Original Article

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Effect of power on agility, linear speed and change of direction deficit in female soccer players

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Abstract

Introduction: The aim of the study was to examine relationships between power of the lower limb and agility, speed, and change of direction (COD) deficit in professional female soccer players. *Material and methods:* Thirty-three elite Polish Extraliga league soccer players (aged 22 ±5 years; body height 166 ± 4 cm; body weight 58 ± 8 kg) performed the following fitness tests: lower limb muscle power (Leg Press, Half Squat, Counter Movement Jump), straight linear speed (SLS 20 m), and COD speed (Zig-Zag test, COD deficit). Using the median value as a reference, the players were subdivided into two groups (n=17; n=16) according to their LP, HS 60% 1RM, CMJ (High values below median = stronger group and Low = weaker group). *Results:* The COD deficit was calculated as the difference between the 20m speed and the Zig-Zag test. The stronger group was better than the weaker group in SLS 20m ($p<0.05$; ES=1.23; 0.83; 0.93), but in the Zig-Zag agility test, the difference in the results was not statistically significant ($p>0.05$; ES=0.48; 0.34; 0.34) and this affected the COD deficit, which was higher ($p<0.05$; ES=0.9; 0.73; 0.72). The most important finding was that the stronger group had a higher COD deficit and its improvement (reduction) occurs only if the results of the agility test are improved (through agility training) [$Y_{\text{deficit All groups}}=0.10+0.87*20m - 0.83*$ Zig-Zag]. Increasing power (HS, LP) lead to the improvement in SLS $p<0.05$, not to COD abilities. *Conclusion:* This can be useful for coaches during agility training and to improve COD deficit in soccer players and women in general.

Keywords: COD deficit, change of direction, power, strength, agility, straight linear speed, soccer, female, peak power

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INTRODUCTION

During a soccer game, players perform repeated high-intensity bouts of physical activity (e.g. maximum sprints, accelerations, jumps, sliding tackles, changes of direction) which are regularly interspersed with low and moderate-intensity activities (e.g. slow relaxed running, walking) [1-2]. Activities of short duration such as those that require the ability to quickly accelerate, change directions, and perform cuts are an integral part of a successful game regardless of the gender [3-6]. A study by Faude also shows where players usually score goals after a sprint in a straight line, with a change of direction and jump [7].

Ability and speed are motor skills that strongly depend on the power of the lower limbs in both men [6,8,9] and women [8-11]. In team sports, a player will not achieve a high level of agility and leg speed without adequate strength training of the lower limbs. Therefore, coaches and experts in strength and conditioning must evaluate and help athletes improve agility, power, and speed skills [12].

Measurements of change of direction (COD) performance and agility take into account the total time to complete various agility tests or the mean speed achieved over a specific distance used in the test. Unfortunately, most tests involve running in a straight line. It is hard to assess whether a player is agile or just fast. To measure the real ability to slow down and accelerate again in a new direction, a method of change of direction deficit (COD-D) was proposed, with the sprint time with a change of direction subtracted from the straight-line sprint time at the same distance, [13] or differences in velocity between linear sprint test and agility test of equal distance were calculated [14].

COD-D appears to be a good measure to isolate the COD ability to change directions of running because in previous studies, COD-D correlated with agility tests but it did not correlate with straight-line speed tests [15-17]. COD-D can help coaches understand the athlete's ability to change the direction of running without the misleading factor of running in a straight line related to most agility tests. Many researchers have been interested in measuring COD deficit [7,14-15,18-21].

The strength and muscle power are related to the speed of running in a straight line, acceleration, and the ability to change direction, but what is the effect of COD Deficit?

In a study by Pereira (2018), the COD deficit correlated with the results of the jump tests (CMJ, JS), strength tests that measured relative mean propulsive power during the jump squat (MPP REL JS), and speed tests (10, 20m linear sprints, $p<0.05$). In both sexes, men outperformed women in speed and power tests but showed a higher COD deficit than women. This may be due to lower efficiency in changes in running direction [14].

Emmonds conducted a study on female soccer players and, based on multiple linear regression analysis, he concluded that an improvement in the drop jump (DJ) performance reduces the straight line 10m and 20m sprint times, whereas an improvement in CMJ performance reduces the times in Agility 505 and COD deficit tests. Furthermore, the researcher observed a strong correlation between COD deficit, COD, and linear sprint but this study analysed only 10 female soccer players and the results do not have to be reliable enough [21].

Lockie found that stronger female soccer players (vertical jump VJ) playing in Division I had a smaller deficit than the weaker players in Division II. This was due to similar 10 m speed test results and a difference in the Agility 505 test where the group from Division I was faster in the COD test. Based on these results, it can be concluded that players from Division I had better COD abilities [22].

In a study by Freitas (2019) [23], the high strength and power group exceeded the weaker group in all speed and power measurements (VEL 5,10,20 m, VEL Zig-Zag COD, CMJ, and SJ height), but the COD deficit was higher.

Faster players (sprint speed, maximum acceleration) have a higher COD deficit compared to the slower group (worse ability to change direction) in the case of both men [15] and women [16]. Studies that compared the COD deficit to the speed, agility, and strength abilities between men and women have shown that men have a higher COD deficit [14,18].

Based on the above-mentioned studies by other authors, it turns out that the COD deficit is a new separate measure of the ability to change direction in which the effect of force and power is unclear, especially in women [22].

In conclusion, the contribution of force during the change of direction (COD agility and COD deficit) is unclear, agility is a multi-faceted ability, and the authors emphasize the need for further research to look for the predictors of the improvement in COD abilities [24], especially in women [22]. Therefore, the aim of the study is to analyse the possible relationship of the explosive power of the lower limbs with maximum acceleration, agility, and COD deficit in elite female soccer players.

MATERIAL AND METHODS

Characterization of the study group

The examination was carried out in the Laboratory of Muscle Strength and Power and in an indoor arena of the Jerzy Kukuczka Academy of Physical Education in Katowice, Poland. The study involved 33 soccer players, playing in two separate clubs of the Polish Ekstraliga league (22 ±5 years old; body height 166 ± 4 cm; body weight 58 ± 8 kg).

Description of the experiment

The testing of the parameters of jumping ability and the strength and power of the lower limbs was conducted until noon at full rest on two days. On the first day, one club, after a 15-minute warm-up, started a speed test. After a 5-minute break, the agility test was carried out. Then the athletes moved to the Laboratory of Muscle Strength and Power where they performed power tests on the Leg Press and Kaiser Squat devices and jumping tests using Force Decks device. A 5-minute break was administered between each jumping strength test so that each subsequent test was performed after full recovery. At that time, the players were performing exercises to maintain the right body temperature. On the next day, another club followed the same testing protocol.
Measurements of speed in a straight line and with a change of direction were used to evaluate a speed deficit for 10 and 20m (20m speed - Zig-Zag test speed) [18].

20m speed test

The female players sprinted 20 m measured by photocells. They run the sprint twice, starting from a standing position 0.3 m behind the starting line. The test was conducted in an indoor area. A 5-minute break was allowed between two tests. The best time of both tests was taken into account.

Zig-Zag agility test

The Zig-Zag test consisted of four 5-metre sections marked with cones at an angle of 100° [18]. The procedure was the same as in the straight-line speed test. The athletes performed the test twice and the best results were recorded.

Testing using FD4000 Dual Force Platforms [CMJ]

The test was carried out on a dual force platform where the participants performed 4 maximum vertical jumps while holding their hands on their hips (CMJ). Before the test, they were informed in detail about how the test should look like.

The purpose of the test is to assess the power of the lower limbs during a counter-movement jump (CMJ) based on the measurement of ground reaction force. The mean of all test jumps was used for the analysis. During the jump, hands were held on the hips.

Testing using the Kaiser A300 Squat device [HS]

After the warm-up, 1RM was measured in each athlete using the Beachle 2008 procedure. After a 5-minute break, the maximum force during the concentric phase was tested in the same order. The movement consisted in standing up from the squat position (90° knee flexion) as fast as possible with a load of 60% 1RM. The best result of three tests was chosen for further analysis.

Testing using the Keiser Air300 Leg Press [LP]

During this test, the participant performed the seated leg press. The adjustable sitting position protected the lower back by keeping it stable, allowing the gluteal muscles to be better stretched and more active during the exercise. Firstly, 1 RM was evaluated and, 5 minutes later, a test was performed with the athlete performing leg press at a load of 60 %1RM (4 repetitions). This test was used to evaluate the maximum concentric force of the lower limbs.

Statistical analysis

The test results were initially processed in MS Excel and then analysed in STATISTICA 9.1 (StatSoft, Cracow, Poland). Using the median value as a reference, the group was subdivided into weaker and stronger groups (LP, HS, CMJ). The analysis was performed using analisis of variance (ANOVA) and multiple regression test, with the level of significance set at p<0.05. The magnitude of the differences or effect size (ES) was calculated according to Cohen's formula and interpreted as small (> 0.2 and <0.5), moderate (≥ 0.5 and <0.8), or large (≥ 0.8). The group was divided into weaker and stronger based on the median value as a reference.

RESULTS

Descriptive statistics for the variables measured with a breakdown into weaker and stronger groups are presented in Table 1. Table 1 shows descriptive data. The athletes who were stronger in LP and HS were much heavier (ES=1.25; 0.98) and taller (ES=1.08; 1). The skeletal muscle mass in all three stronger groups was much higher than in those weaker (ES=1.73; 1.26, 1.05). Stronger athletes generated higher straight-line speed (ES=0.83 to 1.23) and had a higher COD deficit (ES=0.73 to 0.9). No significant differences were found between the groups in the Zig-Zag agility test (ES= from 0.34 to 0.48). Table 2 shows the results of the ridge regression for modelling the improvement of the change of direction and linear speed in terms of improving muscular power. Increasing muscular power can statistically improve the straight line speed (20m) (p<0.05) but not improve agility. Table 3 presented the results of the ridge regression for modelling the improvement of the COD deficit. Multiple regression analysis results showed that the improvement of 1m/s in SLS increases COD/D by b=0.76 m/s in the group with higher COD/D [$Y_{deficit}$=0.10+0.76* 20m - 0.71* Zig-Zag], by b=0.59 m/s in the group with lower COD/D [$Y_{deficit}$ =0.10+0.59* 20m - 0.31* Zig-Zag] and in the whole study group by b=0,87 m/s [$Y_{deficit\ All\ groups=}$0.10+0.87* 20m - 0.83* Zig-Zag]. Improvement of 1m/s in COD reduses COD/D by b=-0,71 m/s for the higher deficit group. In the case of a group with a smaller deficit, the improvement is statistically insignificant because the result is optimal. We are aiming for a reduced COD/D.

Table 1. Means and standard deviations in weaker (low) and stronger (high) individuals in terms of power measured on the LP, SQ, and CMJ devices.

Indicator	Group	Mean ± SD					
		Mass [kg]	Height [cm]	Skeletal muscle mass [kg]	Velocity 20m [m/s]	Zigzag [m/s]	COD Deficit [m/s]
Leg Press [W/kg]	low	55.9 ± 5.28	163.94±6.09	25.2 ± 2.02	5.84 ±0.143	3.63 ± 0.14	2.21 ± 0.18
	high	62.42 ± 6.79	169.29 ± 5.87	29.14 ± 3.05	6.08 ± 0.24	3.69 ± 0.128	2.39 ± 0.22
	p	0.0012	0.0042	0.00004	0.001	0.18	0.01
	ES	1.25	1.08	1.73	1.23	0.48	0.9
HS Squat [W/kg]	low	56.43 ± 5.4	164.44 ± 5.97	25.45 ± 2	5.87 ± 0.18	3.64 ± 0.15	2.22 ± 0.18
	high	61.93 ± 7.16	168.82 ± 6.33	28.91 ± 3.34	6.05 ± 0.24	3.68 ± 0.12	2.36 ± 0.20
	p	0.0089	0.0075	0.0011	0.022	0.333	0.043
	ES	0.98	1	1.26	0.83	0.34	0.73
CMJ [W/kg]	low	57.36 ± 5.29	165.19 ± 6.13	25.75 ± 2.04	5.86 ± 0.20	3.64 ± 0.13	2.22 ± 0.21
	high	61.05 ± 7.80	168.12 ± 6.60	28.63 ± 3.6	6.06 ± 0.21	3.68 ± 0.14	2.37 ± 0.19
	p	0.13	0.22	0.0088	0.012	0.333	0.046
	ES	0.56	0.43	1.05	0.93	0.34	0.72

SD – standard deviation; CMJ - counter-movement jump; W/kg - watt per kilogram; HS - half-squat; COD: change of direction; p - significance level, ES - effect size

Table 2. Results of ridge regression for modelling of the improvement of running ability in terms of improved muscle strength.

Indicator	20m Sprint linear speed			Zigzag COD test			COD deficit		
	b*	b	p	b*	b	p	b*	b	p
LP [W/KG]	0.37	6.81	0.03	0.02	0.68	0.93	0.21	4.08	0.56
HS [W/KG]	0.37	3.05	0.03	0.03	0.44	0.91	0.20	1.77	0.57
CMJ PP [W/KG]	0.26	9.13	0.13	-0.03	-1.68	0.91	0.17	6.39	0.65
CMJ [CM]	0.54	7.80	0.001	0.08	1.96	0.73	0.23	3.58	0.48

LP - leg press; HS - Half-squat; CMJ - counter-movement jump; PP - peak power; COD - change of direction; b - regression coefficient, p - significance level; b* - normalized beta factor

Table 3. Regression results for change of direction deficit

COD-D deficit	All Groups COD-D	high COD-D	low COD-D
Velocity 20M [M/S]	b=0.87; p<0.01	b=0.76; p=0.000015	b=0.59; p=0.009
Zigzag COD [M/S]	b=-0.83; p<0.01	b=-0.71; p=0.000229	b=-0.31; p=0.156

b - regression coefficient; p - level of significance p<0.05; COD - change of direction; COD-D - change of direction deficit

DISCUSSION

The aim of the study was to analyse the possible relationship between power and speed abilities, agility, and COD deficit in female soccer players. The most important statement is that the COD Deficit is greater in stronger athletes than in those weaker in all strength tests ($p<0.05$; ES=0.72; 0.73; 0.91). It is worth noting that this is the first study to investigate the effect of stronger and weaker groups in terms of muscle strength and power on COD deficit in women. Previous studies compared the effects of strength and power on COD deficit in terms of gender [14,18,22] or strength in a group of men [23].

In our study, the magnitude of the COD deficit results from the fact that the stronger group (LP, SQ, CMJ) outperformed the weaker group in the straight-line sprint test over a distance of 20m ($p<0.05$; ES=1.23; 0.83; 0.93), but in the agility test, the difference in muscle power between the weaker and stronger groups was not statistically significant ($p>0.05$) (Table 1).

The insignificant difference in the Zig-Zag agility test between the stronger and weaker groups in our study could be due to the high proportion of concentric force (N - seated leg press from flexed to extended leg position; HS - movement from the squatting position upwards; CMJ - maximum force during a jump). In the case of agility, several types of strength (eccentric, concentric, and isometric strength) impact on the efficiency of changes in running directions [4,25,26].

It turns out that the greatest contribution to COD performance is made by all types of strength, especially eccentric and later isometric strength. The eccentric strength during changing direction slows down the body and maintains a dynamic balance in preparation for the next acceleration phase [4,26-27]. The concentric strength is very important in the acceleration phase of sprinting [28-29]. In our study, the increase in peak power LP, HS, CMJ [cm] improved 20m sprint speed. ($p<0.05$).

Studies by other authors confirm the effect of strength training (half squat, jump squat) on the improvement of straight-line sprinting [30-32]. The Keiser Air300 Leg Press device has not yet been included in the list of equipment used to assess the effect of strength and power on running performance. Similar devices were used to assess the power of the lower limbs in the propulsion phase (Plyo Press, Agaton Max Series Leg Press) [33-35] but the difference in the body position (sitting position on Keiser Air300 and lying position on Plyo Press) and the leg press machine that is moved in the push phase (in Keiser Air 300, legs press on the sliding component of the machine whereas in Plyo Press, the pressure is performed through the shoulders) can substantially affect the evaluation of the power of the lower limbs. The Keiser Air 300 Leg Press is a modern device where the athlete presses the weight while sitting with 90° flexion in the knees and maximally stabilized pelvis. In our research, the stronger LP/high athletes achieved the best results in the 20m speed test (p<

0.001ES: 1.23) compared to HS/high and CMJ/high (Table 1) This may suggest a very good evaluation of running performance in terms of muscle power using this device.

In the case of peak power CMJ [W/kg], the result was not statistically significant in modelling the improvement in speed and agility (Table 2). The force developed during the vertical jump does not have to translate into sprinting speed or agility: the athletes with more weight can generate greater power during a jump [W/kg], but their jump does not have to be high as they can be too heavy. Studies by other authors confirm that the jump height affects speed and agility [8-9].

In the case of stronger players, the COD deficit is high. According to the statistical calculation of ridge regression, the improvement in the agility test results in the weaker group by 1m/s reduces COD deficit by b= -0.87 to -0.89 m/s and, in the case of the stronger group, only by b= from -0.79 to -0.81 (Table 4). In general, the improvement in the agility test reduces the COD deficit whereas the improvement in the 20m speed test increases the deficit (Table 5).

This study shows the effect of explosive power on speed performance but not on agility (COD deficit).

Studies by other authors confirm the lack of consistency between strength and agility, [26,31,36-37] but there are also contradictory findings showing that strength correlated with agility [5]. It is critical to choose strength training or an exercise that improves COD ability and COD deficit. For example, Nordic hamstring exercise improves COD ability [38] and plyometric exercises improve the COD performance [39].

In this study, maximum strength did not translate into COD and COD deficit performance but into straight linear speed. This statement can be useful for strength and conditioning coaches working with female soccer players.

CONCLUSION

The findings presented in this study show the importance of strength, speed, and agility in women's soccer. By dividing the players into weaker and stronger, differences can be observed in maximum acceleration and agility (Zig-Zag test, COD/D). To improve COD/D, athletes must focus on agility training. To increase the speed in a straight-line run, the athletes must focus on strength training (peak power). However, further research is needed to confirm or exclude whether the training stimulus proposed in our study is likely to help improve the ability to change direction (lower COD/D) and maintain an appropriate level of speed.

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