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ORIGINAL ARTICLE

EVALUATING RELATIONSHIP BETWEEN ISOKINETIC MUSCLE STRENGTH AND DIFFERENT KICKING TECNIQUES BALL VELOCITIES IN SOCCER

Abstract

The aims of this study are to identify isokinetic strength and different kicking techniques ball speed differences between professional and amateur soccer players and to identify the relationship between isokinetic knee extensions, flexion strength parameters with soccer kick ball speed during six different kicking techniques in amateur and professional soccer players. 10 (age: 23.10±2.64) professionals and 17 (age:23.38±2.96) amateurs, volunteered to participate the current study. Professionals produced a significantly higher ($p<0.05$) ball speed than amateurs in 5 kicks types (inside, lofted, instep, outside, outside curve). As a consequence the flexor/extensor (H/Q) ratio was significantly higher in professionals than amateurs. However, there were no significant differences between professionals and amateurs although amateurs tended to have a lower knee flexion peak torque over all speeds. For the professionals, none of the muscle torque data correlated significantly with ball speeds while significant correlations were found between different isokinetic angular velocities with different ball speeds in amateurs. In conclusion, ball velocities differ according to kick types and the resultant ball velocities occurs regarding knee extensor and especially flexor strength in amateurs; however; the resultant ball velocity of professional soccer players could have occurred other factor regarding techniques rather than strength parameters. Therefore, additional strength training is recommended against a resistance while the ankle, knee and hip movement represent the kicking techniques in order to train specific kicking motion strength generation.

Keywords: Extensor-flexor strength, professional, amateur

INTRODUCTION

It is important to achieve a highball speed in soccer kicking, since this gives the goalkeeper less time to react, thus improving one' s chances of scoring (Dorge et al., 1999). In this sense, the soccer kick is one of the important performance criteria because it directly contributes game results. Several studies have investigated the relationship between isokinetic peak torques and in-step soccer kick performance; however; some of these have found a correlation (Cabri et al., 1988; De Proft et al., 1988b; Narici et al., 1988; Luhtanen, 1988; Poulmedis et al.,1988; Anderson and Sidaway, 1994; Mognoni et al., 1994) while others have not (Mc Lean and Tumilty, 1993; Saliba and Hrysomalis, 2001; Masuda et al., 2005). These conflicting findings could be caused through the use of different protocols, but also from using subjects of different ability levels. On the other hand biomechanical studies concerned with ball speed and kicking distance have revealed that lower limb and/or toe velocity are important determinants of kick performance and muscle strength is directly responsible for increasing the speed of the foot (Dorge et al. 1999, Lees and Nolan, 1998; Kellis et al. 2006). However; Asami and Nolte (1983) reported an interesting perspective that the relationship between ball speed and knee extensor strength in the kicking leg might depend on the skill level of the players, and suggested that the muscular strength of the knee extensor has less influence on ball speed in soccer players with higher skills. With parallel to this study, Cerrah et al. (2011) analyzed EMG characteristic and isokinetic strength values relationship with ball velocities between professional and amateur soccer players and stated that the superior performance of professional players compared to amateurs appears not to be due to muscle strength factors but rather to subtle differences in technique throughout both the build up and execution of the kick. In practical terms this means that once players have developed suitable muscle strength, further enhancement in performance would come from practice rather than greater strength development.

Although previous studies have already presented some evidence relating to relationship between isokinetic strength and in-step kick performance, the isokinetic and ball velocity relationship differences in different soccer kick techniques between amateur and professional soccer players have not been equally investigated. It is known that when the kick types change (from inside to outside), the movement of the ankle, knee and hip movement changes, thus the contributed muscles differ. Therefore, the primary aims of this study is (1) to identify isokinetic strength and different kicking techniques ball speed differences between professional and amateur soccer players (2) to identify the relationship between isokinetic

knee extension, flexion strength parameters with soccer kick ball speed during six different kicking techniques in amateur and professional soccer players.

METHODS

Subjects

Two groups of male soccer players, 10 professionals (1. division: 2, 2. division: 2, 3. Division: 6) and 17 amateurs (Super Amateur: 13, 1. Amateur: 4), volunteered to participate the current study. Their descriptive statistics are summarized in Table 1. None of the subjects had any previous injury of their lower limbs. The investigation was approved by the local University Ethics Committee.

Table 1: Descriptive statistics for players

Players (n)	Age (years)	Athletic History (years)	Position				Kicking Leg	
	mean±SD	mean±SD	GK	D	MF	F	Right	left
Professional (10)	23.10±2.64	12.80±2.94	1	2	3	4	12	2
Amateur (17)	23.38±2.96	12.63±2.63	1	4	7	5	12	5

GK=goal keeper, D=defence, MF=midfielder, F=forward.

Soccer Kick Tests

The soccer kick test was performed in an indoor sport area. Following a warm up (10 min jog) and 5 soccer specific dynamic stretching exercises (10 min), players performed the inside kick (IK) (0-10^0 approach angle), lofted kick (LK) (0-10^0 approach angle), inside curve kick (ICK) (30-45^0 approach angle), instep kick (INK) (0-10^0 approach angle) outside kick (OK) (0-10^0 approach angle) and outside curve kicks (OCK) (30-45^0 approach angle). Inside kick was performed with one step and the rest of the kicks were performed with two steps to a stationary ball towards a target (width 3.00 m, height 2.44 m) 15 m away with a full size (number 5) soccer ball approved by the International Football Federation (Cerrah et al. 2011). Ball pressures were adjusted to 11 psi with a pressure measurement device (Rucanor, Netherland). Subjects were asked to kick the ball with maximal velocity so as to strike a target and accurate 3 kicks were analyzed. Ball speed was measured by a radar gun (Bushnell Velocity Speed Gun, USA) held behind the goal.

Isokinetic Strength Test

The isokinetic tests were performed 30 min after the kick test. A 5-min warm-up consisting of cycling (Monark) preceded the actual test. Concentric isokinetic strength of the knee extensors, flexors and flexor/extensor ratio (H/Q) of the kicking leg were measured using the CSMI-Humac/Norm^{TM} -770 model (Humac Norm Testing and Rehabilitation System, USA). Concentric strength was considered representative of a player's strength and high levels of eccentric strength are not thought to be required during the preparatory and action phases of the kick. The dynamometer was calibrated prior to the testing session according to the procedures prescribed by the manufacturer. Measurements were made with the subjects in the sitting position, trunk fixed to the chair by a belt. The pelvis and thorax were firmly strapped to avoid movement. The thigh was strapped in place above the knee. The dynamometer rotation axis was adjusted to correspond to the femoral condyle axis and the lever arm was secured 10 cm above the ankle (Cerrah et al. 2011). The range of motion for the knee was from 100° to 0° (Kellis and Katis 2007). Muscle strength was measured at angular velocities of 60, 180, 240 and 300 °.s^{-1} (Cometti et al., 2001). Angular velocities were adjusted randomly for each subject. For each test, three submaximal efforts were performed for familiarization before the maximal test. A 30 s rest period was given between the submaximal and maximal tests and between changes in angular velocities. Five trials at each velocity were performed and the maximal peak torque for knee extension, flexion and hamstring/quadriceps ratio was registered by the Humac® (2004) via computer (4.5.5 version, CSMI, USA) and the best value used as the outcome measure.

Statistical Analysis

Descriptive statistics were applied to identify the characteristics of the subjects and groups. Mean scores were calculated for each subject's three kicks from each type of kicks and averaged across each group. Ball velocities are expressed as mean ± SD. A T-test was used to compare ball velocities in each type of kicks and isokinetic peak torque values between groups. To evaluate the relationship between ball velocities and isokinetic peak torque, Pearson's correlation coefficient was calculated. The level of significance was set at $p<0.05$.

RESULTS

Kick Performance Results

Professionals produced a significantly higher ($p<0.05$) ball speed than amateurs in 5 kicks types (inside, lofted, instep, outside, outside curve). The only significant differences did not occur during inside curve kick; despite the ball speed was higher in professionals (91.8±8.9) than amateurs (86.9±5.1) (Table 2).

Table 2: Ball speed of professional and amateur soccer players in six different kicking techniques

		Professional (n=14)	Amateur (n=17)
	Kick Techniques	Mean±SD	Mean±SD
Ball Velocities ($km \cdot h^{-1}$)	Side-foot	**82.0±3.6***	76.6±3.9
	Lofted	**93.3±9.6***	88.7±4.5
	Inside Curve	91.8±8.9	86.9±5.1
	In-step	**99.5±4.7****	90.6±5.5
	Outside	**89.9±6.8****	82.7±6.1
	Outside Curve	**83.8±5.5****	77.4±4.8

*: $p<0.05$, **: $p<0.01$ SD:standart deviation

Isokinetic Test Results

Both knee flexors and extensor strength reduced as angular velocity increased following the force-velocity characteristics of muscle (Table 3). There were no significant differences between professionals and amateurs although amateurs tended to have a lower knee flexion peak torque over all speeds. As a consequence the flexor/extensor (H/Q) ratio was significantly higher in professionals than amateurs.

Table 3: Comparison of peak torque values (Nm) of kicking knee flexors and extensors and flexor/extensor ratio (H/Q) of professional and amateur soccer players at 60, 180, 240 and 300°.s^{-1} angular velocities

	Angular Velocity	Amateur (n=17) Mean ±SD	Professional (n=10) Mean ±SD
Knee Extension (Nm)	60°.s^{-1}	205.7 ±32	205.1 ±28
	180°.s^{-1}	140.0 ±21.1	140.2 ±24.3
	240°.s^{-1}	114.6 ±16.6	122.0 ±21.8
	300°.s^{-1}	101.2 ±19.2	103.9 ±11.1
Knee Flexion (Nm)	60°.s^{-1}	152.0 ±25	170.4 ±37
	180°.s^{-1}	117.7 ±26.2	132.7 ±30.6

	240°.s^{-1}	96.1 ±16.2	117.2 ±27.2
	300°.s^{-1}	87.7 ±19.3	93.5 ±20.3
Flexion/Extension (H/Q) ratio	60°.s^{-1}	74.4 ±8.6	**83.1 ±13.4***
	180°.s^{-1}	83.3 ±11.3	**94.3 ±11.7***
	240°.s^{-1}	84.3 ±11.6	**94.2 ±11.9***
	300°.s^{-1}	87.0 ±12.8	90.1 ±18.5

*: P<0.05 , **: P<0.01

Relationship Between Isokinetic Torque and Ball Speed

For the professionals, none of the muscle torque data correlated significantly with ball speed (Table 4). On the contrary, for amateurs, significant correlations were found between different isokinetic angular velocities with different ball speed. For knee extensors correlation occurred with OK and OCK in 60°.s^{-1} and with OCK in 300°.s^{-1}. For knee flexors correlation have been found with ICK, INK, OK, OCK in 60°.s^{-1} and ICK and INK in 180 and 240°.s^{-1}, in OK and OCK in 300°.s^{-1}. For the H/Q ratio correlation has seen with LK, ICK, INK in 60°.s^{-1}, with ICK and INK in 180°.s^{-1}, with ICK in 240°.s^{-1} and 300°.s^{-1}. The highest number of correlation between kick types and angular velocities occurred in 60°.s^{-1}, Furthermore, there was no correlation between inside kick and angular velocities in both groups.

Table 4: Relationship between ball speed occurred after six different kicking techniques and isokinetic peak torque values (Nm) of the kicking knee flexors and extensors and the flexor/extensor ratio (H/Q) of professional and amateur soccer players at 60, 180, 240 and 300°.s^{-1} angular velocities

		Amateur						Professional					
		IK	LK	ICK	INK	OK	OCK	IK	LK	ICK	INK	OK	OCK
60^{0}.s^{-1}	EX	-0.29	-0.07	0.08	0.32	**0.60***	**0.62****	-0.51	-0.37	-0.35	-0.1	-0.34	0.04
	FLX	-0.14	0.25	**0.60***	**0.72****	**0.54***	**0.58***	-0.24	0.14	0.20	0.33	0.09	0.46
	FER	-0.23	**0.49***	**0.68****	**0.57***	-0.09	-0.06	0.02	0.44	0.50	0.5	0.41	0.57
180^{0}.s^{-1}	EX	-0.18	-0.05	0.17	0.35	0.46	0.47	-0.30	0.21	0.14	0.46	0.22	0.6
	FLX	-0.08	-0.14	**0.57***	**0.64****	0.42	0.39	-0.31	0.14	0.02	0.31	0.25	0.47
	FER	0.18	0.37	**0.70****	**0.60***	0.06	0.06	-0.2	-0.08	-0.22	- 0.13	0.18	0.01
240^{0}.s^{-1}	EX	0.07	-0.04	0.12	0.32	0.34	0.38	-0.19	0.29	0.22	0.58	0.28	0.48
	FLX	-0.02	0.20	**0.60***	**0.53***	0.39	0.37	-0.20	0.36	0.21	0.50	0.43	0.55
	FER	-0.03	0.28	**0.56***	0.27	0.11	0.05	-0.09	0.02	-0.14	-0.15	0.24	0.00
300^{0}.s^{-1}	EX	-0.09	-0.12	0.07	0.30	0.37	**0.50***	-0.16	0.34	0.21	0.53	0.39	0.47
	FLX	-0.27	-0.14	0.47	0.31	**0.50***	**0.51***	-0.15	0.28	0.07	0.23	0.50	0.35
	FER	-0.24	-0.10	**0.55***	0.02	0.27	0.12	-0.08	0.10	-0.07	-0.07	0.32	0.10

*: P<0.05 , **: P<0.01

(IK; inside kick, LK; lofted kick, ICK; inside curve kick, INK; instep kick, OK; outside kick, OCK; outside curve kick, EX; extension, FLX; flexion, FER; flexion/extension ratio

DISCUSSION

According to previous studies, ball speed of three different kick techniques (side-foot, inside curve, instep kick) have been analyzed and results shows that the ball speed could change according to age of player, types of kick, level of player, approach angle, step distance and the biomechanical characteristic of the kicks (Isokawa and Lees, 1988; Commetti et al., 2001, Dorge et al., 2002, Asai et al., 2002, Manolopoulos et al., 2006, Nunome et al., 2002). Because only the ball speed of inside, instep and inside curve kick have analyzed in previous studies, the new evidences have obtained in terms of the ball speed of 6 different kicking techniques in the current study. The present study contributes our knowledge that following instep kick the highest ball speed occurred in lofted kick, inside curve kick, outside kick, outside curve kick respectively in both groups. Results shows that the highest ball speed occurred after a kick using inside of the foot compared to outside of the foot in professionals and amateurs. In previous researches, Dorge et al., (2002), have found the ball speed of 7 skilled players during instep kick as 88.92±8.2 5 $km.h^{-1}$. Lees et al., (2003) have found similar ball velocity (88.2 $km.h^{-1}$) during instep kick of 8 amateur players. Whereas these results are similar with amateur players of the current study, they are lower than the professional's ball velocity of the current study. According to Nunome et al. (2006)'s studies, they demonstrated the ball speed of 9 professional players as 94.3 $km.h^{-1}$, which is similar professionals ball speed of the current, study during instep-kick (Nunome et al., 2006) and have found the ball speed of inside kick as 87.48±2.88 $km.h^{-1}$ (Nunome et al., 2002). Levanon and Dapena, (1998) indicated inside kick ball velocity as 81 $km.h^{-1}$. Both study have found high ball velocity then the current study during inside (am: 76.6±3.9 $km.h^{-1}$; prof:82.0±3.6 $km.h^{-1}$) kicks. In another study Kawamato et al., (2007), indicated inside kick ball velocity of 7 professionals (77.04 $km.h^{-1}$) and 8 amateurs (57.6 $km.h^{-1}$) players. Asai et al., (2002) have analyzed inside curve kick of 6 amateur players and indicated ball velocity (91.58 $km.h^{-1}$) similar to the current study. As a result of previous studies the velocities of 3 different kicking techniques have analyzed and the average ball speeds have found between 72-108 $km.h^{-1}$ (Lees and Nolan, 1998). It is thought that the generation of conflicting findings arises from different protocols, player level and measurement techniques.

The other main findings of the current study indicated that there were no significant differences between professionals and amateurs although amateurs tended to have a lower knee flexion peak torque over all speeds. As a consequence, the flexor/extensor (H/Q) ratio was significantly higher in professionals than amateurs in 60, 180 and 240° s^{-1} angular

velocities. Cometti et al., (2001), have analyzed isokinetic con/con strength parameters at 60,120,180, 240 and 300°.s^{-1} angular velocities of different level players. According to results, first division soccer players flexor muscle strength parameters velocity have been found statistically higher in all velocities except 300°.s^{-1} angular velocity; however; amateurs extensor strengths parameters have been found statistically higher at 60 and 120°.s^{-1} angular velocities. Furthermore 1. and 2. division soccer player's H/Q ratio have been found statistically higher in professionals than amateurs in all velocities except 300°.s^{-1}. In the current study, there were no statistically significant differences between amateurs and professionals, even though, the flexor peak torques have found higher in professionals. Moreover, the H/Q ratio results of the current study are in accordance with Cometti et al., (2001). Oberg et al., (1986), have analyzed isokinetic con/con strength parameters at 30 and 180°.sn^{-1} angular velocities of 13 national team professionals, 15 first division professionals, 12 forth division professionals and 32 non-soccer players. Whereas there were no statistically significant differences in terms of flexor and extensor muscle strength among groups, H/Q ratio was statistically higher in soccer players than non-soccer players, which is in concordance with the current study. It is normally considered that the quadriceps muscle group plays an important role in jumping and ball kicking while the hamstring controls the running activities and stabilizes the knee during turns or tackles (Fried and Lloyd, 1992). Moreover, it seems that knee flexor contribution to joint stability becomes increasingly important with increasing limb velocity (Hagood et al, 1990). In our study even though there were no statistically significant differences, professionals showed stronger in their knee flexor muscles than the amateurs at all angular velocities measured. Limited biomechanical and electromyography analyses reported that during follow through phase eccentric contraction occurred to stabilize the knee joint (Cerrah et al. 2011). This result also demonstrates the importance of H/Q ratio. Furthermore, most of the studies are agree that having low H/Q ratio could raise risk of hamstring injury (Bennel et al. 1998; Holm et al., 1994) and Nosse (1982) have stated that concentric isokinetic H/Q peak toque ratio changes between %43-90. Based on these observations and on our own results, it appears that knee flexor strength and the H/Q ratio are extremely important in soccer players for joint stabilization during eccentric action of the soccer kick and also other notably actions. From the perspective of our results, the reason not having any significant differences regarding flexor and extensor peak torques at all angular velocities, it is thought that similar age and training age status could be a reason. However, having professional higher H/Q ratio at 60,180 and 240 °.s^{-1} than amateurs, it is

thought that the professionals have well developed agonist and antagonist muscle proportion for self-prevention from hamstring injury.

Besides, all the above-mentioned factors that affect ball velocity, the relationship between ball velocity and the strength parameters of dominant leg quadriceps hamstring muscles have been analyzed in several studies. Saliba and Hrysomalis (2001) have correlated 19 Australian soccer players ball speed results with concentric/concentric kicking knee isokinetic strength parameters in 60, 240 and 360°.s^{-1}. According to results they have not found any statistical correlation between isokinetic parameters and ball velocities. Mc Lean and Tumilty (1993) reported that there were no significant correlations between concentric/concentric extensor flexor strength parameter at 60, 180 ve 240°.s^{-1} and 12 young soccer players during instep kick. Both studies results demonstrated similarities with professionals but not amateurs. On the contrary to Saliba and Hrysomalis (2001) and Mc Lean and Tumilty's results, Cabri et al., (1988), DeProfit et al., (1988), Mognoni et al., (1994); Narici et al., (1988), Poulmedis et al., (1988) reported significant correlation between ball velocity and isokinetic strength values in different angular velocities. Masuda et al. (2005) have divided 14 college soccer players into 2 groups as skilled and non-skilled and analyzed isokinetic strength parameters for knee extension-flexion (90, 180, 240°.s^{-1}), for hip extension and flexion (90, 180, 240°.s^{-1}) and for hip adduction, abduction (90, 180°.s^{-1}). They have also correlated these isokinetic results with ball speed occurred during different approach angle. According to results, they have reported no statistical significant differences in terms of kicking limp isokinetic strength parameters in any angular velocities. According to relationship between ball speed with isokinetic strength parameters for both groups, non-skilled players showed no statistical correlation. However, the skilled players showed a significant relationship with hip Add strength (180°.s^{-1}; r=0.85, p<0.01) at the free approach angle, 90°.s^{-1} approach angle correlated with all isokinetic strengths except for hip flexion strength, an approach angle of 90°.s^{-1} showed significant correlation coefficients with knee extension strength (r=0.82 and 0.84, p<0.01), knee flexion strength (r=0.79 and 0.83, p<0.05), hip flexion strength (90°.s^{-1}; r=0.85, p<0.01) and hip adduction strength (r=0.75 and 0.93, p<0.05).

Asami and Nolte (1983), reported that the ball velocity with knee extension strength relationship in the kicking leg might depend on the skill level of the players, and suggested that the muscular strength of the knee extensor has less influence on ball velocity in soccer players with higher skills. Although the performance of the inexperienced and unskilled

players tended to depend more on their muscular strength than is the case in skilled players, this trend is inconsistent with the Masuda et al. (2005) study; however; it is in accordance with the current study.

The soccer kick is a kind of technique, which requires proximal to distal segmental movement occurred as a result of motion dependent moment that is, generated active involvement of total body. It means that not only results from the muscular joint moment about its corresponding joint axis but also from the net moment originating from other joint rotations. As a result of this action, thigh angular velocity contributes to shank rotation and assists knee extension just before ball contact (Dorge et al., 1999, Dorge et al., 2002; Nunome et al., 2006). However, knee extension during the instep kick results not only from muscular moment due to the knee extensor muscles but also from motion-dependent moment due to the thigh linear or angular motion. Having such coordinated movement pattern for unilateral joints, the synchronized muscle work is needed for successful kick. This neuromuscular coordinated action (multi-joint coordination) called as whip-like movement (Shan and Zhang, 2011). For the professionals, none of the muscle torque data correlated significantly with ball speed. On the contrary, for amateurs, significant correlations were found between different isokinetic angular velocities with different ball speed in the current study. According to above description and Asami and Nolte (1983)'s study these results shows that technical maturation has been well completed in professionals than amateurs, therefore, in order to have higher ball velocity professional's technical coordination is more determinant factor for ball velocities rather than the strength of knee extensor and flexors.

In the case of isokinetic parameters of amateurs, the highest statistical significant correlation between isokinetic strength parameters with different techniques ball velocities occurred in instep, inside curve, outside, and outside curve kick respectively. Furthermore, there was no statistical significant correlation occurred with inside kick and very little correlation occurred with lofted kick. The reason not to find any correlation between inside and inside curve kick ball velocity with isokinetic strength parameters could result from the eversion of ankle and the lateral hip rotation on transvers plane. Therefore, hip adductor muscles could generate the power instead of knee extensor.

Furthermore, it is thought that the dominant flexors are important determinant for kicking performance and the ball velocity increases with the flexor isokinetic strength parameters increases in amateurs. Especially, while dominant flexor strength increases, the

instep and inside curve kick ball velocity increases in all angular velocities. Moreover, the correlation occurred between outside and outside curve kick ball velocity and the extensor and flexor strength parameters at 60 and 300°.s^{-1} angular velocities. This could be the reason of biomechanics of the outside and outside curve kick, the movement angle could decreases because during back swing phase enough hip extension do not occur and the power transfer (motion dependent moment) cannot be done properly because support leg is placed behind the ball. This situation could cause a need of strength generation parallel to the limbs coordination for amateurs during forward swing phase.

In conclusion, ball velocities differ according to kick types and the resultant ball velocities occurs regarding knee extensor and especially flexor strength in amateurs; however; however; the resultant ball velocity of professional soccer players could have occurred other factor regarding techniques rather than strength parameters.. Therefore, additional strength training is recommended for the weekly training program because, the nature of soccer does not allow to develop hamstring muscle strength and motion dependent moment of the joints. This training is recommended against a resistance while the ankle, knee and hip movement represent the kicking techniques in order to train specific kicking motion strength generation.

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