis et al., 2010) are of high importance in soccer, to our knowledge, there are no studies evaluating abdominal strength in professional soccer players. The various tests that evaluate abdominal fitness are mainly measuring abdominal muscular endurance (Robertson and Magnusdottir, 1987), rather than strength. Additionally, these muscular endurance tests demonstrated low to moderate relationships to an isokinetic abdominal strength test, as suggested by Hall et al. in 1992. The Abdominal Test and Evaluation Systems Tool (ABTEST) is a valid and reliable method that effectively and accurately assesses core strength (Glenn et al., 2015). This system has previously been used to evaluate abdominal strength in female athletes (Brown et al., 1999) and firefighters (Michaelides et al., 2011). To our knowledge, there are no studies examining abdominal strength in professional soccer players. Thus, the purpose of this study was to evaluate abdominal strength in professional soccer players and determine its relationship with lower body strength.

Methods

Participants

Professional male soccer players (n = 132) (Mage = 25.27 ± 4.37 years, Mheight = 178.88 ± 6.84 cm, Mweight = 77.80 ± 8.02 kg) participated in this study. The participants were selected from two different playing levels in Cyprus (divisions 1 and 2) (Table 1). All participants signed an informed consent form, and the procedures were approved by the ethics committee board (reference number STEMH 541) and by the National Committee on Bioethics (CNCB). An observational design method was used to examine abdominal and lower body strength of professional soccer players. Their performance was assessed through two functional performance tests (a lower body isokinetic test and an isometric abdominal test, respectively). The functional tests were performed on two different occasions to avoid potential fatigue from subsequent testing. All participants were advised to abstain from any activity the day before testing. Measurements were obtained between 8:00 am and 5:00 pm. Each player was tested separately and verbally encouraged to give maximal effort during the functional performance tests. All participants were healthy and reported no recent musculoskeletal injuries. Anthropometric measurements included height (wall stadiometer), body mass, body mass index, and percent body fat (Bioelectrical Impedance, BC 418 MA, Tanita, Japan).

Design and Procedures

The isokinetic muscle function of the knee joint was determined using the Humac Norm Testing and Rehabilitation system (CSMi Medical and Solution, USA) isokinetic dynamometer. A 10-min warm up (100 watts at 70 rpm) on a mechanically braked cycle ergometer (Monark 894 E Peak Bike, Weight Ergometer, Vansbro, Sweden) was required prior to testing. The participants were tested in a seated position with the thigh at an angle of 1100 to the trunk, and the mechanical axis of the dynamometer aligned with the knee lateral epicondyle. The knee range of motion was set at 110° (0° of extension to 110° of flexion). The thigh area and the upper body were tightly fixed using the device's belts. The shin pad attachment was placed approximately 2 cm proximal to the player's lateral malleolus. The participants performed five sub-maximal repetitions of concentric knee flexion and extension for familiarization at speeds of 60°/s and 300°/s, respectively. Testing included three and twenty-five maximal concentric flexion and extension repetitions at angle speeds of 60°/s and 300°/s, respectively.

On a separate occasion, participants completed two trials on the ABTEST Gen 3 system (Arkansas, USA) (Figure 1). A 5-min rest between trials was provided to allow full recovery. Before

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testing, a goniometer (Lafayette Instrument Guymon Goniometer, Model 01129, IN, USA) was used to verify that participants were placed with knees and hips at a 90° angle, respectively. The footrest was adjusted accordingly based on the stature of the participant. The force transducer belt was firmly fixed directly over the xiphoid process, which was located by palpation. The arms were crossed over the transducer pad, and the hands were placed on the opposing acromion processes throughout the entire testing procedure. The participants were instructed to inhale normally and then exhale slowly while exerting a maximal isometric contraction against the force transducer pad. This technique was used to avoid the Valsalva manoeuvre and to prevent possible ballistic movements. The investigators waited approximately 2 s for the participants to reach maximal isometric contraction before starting the 10-s graphic recording. The ABTEST software automatically recorded the 10-s isometric contraction and displayed the results in a graphic form with the abscissa reflecting time in seconds and the ordinate scale force in kg. Maximal force was measured in kg, the fatigue Index (FI) represented the loss of force over the 10-s testing period and the power represented the area under the curve. Since there was no movement during this isometric test, the power index did not receive a unit of measurement.

The sit and reach test was used to obtain flexibility measurements for lower back and hamstring muscles. A traditional box (32.4 cm high and 53.3 cm long) with a 23 cm heel line mark was used to obtain the measurements. The participants sat in front of the test apparatus barefoot with knees fully extended and the heels placed against the box. To ensure complete leg extension, the investigators held one hand lightly against the participant's knees. The participants placed their hands on top of each other, palms down, and slowly bent forward along the measuring scale. The forward hold position was repeated twice. The third and final forward stretch was held for 1 to 2 s and the score along the measuring scale was recorded to the nearest cm.

Statistical Analysis

SPSS V24 (SPSS Inc., Chicago, IL, USA) was used for analysis of the results. The Shapiro-Wilk and Brown and Forsythe's tests were used to verify approximately normal statistical distributions and homogeneity of variance. Descriptive statistics, such as the means and standard deviations (SD), were calculated for all the variables. The level of significance was set at $p \leq .05$. For analysis purposes, the participants were divided into five groups based on the playing position. The five playing positions included goalkeepers (GK) (n = 13), defenders (D) (n = 36), full backs (FB) (n = 14), midfielders (MF) (n = 43), and forwards (FW) (n = 25). The results were analysed using a one-way ANOVA between-subjects design to determine the effect on the playing position. The independent t-test with the Levene's equality of variance test was used to compare the participants of the two playing levels (divisions 1 and 2). The Pearson Product Moment correlation coefficient was used to determine the inter-correlations among measurements of isokinetic testing, low back and hamstring flexibility, and abdominal testing. A 95% confidence interval (CI) for the mean scores was determined from the difference between means for each variable (see Tables 2 and 3 for the participant's performance statistics).

Results

Independent t-test analyses demonstrated significant differences among playing divisions, with participants playing in division-1 exhibiting significantly greater scores in isokinetic testing. Specifically, division-1 players demonstrated significantly ($p < .05$) higher scores for the left quadriceps (isokinetic speed of 60°/s). At the isokinetic speed of 300°/s, division-1 players demonstrated significantly ($p < .05$) higher scores for quadriceps and hamstrings in both right and left legs (Table 2). In division-1 players, abdominal strength and power were higher, but not significantly. In division-1 players, the fatigue index was lower, but not significantly (Table 3). The Levene's equality of variance test demonstrated equal variances for all the variables used.

At isokinetic speed of 60°/s, abdominal strength had a low to moderate significant correlation ($p < .001$) with quadriceps and hamstring strength in both right and left legs. In addition, abdominal strength had a low, but significant correlation ($p < .05$) with left quadriceps and right hamstring strength at isokinetic speed of 300°/s. A low to moderate significant correlation ($p < .001$) was also demonstrated between abdominal strength and

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low back and hamstring flexibility (Table 4). The coefficient of determination (R2) demonstrated that the variability in isokinetic variables accounted for only 14-16% of the variability of the abdominal strength. The ANOVA results demonstrated no significant differences among professional players in all fitness testing variables based on the playing position.

Table 1

Participants' Characteristics

	Sports level	*n*	*M*	*SD*	*p*	95% *CI*	
Age (years)	D1	73	25.42	4.41	0.66	1.18	1.86
	D2	59	25.08	4.37			
Body height (cm)	D1	73	179.10	6.65	0.69	1.89	2.86
	D2	59	178.62	7.13			
Body mass (kg)	D1	73	78.18	7.69	0.549	1.94	3.63
	D2	59	77.33	8.46			
Body fat (%)	D1	73	11.37	3.42	0.200	0.42	2.02
	D2	59	12.18	3.68			

Note. D1-division 1; D2-division 2

Table 2

Lower Body Fitness testing in Professional Soccer Players

	Playing standard	n	Mpeak torque (Nm)	SD	p	95% CI		ES
Right quadriceps (60°/s)	D1	72	248.42	39.99	0.200	5.34	25.22	0.11
	D2	59	238.59	47.80				
Left quadriceps (60°/s)	D1	72	244.92	38.41	0.012*	4.04	32.61	0.21
	D2	59	227.47	44.41				
Right hamstrings (60°/s)	D1	72	177.85	31.30	0.136	2.67	19.40	0.12
	D2	59	169.93	32.11				
Left hamstrings (60°/s)	D1	72	175.32	28.22	0.458	6.87	15.17	0.13
	D2	59	171.17	35.54				
Right Quadriceps (300°/s)	D1	71	137.62	37.44	0.015*	2.71	24.91	0.22
	D2	59	123.98	22.75				
Left quadriceps (300°/s)	D1	72	133.51	33.33	0.09	3.43	23.68	0.23
	D2	56	120.21	20.88				
Right hamstrings (300°/s)	D1	71	108.48	28.26	0.019*	1.8	19.72	0.20
	D2	59	97.97	21.90				
Left hamstrings (300°/s)	D1	72	108.76	25.08	0.014*	2.06	17.93	0.21
	D2	56	99.34	19.04				

Note. D1 division 1; D2 division 2;
Concentric at isokinetic testing at speeds of 60°/s and 300°/s

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Table 3

Abdominal Performance Characteristics in Professional Soccer Players

	Playing standard	*n*	*M*	*SD*	*p*	95% *CI*		ICC
Abdominal strength (kg)	D1	69	54.40	9.92	0.540	-2.19	4.17	0.912
	D2	56	53.41	7.53				0.891
Power (AUC)	D1	68	4279.13	793.06	0.233	-103.64	421.16	0.857
	D2	54	4120.37	633.92				0.812
FI	D1	68	21.96	9.52	0.385	-4.60	1.79	0.873
	D2	55	23.36	8.06				0.825

N D1 NNote. D1 division 1; D2 division 2; AUC Area under the curve;
FI Fatigue index; ABTEST consisted of 10 s maximal isometric contraction.

Table 4

Intercorrelations between Performance Measures

	AbS.	POWER	RQ300	RH300	LQ300	LH300	RQ60	RH60	LQ60	LH60
AbS.	1	0.94**	0.14	0.19*	0.19*	0.14	0.36**	0.27**	0.39**	0.24**
Power		1	0.18	0.19*	0.23*	0.16	0.34**	0.24**	0.37**	0.22*
RQ300			1	0.80**	0.84**	0.72**	0.48**	0.38**	0.31**	0.30**
RH30				1	0.68**	0.78**	0.51**	0.59**	0.40**	0.42**
LQ300					1	0.84**	0.41**	0.42**	0.80**	0.38**
LH300						1	0.38**	0.49**	0.46**	0.52**
RQ60							1	0.68**	0.70**	0.50**
RH60								1	0.62**	0.71**
LQ60									1	0.66**
LH60										1

*Note. *p < .05 **p < .001; AbS.-abdominal strength; Power abdominal power production;*
FI-abdominal fatigue index; RQ-right quadriceps; RH-right hamstrings; LQ-left quadriceps;
LH-left hamstrings; Flexibility-low back and hamstrings flexibility;
300-isokinetic speed of 300°/s; 60-isokinetic speed of 60°/s.

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Figure 1
Abdominal test and evaluation systems tool (ABTEST version 3) device used for the evaluation of abdominal strength.

Discussion

The purpose of this study was to assess abdominal strength of professional soccer players and determine its relationship with lower body strength. The knees flexion and extension isokinetic values reported in the current study are in line with previous reports (Fousekis et al., 2010). Isokinetic testing in soccer players is a frequent routine procedure for fitness evaluation, but it is not always predictive of soccer functional performance (Requena et al., 2009). However, isokinetic testing is considered a valid and reliable tool for assessing lower body muscle performance and asymmetries that could lead to musculoskeletal injuries (Dauty et al., 2016). In addition to the hip adductor muscle group, professional soccer players exhibit the highest injury rate on quadriceps and hamstrings muscle groups (Hagglund et al., 2012). On the contrary, abdominal strength testing is not a routine procedure, as the tests used to evaluate the fitness level in this area mainly examine the ability of the muscles to sustain repeated contractures, thus, are actually measures of muscular endurance. Although there are no studies on professional soccer players for comparison, the values recorded in this study are higher than other populations who underwent similar testing. Glenn et al. (2014) demonstrated normative data on the same device

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in American and Korean populations. The values on 284 males from US and Korea were approximately 26 and 20 kg of maximal isometric effort for Korean and US males, respectively. The maximal efforts of the professional soccer players in this study were 54.40 and 53.41 kg for divisions 1 and 2, respectively. The large differences observed could be because of the use of non-athletic populations, with a large age range (Glenn et al., 2014). The Korean male population was significantly older compared to American participants. The results of another study (Michaelides et al., 2011) on the ABTEST demonstrated that abdominal strength of firefighters was similar to the values of this study. The reported values were significantly related to firefighting performance, wherein the best performers demonstrated an average value of 46.83 kg of maximal abdominal strength. The older and poorer firefighter performers demonstrated values of approximately 27 kg. The study (Glenn et al., 2015) that validated the ABTEST used younger adults in their low 20s, but the values reported were also lower compared to the professional soccer players. Thus, it is safe to assume that professional soccer players possess high abdominal strength.

The low to moderate correlations indicate that lower body strength and abdominal strength are associated. However, the coefficient of determination values are small, which indicates that only a small fraction in the fluctuation of abdominal strength is predictable from lower body strength. The reason for this could be that soccer related activities and competition at the professional level induce critical strength adaptations in the function of the knee strength (Fousekis et al., 2010); in contrast, it does not lead to balanced trunk musculature and core stability (Ezechieli et al., 2013). Thus, failure of a weak trunk musculature to react and support the core of the body during forceful movements of the lower limbs, such as in soccer, may have detrimental effects and could lead to severe musculoskeletal injuries (Elattar et al., 2016). Having said that, a major limitation of this study is the lack of other trunk muscle strength measurements, such as the lower back musculature.

The results of this study demonstrated no positional differences among professional soccer players in regard to functional testing. Similar to these findings, Ruas et al. in 2015 demonstrated no positional strength differences among professional soccer players with regard to isokinetic testing. Although soccer players vary in functional and anthropometric characteristics according to their playing position, a possible explanation for the lack of differences in these functional variables is the ability of the utility players to physically and technically adapt to game position or interchanging demands (Schuth et al., 2016). There is limited literature concerning the physical characteristics of soccer players playing in different divisions. Similar to this study, Metaxas et al. (2009) presented isokinetic results of soccer players for four different playing divisions during preseason training. Although their study compared soccer to basketball athletes, the results presented have similar trends to this study with values greater among athletes from higher playing levels for both 60 and 300°/s. Their results on divisions 1 and 2 were higher than those of this study for quadriceps at 60°/s, but lower for hamstrings at 60°/s, and lower at 300°/s for both quadriceps and hamstrings groups. To quantify the functional variables, participants in this study were evaluated at the beginning of the preseason period, which is the time of the year that players return from an extended period of inactivity. The differences observed between division 1 and division 2 players, particularly for isokinetic testing, could be attributed to the different transition time allowed between the two playing divisions. Division 1 in Cyprus has a shorter transition period than division 2, since the competitive season starts earlier (end of August). In addition, division 1 teams who participate in the European league qualification rounds have even shorter transition periods. Thus, the large transition time for division 2 allows for more inactivity, and consequently, detraining effects are maximized. However, most professional soccer players follow an individualized training regimen prescribed by their fitness coaches. Their activities during the transition rest period were not recorded, supervised, or organized, and thus it is considered a limitation. Further investigation is needed to determine the seasonal variations in abdominal and lower body strength and their impact on performance. In addition, it would be interesting to investigate if the ABTEST could be used as a predictive tool for future groin and back

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injuries, especially in professional soccer players.

In summary, this study examined for the first time the abdominal strength of professional soccer players, and the results demonstrated high abdominal strength compared to results from other populations (Brown et al., 1999; Glenn et al., 2015; Michaelides et al., 2011). Abdominal strength appears to be non-dependent on the sports level and/or a playing position. The poor coefficient of determination is an indication that abdominal strength and knee joint strength need to be evaluated separately. Further investigation would allow for normative data on soccer players and a diagnostic tool for predicting possible groin injuries.

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