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Relationship among Change of Direction Performance, Muscular Power and Sprint Speed in Female and Male Elite Soccer Players

Norikazu Hirose*

Abstract

We aimed to identify useful parameters to develop an effective fitness training strategy for senior female soccer players. Hence, we examined the change of direction performance (CODp), sprint speed, muscular power, and anthropometric data among female soccer players, and compared the findings with those from similar tests applied in male soccer players. Thirty-three female and forty male soccer players from the top Japanese league were examined. The differences between elite vs. sub-elite players and playing position were assessed, and simple correlation coefficients between motor performance and anthropomorphic parameters were analyzed. As a result, elite male and female players had better CODp and muscular power than sub-elite players. Elite male players had higher sprint speed than sub-elite players (p<0.01), regardless of position. However, in female players, the sprint speed was dependent on position. A large difference in the effect size for sprint speed was observed between female forwards (FW) and midfielders (MF) (*d*=0.85) and defenders (DF) (*d*=1.00) (FW<MF/DF). The CODp was correlated with sprint speed (r=0.62 for female; r=0.54 for male, p<0.01) and muscular power (r=-0.54, p<0.01; r=-0.50, p<0.05). These results indicate that the absence of a gender difference in the correlation coefficients among CODp, muscular power, and sprint speed, suggesting that the training strategy should be depend on a player's motor ability level rather than on gender in senior top-level soccer players.

Keywords

Football; Specificity; Training; Agility

Introduction

Soccer is a multifaceted sport, wherein success depends not only on technical and tactical factors but on several physical factors [1]. In particular, male soccer players are expected to possess greater sprint speeds [1,2] and muscular power [3]. In addition to these fundamental factors, the change of direction performance (CODp) is essential for competing at the elite level in soccer [4], in which each player performs over 1000 change of direction maneuvers during a match [5]. From the technical aspect, CODp is also important as one of the trends of modern soccer that is the rapid transition between attack and defense [6,7]. In fact, professional elite senior players have a quicker CODp than youth players [8]. Based on this information, fitness training strategies [1.9] and talent identification indices [10] for elite male players have been developed.

With regard to female soccer players, only few studies comparing motor abilities between different competitive levels have been conducted. Todd et al. [11]. reported no competitive standard difference in the sprint ability of female soccer players. However, several studies implied that CODp is a determinant of senior elite female soccer players, and that senior elite players have a quicker CODp than junior elite female players [8,12]. Thus, there are several similarities and dissimilarities in the characteristics of motor performance between elite female and male soccer players. Furthermore, empirical studies regarding senior elite female players are limited [1]. Consequently, an effective fitness training strategy for senior female soccer players has not been established thus far. As the number of female soccer players has markedly increased in recent years [13], there is a growing need for elucidating fundamental scientific knowledge to establish proper fitness training programs for female soccer players. Considering the similarity in the current tactical trends between elite female and male soccer players, such as a quick transition between defense and attack (which requires faster CODp and greater muscular power) [6,7], it is hypothesized that senior elite female players also require faster CODp, compared to senior sub-elite players.

Creating an effective training program for improving CODp requires the identification of physical factors that can potentially be trained to improve motor performance. As Sheppard and Young proposed [4], CODp depends on four sub-elements: technique, sprint speed, leg muscle qualities, and anthropometry. Although considerable research has focused on the relationship between CODp and its sub-elements in male athletes [14,15], only a few studies have investigated these relationships in female athletes [8,16]. These few studies indicated that the correlation coefficients between CODp and both sprint speed and muscular power among female athletes are stronger than those among male athletes [8,16]. These differences indicate that the training program for improving CODp in female athletes should differ from that in male athletes. As the number of female soccer players has markedly increased, it has become important to know how to develop CODp in female soccer players, similar to that in male soccer players.

To achieve these aims, we compared the anthropometric data and motor performances between elite and sub-elite groups of senior female and male soccer players. Moreover, we investigated the relationship between each motor performance parameter and anthropometric data in senior female and male soccer players.

Methods

Subject

In this study, we recruited 45 female and 46 male professional soccer players. All female and male players belonged to teams in the Nadeshiko League and J League, which are the most elite leagues in Japan. Among these subjects, we excluded nine goalkeepers because they underwent different training programs involving improvements of goalkeeper-specific footwork (female; 6, male; 3). Seven field players

***Corresponding author:** Norikazu Hirose, Faculty of Sport Sciences, Waseda University, Nishitokyo, Tokyo, Japan. E-mail: toitsu_hirose@waseda.jp

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could not participate in this study because of injury. Finally, 33 female (mean age, 23.2±2.2 years) and 40 male (mean age, 24.7±4.4 years) field players participated in this study. All the players were divided into elite and sub-elite players. The definition of elite players was as follows: players who had been selected as part of the team in official matches in at least 90% of the total matches in the experimental year, and had played >50% of the total game as a starter or substitute. The other players were determined as sub-elite players.

Procedure

The anthropometric measurements included body height, body weight, and lean body mass (LBM). Motor performance included 10-m sprint, 10-m×5 COD test, and 5-step bounding test. All measurements were performed during pre-season (February). All motor performance tests were performed on natural grass.

Body height was measured using a stadiometer (YL-65S, Yagami Co, Nagoya, Japan) without shoes. Body weight and LBM were measured using a body composition analyzer (MC-190EM, Tanita Co., Tokyo, Japan). These tests were conducted before motor performance testing.

Participants were instructed to refrain from vigorous exercise and high water intake before the measurement. Before motor performance testing, all participants performed warm-up exercises for approximately 15 minutes that included static stretching, jogging, ballistic stretching, bounding, and COD. Before the motor performance test, players were randomly divided into three groups (A, B, and C), and the order of motor performance tests was also decided. A minimum of two minutes of rest was permitted between each trial, and approximately 7 minutes of rest was permitted between tests to reduce fatigue. Thus, no more than 15 players were assessed in a single session and the rest periods were maintained constant during all the test sessions. Each group completed three performance tests in the following order: group A, 10-m sprint, 10-m×5 COD test, and 5-step bounding test; group B, 10-m×5 COD test, 5-step bounding test, and 10-m sprint; group C, 5-step bounding test, 10-m sprint, and 10-m×5 COD test. After warming up, the participants completed one or two practice trials before completing two test trials; the better score was used for the statistical analysis. The players wore shorts, t-shirts, and soccer cleats during testing.

The 10-m linear sprint speed was evaluated using infrared timing gates (Brower Timing, Draper, UT, USA) and phototubes installed at the starting and 10-m point. The participants began the 10-m sprint whenever they wanted, and the time to travel to each phototube was calculated. The inter-correlation coefficient (ICC) of this measurement value was 0.89 (ICC [1,1]).

For the 10-m×5 COD test, the participants completed two and a half round-trips between two lines, drawn 10 m apart, which necessitated making four 180° turns, alternating between the left and right foot, and then sprinted for 10 m in a straight line. The participants were instructed to complete the test as quickly as possible, and the time to completion was measured with a stopwatch (SVAE101, Seiko Inc., Tokyo, Japan). The ICC of this measurement value was 0.90 (ICC [1,1]).

To complete the 5-step bounding test, the players positioned themselves at the starting line with the toes maintained at shoulder width. Starting with either the left or right foot (as per their choice), the players jumped four times without any running start, while alternating between the left and right foot, before performing a two-legged landing after the fourth jump. A tape measure was used to measure the shortest distance from the start line to the landing point (heel of the landing foot). The ICC of this measurement value was 0.85 (ICC [1,1]).

All study protocols conform to the Declaration of Helsinki, and were approved by the Ethics Committee on Human Research of Waseda University. All subjects were fully informed of the procedures and the purpose of this study, and they provided written informed consent.

Statistical analyses

The statistical significance in the distribution of playing position was analyzed using the χ2 test. All collected data according to each position and performance level (elite vs. sub-elite) were analyzed as normally distributed data by the Kolmogorov-Smirnov test. Thus, the means ± *s* of motor performance and body size for each position were compared, and the significant differences were evaluated by using analysis of variance, followed by the Bonferroni test. In addition, the effect size among each category was evaluated. Effect sizes of 0.2, 0.5, and 0.8 were regarded as small, medium, and large, respectively. Thereafter, the measurements between elite and sub-elite players were compared using Student's t-test, and the effect size was also calculated. A linear regression analysis was performed to assess the relationship between 10-m×5 COD test results and the other measurements. If a statistically significant correlation was observed both in female and male players, we analyzed the difference in the regression co-efficient value between the male and female players using the following calculation:

$$Z = Z'_1 - Z'_2 / \sqrt{(1/(n_1-3)+1/(n_2-3)}$$

The p value was calculated using the Z value and standard normal distribution

Z'_1 (Z'_2) represents the *r* value of female (male) players, which was converted to Z transformation

n_1 (n_2) represents the number of subjects for female (male) players

Values that reached a $p<0.05$ level of significance were considered statistically significant.

Results

The senior female soccer players included 10 forwards (elite vs. sub-elite; 4 vs. 6), 10 midfielders (4 vs. 6), and 13 defender (6 vs. 7). The male players included 12 forwards (6 vs. 6), 12 midfielders (6 vs. 6), and 16 defenders (8 vs. 8). There was no difference in positional distribution between the female and male players (χ2=0.125, not significant).

There was no difference in any of the measurements among forwards, midfielders, and defenders in both genders (Tables 1a and 1b). However, with regard to the effect size of the 10-m sprint, the differences between female forwards and midfielders (*d*=0.85) and defenders (*d*=1.00) were large (FW<MF/DF). Moreover, 10-m×5 COD results also showed that the differences between female forwards and midfielders was large (*d*=1.25) (FW<MF).

The 10-m×5 COD results of the elite female and male soccer players were quicker than the sub-elite players (p<0.01), and the differences were large (female: *d*=0.87; male: *d*=1.06) (Table 2). The distance of 5-step bounding in elite female and male players were greater than that in sub-elite players, and these differences were large

Table 1: (a) Mean (± standard deviation) of all measurements in each position and the results of the analysis of variance and effect size of female senior soccer players. (b) Male senior soccer players

a. Female players	Mean±s			F value (p value)	Effect size		
	FW	MF	DF		FW vs. MF	FW vs. DF	MF vs. DF
Age (years)	23.5±2.3	23.3±3.4	22.9±2.5	0.19 (0.83)	0.09	0.24	0.18
Body height (cm)	162.4±4.4	161.4±4.0	164.3±3.8	1.53 (0.23)	0.25	0.49	0.77
Body weight (kg)	56.6±4.1	55.6±4.4	57.9±3.8	0.88 (0.43)	0.23	0.35	0.58
LBM (kg)	45.9±3.2	45.9±3.4	47.8±2.8	1.56 (0.23)	0.01	0.69	0.67
10-m sprint (s)	1.94±0.08	2.02±0.12	2.00±0.06	2.53 (0.10)	0.85	1.00	0.22
5-step bounding (m)	10.33±0.45	10.19±0.65	10.30±0.39	0.21 (0.81)	0.26	0.07	0.22
10-m×5 COD (s)	10.62±0.10	11.95±0.38	11.75±0.33	3.06 (0.06)	1.25	0.49	0.61
b. Male players	**Mean±s**			**F value (p value)**	**Effect size (*d* value)**		
	FW	**MF**	**DF**		**FW vs. MF**	**FW vs. DF**	**MF vs. DF**
Age (years)	23.7±2.9	24.9±5.3	25.6±4.7	0.57 (0.57)	0.30	0.51	0.13
Body height (cm)	178.2±5.6	175.5±4.1	178.2±7.4	1.08 (0.35)	0.59	0.00	0.49
Body weight (kg)	72.7±9.0	69.6±5.4	73.0±6.4	1.05 (0.36)	0.45	0.04	0.60
LBM (kg)	68.8±9.7	68.1±6.4	67.9±5.8	0.04 (0.96)	0.08	0.11	0.04
10-m sprint (s)	1.77±0.06	1.75±0.10	1.80±0.09	1.15 (0.33)	0.61	0.35	0.55
5-step bounding (m)	12.65±0.49	12.91±0.59	12.78±0.62	0.73 (0.49)	0.49	0.25	0.22
10-m×5 COD (s)	10.89±0.35	10.92±0.28	10.94±0.27	0.08 (0.92)	0.08	0.16	0.10

LBM: lean body mass; COD: change of direction; FW: (Forward); MF: (Mid Fielder); DF: (Defender)
FW: (Forward); MF: (Mid Fielder); DF: (Defender)

Table 2: Comparison of all measurements between elite and sub-elite female/male soccer players

	Female			Male		
	Elite	Sub-elite	*d*	Elite	Sub-elite	*d*
Age (years)	23.5±2.5	23.0±2.0	0.24	26.8±4.0**	22.8±4.0	1.02
Body height (cm)	162.0±4.5	163.5±3.8	0.37	178.0±4.5	176.2±6.7	0.34
Body weight (kg)	56.0±3.7	57.4±4.3	0.35	73.9±6.5*	69.2±6.8	0.72
LBM (kg)	46.4±3.0	46.8±3.4	0.12	69.7±7.8	66.8±6.4	0.43
10-m sprint (s)	1.96±0.01	2.01±0.10	0.61	1.75±0.08*	1.80±0.08	0.66
5-step bounding (m)	10.57±0.44**	10.06±0.41	1.23	13.03±0.54**	12.57±0.50	0.90
10-m×5 COD (s)	11.63±0.28*	11.88±0.31	0.87	10.78±0.26**	11.05±0.27	1.06

**p<*0.01*, *p<*0.05*
LBM: lean body mass; COD: change of direction

Table 3: Pearson's correlation coefficient analysis of testing performance and anthropological measurements of female (F) and male (M) soccer players

		Body height	Body weight	LBM	10-m sprint	5-step bounding	10-m×5 COD
10-m sprint	F	0.06 (0.00)	-0.08 (0.01)	-0.16 (0.02)	-	-0.67** (0.45)	0.62** (0.39)
	M	0.08 (0.01)	0.05 (0.00)	0.15 (0.02)	-	-0.54** (0.29)	0.54** (0.29)
5-step bounding	F	0.11 (0.01)	0.16 (0.02)	0.29 (0.08)	-0.67** (0.45)	-	-0.54** (0.29)
	M	0.10 (0.01)	0.14 (0.02)	-0.01 (0.00)	-0.54** (0.29)	-	-0.50* (0.25)
10-m×5 COD	F	-0.11 (0.01)	-0.10 (0.01)	-0.27 (0.07)	0.62** (0.39)	-0.54** (0.29)	-
	M	-0.14 (0.02)	-0.35* (0.12)	-0.18 (0.03)	0.54** (0.29)	-0.50* (0.25)	-

**p<*0.01*, *p<*0.05*
( ) demonstrates value of r^2
LBM: lean body mass; COD: change of direction.

(p<0.01, *d*=1.23 and 0.90). In addition, elite male players were faster during the 10-m sprint (p<0.05, *d*=0.66) and heavier in body weight (p<0.05, *d*=0.72) than sub-elite players, although the differences were moderate. Moreover, the elite male players were significantly older than the sub-elite players (p<0.01, *d*=1.02).

The 10-m×5 COD results correlated with the 10-m sprint and 5-step bounding results (p<0.01) in both genders; however, these correlations were not strong (r^2<0.5) (Table 3). There were no significant differences in the correlation co-efficient value between female and male players (p=0.603 for 10-m sprint, p=0.841 for 5-step bounding). Body weight correlated with the 10-m×5 COD performance only in male players (p<0.05), although the coefficient was not strong.

Discussion

The main results of present study were that elite female and male soccer players had better muscular power and CODp than sub-elite players, and that there was no gender difference in the correlation coefficient among CODp, sprint speed, and muscular power.

As previously reported [11,17], a difference in 10-m sprint speed according to the competitive level was only observed in male players. However, the present study also demonstrates that female forwards have a faster 10-m sprint speed than midfielders (*d*=0.85) and defenders (*d*=1.00). These findings suggest that the 10-m sprint ability is a determinant of elite male soccer players and female forwards. With regard to the developmental characteristics of sprint ability,

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which showed no remarkable improvements in female soccer players aged 12 years [12,18] and did not result in a rank change in adolescent male soccer players [19], the 10-m sprint performance may serve as a useful component of the talent identification index for elite male soccer players and female forwards.

Our results also suggest that elite female/male soccer players have greater muscular power and faster CODp than sub-elite players. Several previous studies considered muscular power and CODp as determinants of motor performance for elite male soccer players [2,8]. In contrast, empirical studies on elite female soccer players are limited. Few studies have indicated that muscular power and CODp would serve as a determinant of motor performance for elite female soccer players [8,12]. However, the limitation of these previous studies, which compared senior and junior players and not senior elite and sub-elite players, made it difficult to conclude that improvements in muscular power and CODp contribute to enhancing soccer performance level in senior female soccer players. Thus, our findings are a valuable addition to the current knowledge-better muscular power and CODp is related to the competitive level of top-level female soccer players, as much as in male players. However, CODp and muscular power are less useful indices for predicting future performance because of their high trainability [19]. In other words, these motor abilities can be improved by proper training.

Creating effective training programs for improving muscular power and CODp requires the identification of the trainable physical factors for both indicators. The CODp depends on four sub-elements: sprint speed, muscular function of the lower extremity, anthropometry, and technique [4]. However, the relationship between CODp and its sub-elements differs between the two genders [16]. Based on previous reports, we expected to obtain the same trend in Japanese top-level senior soccer players, which should indicate the importance of providing specific CODp training according to the gender characteristics. In contrast to this hypothesis, our data clearly indicated that no gender difference exists in the correlation among CODp, sprint speed, and muscular power. However, we are unable to clarify the reason for this controversial result. We speculate that this is probably due to a similarity in the motor performance level between male and female players in this study. In general, the motor performance of females is much lower than that of males. The sprint performance, muscular power, and CODp in the Japanese female population aged nineteen years-old was 80.6% (9.13 s for females vs. 7.36 s for males in the 50-m sprint), 73.4% (1.68 m vs. 2.29 m in broad jump), and 82.0% (47.9 vs. 58.4 repetitions/20 s for repetitive side steps) of that in the Japanese male population [20]. This trend is also noted among elite soccer players [1,21]. However, the female players in the present study showed a higher level of motor performance compared to the male players (89.3%, 81.1%, and 92.7% of the sprint performance, muscular power, and CODp of male players). Consequently, our data may suggest that an appropriate training strategy for improving CODp may depend on the level of motor performance and not on the player's gender. Hence, the player's motor performance should be evaluated before the training is planned.

The results of the present study showed a moderate correlation among CODp, muscular power, and sprint speed. Furthermore, there may be another factor influencing CODp improvement. Several researchers have indicated that a major component of CODp development was technical improvement [4,22]. An important factor in technique is posture control, such as forward leaning of the trunk, which enables a low center of gravity and enhanced body stability [4]. In particular, female soccer players demonstrate a lesser knee flexion angle during cutting maneuvers as compared to male soccer players [23], which leads to a more extended posture during the cutting maneuver [24] and may delay the speed of CODp [25]. Moreover, the occurrence of lesser knee flexion in female athletes as compared to male athletes is believed to result from the difference in alignment (Q-angle), motor control, and muscular strength [23]. Of these three factors, motor control and muscular strength can be altered. Thus, we speculate that skill training and strength training, including eccentric stimuli such as jump training that improve landing impact absorption, will be beneficial for improving the CODp in female soccer players. Indeed, in addition to specific skill training, strength training may contribute to the improvement of CODp [26]. Furthermore, as indicated in the present study, LBM is not necessary associated with muscular power. As Stolen et al. [1]. suggested, if players have "enough muscle mass," the players need to perform strength training to develop neural factors such as intra-muscular coordination (i.e. recruitment of motor units) and inter-muscular coordination, which can help modulate the timing and accuracy of multi-joint muscular movement [27]. To develop these factors, plyometric training may be effective [28]. In particular, horizontal jump training is more effective for improving CODp [29] as compared to vertical jump training [30]. Thus, in addition to soccer practice, consecutive horizontal power training and specific technique training for improving CODp is beneficial to improve the soccer performance level.

The main limitation of the present study was that we investigated only senior soccer players. The characteristics of the CODp maneuver and physiological factors can be altered during adolescence [12]. Hence, the correlation coefficients among CODp and other motor performance indicators and anthropometric data will show a gender difference. Moreover, we need to investigate gender differences in the technique of CODp by using biomechanical data, as technique is an important factor in CODp. Finally, no specific training intervention was performed in this study. Therefore, further intervention research is needed to clarify proper training strategies for improving CODp in elite soccer players.

Conclusion

The present study yielded meaningful findings with important implications for training strategy. There was no gender difference in the correlation coefficients among CODp, muscular power, and sprint speed; moreover, these correlations were not strong. In addition, muscular power was not correlated with body mass or LBM. As indicated in previous studies, sprinting ability will be a useful component of the talent identification index for elite soccer players. Hence, coaches should aim to focus on force development in players with sufficient muscular mass, and to improve the players' CODp by specific skill training and strength training. This training strategy depends on the players' motor performance level rather than on the players' gender.

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Author Affiliations

Top

Faculty of Sport Sciences, Waseda University. Nishitokyo, Tokyo, Japan.