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Influence of Strength and Power Capacity on Change of Direction Speed and Deficit in Elite Team-Sport Athletes

by
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The aim of the present study was to investigate the influence of maximum strength and power levels on change of direction (COD) ability and deficit in elite soccer and rugby players. Seventy-eight elite athletes (soccer, n = 46; rugby, n = 32) performed the following assessments: squat and countermovement jumps (SJ and CMJ), 1 repetition-maximum in the half-squat exercise (HS 1RM), peak power (PP) in the jump-squat exercise, and 20-m linear sprint and Zigzag COD tests. Utilizing the median split analysis, athletes were divided into two groups according to their HS 1RM and PP JS (e.g., higher and lower HS 1RM and higher and lower PP JS). The magnitude-based inference method was used to analyze the differences between groups in the physical performance tests. Athletes in the high strength and power groups outperformed their weaker and less powerful counterparts in all speed and power measurements (i.e., 5-, 10-, and 20-m sprint velocity, Zigzag COD speed, and CMJ and SJ height). In contrast, stronger and more powerful athletes displayed greater COD deficits. The present data indicate that players with superior strength-power capacity tend to be less efficient at changing direction, relative to maximum sprinting speed, despite being faster in linear trajectories. From these results, it appears that current strength and power training practices in team-sports are potentially not the "most appropriate" to increase the aptitude of a given athlete to efficiently utilize his/her neuromuscular abilities during COD maneuvers. Nevertheless, it remains unknown whether more multifaceted training programs are effective in decreasing COD deficits.

***Key words**: soccer, agility, sprint velocity, COD performance, cutting.*

Introduction

Match-play demands in soccer and rugby dictate that, during a game, players must engage in several high-intensity activities such as sprinting, jumping, changing direction or shuffling (Bloomfield et al., 2007; Duthie et al., 2005). Among these, change of direction (COD) is considered one of the most decisive efforts, given that rapid changes in movement velocity or direction may lead to a try or a goal, hence impacting the outcome of the match (Nimphius et al., 2018). In a competitive context, COD maneuvers are usually executed in response to external stimuli (e.g., ball movements, opponents' actions, changing game situations, etc.) (Born et al., 2016; Gabbett et al., 2008; Young et al., 2015); nonetheless, studying planned drills may allow better understanding of the mechanisms associated with this multifaceted skill (Nimphius et al., 2018) which involves a myriad of technical and physical aspects (e.g., maximum strength and

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power-related capacity) (Brughelli et al., 2008; Hewit et al., 2013; Sheppard and Young, 2006). Therefore, practitioners have long been interested in identifying the main determinants of COD performance in team-sport athletes (Chaouachi et al., 2012; Delaney et al., 2015; Gabbett et al., 2008; Thomas et al., 2018).

Since multiple accelerations and decelerations are present in COD tasks, it is reasonable to assume that the ability to effectively accelerate and achieve higher velocities over short distances is potentially the most important factor contributing to rapid changes in movement direction. Accordingly, previous studies have shown that different speed qualities (Condello et al., 2013; Freitas et al., 2019; Loturco et al., 2019; Pereira et al., 2018) are positively associated with superior COD ability (determined by test completion time), as faster players in linear trajectories are usually faster when changing direction. On the other hand, when it comes to the influence of strength and power outcomes on COD performance, the latest evidence fails to report a consistent relationship between the abovementioned variables, emphasizing the need for further research (Loturco et al., 2018b).

Of note, recent investigations conducted with elite soccer (Loturco et al., 2018a), rugby (Freitas et al., 2018, 2019), and handball players (Pereira et al., 2018) have all concluded that athletes faster in straight sprints tend to be less efficient at changing direction (i.e., relative to their maximum sprint velocity), due to their potentially greater "COD deficit". This proposed measure is as an alternative and complementary way to evaluate COD ability, which allows its assessment as a separate quality, by isolating the acceleration capability of the athlete (Dos' Santos et al., 2018b; Nimphius et al., 2016). Briefly, the COD deficit corresponds to the additional time required to perform a directional change when compared to the time needed to cover the same distance in a linear trajectory (Nimphius et al., 2016) or to the difference in velocity between a linear sprint and a COD task of equal distance (Pereira et al., 2018). Despite the growing interest of the scientific community in the COD deficit and its different applications (e.g., evaluate COD performance or assess unilateral asymmetries) (Dos' Santos et al., 2018b; Freitas et al., 2018; Loturco et al., 2018a, 2019), little is known regarding the physical capabilities of athletes more and less efficient at changing direction. In fact, the few studies that have focused on this particular topic (Freitas et al., 2018, 2019; Loturco et al., 2018a, 2019; Pereira et al., 2018) have only investigated the influence of sprint momentum, linear speed, and maximum acceleration capabilities on the COD deficit.

Along these lines, to our knowledge, no current evidence exists regarding the maximal dynamic strength and power production characteristics associated with higher and lower COD deficits in elite team-sport athletes. Understanding this relationship may provide important information to coaches and sport scientists and help determine to what extent training regimens aimed at increasing lower-body strength and power are suitable options to improve COD efficiency (i.e., decrease the COD deficit). The aim of the present study was to investigate the influence of maximum strength (i.e., assessed by the Half-Squat [HS] 1-repetition maximum [1RM]) and power levels (i.e., assessed by Jump-Squat [JS] maximum peak power [PP]) on COD ability and deficit in elite soccer and rugby players, using a statistical approach based on the median split analysis. According to previous research and empirical observations from our group, it was hypothesized that stronger and more powerful athletes would present greater COD deficits, thus being less efficient at changing direction, relative to their maximum sprint velocity.

Methods

Participants

Seventy-eight elite athletes (male soccer players: n = 46; 23.5 ± 3.8 years; 75.3 ± 6.1 kg; 176.5 ± 5.6 cm; 1RM: 1.68 ± 0.09 $kg \cdot kg^{-1}$; and male rugby players: n = 32; 25.4 ± 3.6 years; 89.0 ± 9.3 kg; 180.2 ± 8.5 cm; 1RM: 2.22 ± 0.50 $kg \cdot kg^{-1}$) participated in this study. Male soccer players competed in the first division of the *Paulista* State Championship, while rugby players were members of the Brazilian National Team that participated in the Americas Rugby Championship. The study was approved by the Bandeirante Anhanguera University Ethics Committee and the participants signed an informed consent form prior to research commencement.

Study Design

A cross-sectional comparative study

design was employed. Athletes involved in this study were assessed during the competitive phase of the season and were well familiarized with testing procedures due to their constant assessments in our facilities. Physical tests were performed on two consecutive days as follows: on day 1, squat jumps (SJ), countermovement jumps (CMJ), and a 1RM in the HS exercise (HS 1RM); on day 2, PP in the JS exercise, and linear and COD sprint tests. Participants were required to be in a fasting state for at least 2 h, avoiding caffeine and alcohol consumption in the 24 h before the procedures. Prior to the tests, athletes performed standardized warm-up protocols including general (i.e., running at a moderate pace for 10 min followed by active lower limb stretching for 3 min) and specific exercises (i.e., submaximal attempts at each tested exercise). Between each test, a 15-min rest interval was allowed, to explain the procedures and adjust the equipment.

Vertical Jumps

Vertical jump height was assessed using the SJ and CMJ. In the SJ, athletes were required to remain in a static position with a 90° knee flexion angle for ~2 s before jumping, without any preparatory movement. In the CMJ, athletes were instructed to execute a downward movement followed by complete extension of the legs. The countermovement depth was self-determined to avoid changes in jumping coordination. All jumps were executed with the hands on the hips and athletes were instructed to jump as high as possible. The jumps were performed on a contact platform (Elite Jump®, S2 Sports, São Paulo, Brazil). A total of five attempts were allowed for each jump, interspersed with 15-s intervals. The best attempts for the SJ and CMJ were used for further analysis.

Maximum dynamic strength test in the HS exercise

Maximum dynamic strength was assessed using the 1RM test as described elsewhere (Brown and Weir, 2001). Prior to the test, participants executed two warm-up sets as follows: 1) five repetitions at 50% of the estimated 1RM; and 2) three repetitions at 70% of the estimated 1RM. A 3-min rest interval was provided between all sets. After 3 min, athletes started the test and were allowed up to five attempts to achieve their 1RM (i.e., maximum weight that could be lifted once with proper technique), which was measured to the nearest 1 kg (Brown and Weir, 2001). The test was performed on a standard Smith-machine (Hammer-Strength Equipment, Rosemont, IL, USA). Given that the tempo of movement during resistance training may affect performance outcomes (Wilk et al., 2018), all athletes were asked to follow a regular tempo of 2/0/maximum velocity for the eccentric/transition/concentric phases of the lift, respectively. Values were normalized by dividing the 1RM by the athletes' body mass (BM) (i.e., relative strength = $kg \cdot kg^{-1}$).

Bar peak power in the JS exercise

Maximum PP was assessed in the JS exercise on a similar Smith-machine. Participants were instructed to execute three repetitions at maximal velocity for each load, starting at 40% of their BM. Participants executed a knee flexion until the thigh was parallel to the ground and, after the tester's command, jumped as fast as possible without their shoulders losing contact with the bar. A load of 10% of BM was progressively added for each set until a clear decrement in the PP was observed (Loturco et al., 2017b, 2018b). A 5-min rest interval was provided between sets. To determine power output, a linear position transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was attached to the bar and values were automatically derived by custom-designed software. The bar position data were sampled at 1,000 Hz. The maximum PP value obtained was used for further analysis. Values were normalized by dividing the absolute power by the athletes' BM (i.e., relative power = $W \cdot kg^{-1}$).

Linear sprint tests

Four pairs of photocells (Smart Speed, Fusion Sport, Brisbane, AUS) were positioned at the starting line and at the distances of 5-, 10-, and 20-m. Participants sprinted twice, starting from a standing position, 0.3-m behind the starting line. In order to avoid weather influences, the sprint tests were performed on an indoor running track. Sprint velocity (VEL) was calculated as the distance traveled over a measured time interval. A 5-min rest interval was allowed between the two attempts and the fastest time was considered for subsequent analysis.

Zigzag change of direction speed test

The COD course consisted of four 5-m sections marked with cones set at 100° angles, on an indoor court (Little and Williams, 2005).

Athletes were required to decelerate and accelerate as fast as possible without losing body stability. Two maximal attempts were performed with a 5-min rest interval in between. Starting from a standing position with the front foot placed 0.3-m behind the first pair of photocells (i.e., starting line), athletes ran and changed direction as quickly as possible, until crossing the second pair of photocells, placed 20-m from the starting line. The fastest time from the two attempts was registered for further analysis. To evaluate the efficiency of each athlete's ability to use their linear speed during a specific COD task, an adapted COD deficit calculation was used, as described elsewhere (Nimphius et al., 2016; Pereira et al., 2018). Thus, the COD deficit was calculated as follows: *20-m velocity – Zigzag test velocity*.

Statistical analyses

Data are presented as means ± standard deviation. Data normality was tested using the Shapiro-Wilk test. Athletes were divided using a median split analysis into two groups according to their PP JS and HS 1RM (e.g., higher and lower PP JS and higher and lower HS 1RM). The magnitude-based inference method was used to analyze the differences between groups in the physical performance tests (Batterham and Hopkins, 2006). The magnitude of differences in different performance variables was expressed as standardized mean difference (effect size [ES]). The smallest worthwhile change (SWC) was set using the Cohen's principles for a small ES (i.e., 0.2) for each variable tested (Hopkins et al., 2009). To analyze the differences between groups, terms such as possibly and unclear were used if the 90% confidence limits (CL) crossed one or both SWC boundaries, respectively. Otherwise, if the CL did not cross SWC boundaries, the effect was inferred as probably. Additionally, the magnitude of standardized difference was interpreted using the following thresholds: <0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, 2.0-4.0, and >4.0 for trivial, small, moderate, large, very large, and near perfect, respectively (Hopkins et al., 2009). The assessments used in this research presented good levels of absolute and relative reliability (CV < 5% and ICC > 0.90, for all tested variables) (Hopkins et al., 2009).

Results

All data presented normal distribution. Table 1 shows the descriptive data of the performance tests. Figure 1 shows the standardized mean differences for comparisons between higher and lower HS 1RM groups in the SJ and CMJ height, linear and COD speed tests, COD deficit, and PP JS. Likely to almost certain differences were observed in all performance tests when comparing higher and lower HS 1RM groups (ES ranging from 0.36 to 1.49). Figure 2 demonstrates the standardized mean differences for comparisons between higher and lower PP JS groups in the SJ and CMJ height, linear and COD speed tests, COD deficit, and HS 1RM. Likely to almost certain differences were observed in all performance tests when comparing higher and lower PP JS groups (ES ranging from 0.45 to 1.66).

Discussion

The aim of the present study was to investigate the influence of maximum strength and power levels on COD ability and deficit in elite soccer and rugby players. Of note, a novel finding was that stronger and more powerful team-sport athletes (i.e., higher HS 1RM and JS PP, respectively) displayed greater COD deficits, which may have considerable implications for testing and training purposes. Furthermore, in accordance with the initial hypothesis, athletes in the high strength and power groups outperformed their weaker and less powerful counterparts in all speed and power measurements (i.e., 5-, 10- and 20-m sprint velocity, Zigzag COD speed, and CMJ and SJ height).

As expected, our results are in line with previous research showing that higher levels of maximum strength and power are positively associated with superior performance in sprinting and jumping tasks (Loturco et al., 2018b; Requena et al., 2009; Seitz et al., 2014; Styles et al., 2016; Wisloff et al., 2004). In contrast, when considering COD ability, findings in the literature are equivocal. For example, a recent study with a comprehensive sample of 303 elite athletes (Loturco et al., 2018b) identified a lack of consistency concerning the selective influence of strength-power capacities on COD performance, due to the complex and multifaceted nature of this skill. It is important to emphasize that several other aspects have been proposed as influential or determinant factors on the ability to change direction (e.g., reactive strength, technique, and anthropometric characteristics) (Brughelli et al., 2008; Hewit et al., 2013; Sheppard and Young, 2006). Nevertheless, with regard to players assessed in this study, high strength and power groups performed better in the Zigzag test.

Table 1

Mean and standard deviation (SD) of the performance tests.

	Mean ± SD
SJ (cm)	42.8 ± 4.2
CMJ (cm)	43.5 ± 4.5
PP JS (W·kg-1)	23.2 ± 3.2
HS 1RM (kg·kg-1)	1.95 ± 0.63
VEL 5-m (m·s-1)	4.93 ± 0.37
VEL 10-m (m·s-1)	5.85 ± 0.25
VEL 20-m (m·s-1)	6.76 ± 0.33
Zigzag (m·s-1)	3.60 ± 0.17
COD deficit (m·s-1)	3.16 ± 0.25

Note: SJ: squat jump; CMJ: countermovement jump; PP: peak power; JS: jump squat; HS: half-squat; RM: repetition maximum; VEL: velocity; COD: change of direction.

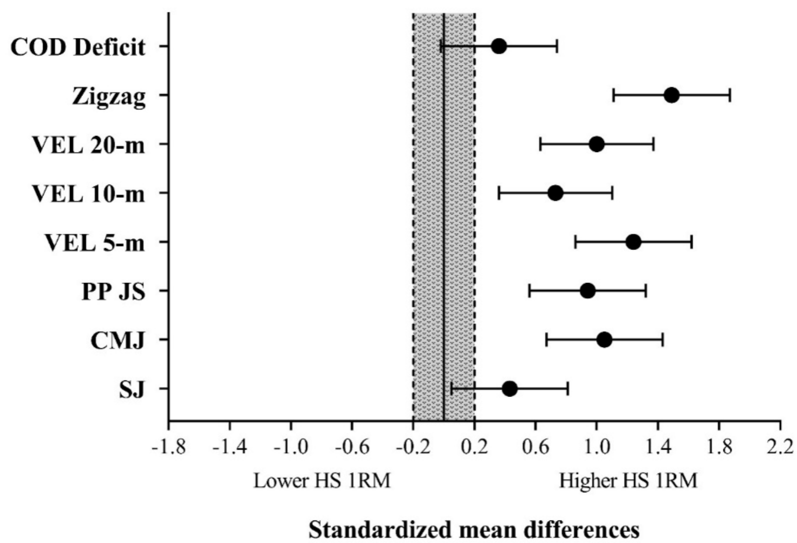

Figure 1

Standardized mean differences for the comparisons between higher and lower half squat 1 repetition maximum (HS 1RM) groups in the squat jump (SJ) and countermovement jump (CMJ) height, linear sprint velocity (VEL) and change of direction (COD) speed test, COD deficit, and peak power jump squat (PP JS).

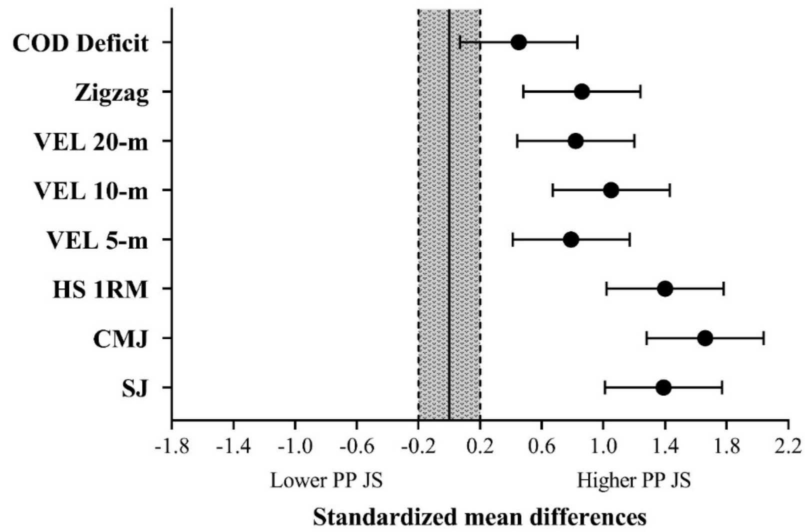

Figure 2
Standardized mean differences for the comparisons between higher and lower peak power jump squat (PP JS) groups in the squat jump (SJ) and countermovement jump (CMJ) height, linear sprint velocity (VEL) and change of direction (COD) speed test, COD deficit, and half squat 1 repetition maximum (HS 1RM).

Notably, this is the first investigation to explore the influence of strength and power levels on the COD deficit by separating players according to their HS 1RM and JS PP. Previous research with elite team-sport athletes divided the sample based on sprint velocity (i.e., faster versus slower players) (Freitas et al., 2018) and the maximum acceleration rate (i.e., high versus low acceleration groups) (Loturco et al., 2019) and found that players with superior ability to rapidly accelerate over linear courses exhibited greater COD deficits. Hence, the present results add to the current body of evidence suggesting that stronger and more powerful athletes tend to be less efficient at changing direction, relative to their top sprinting speed (Freitas et al., 2018, 2019; Loturco et al., 2019; Pereira et al., 2018). This interesting and seemingly paradoxical discovery implies that training regimens currently employed in team-sports are potentially not the “most appropriate” to increase athletes’ efficiency to utilize his or her neuromuscular abilities during COD maneuvers (Freitas et al., 2018; Loturco et al., 2018a, 2019). Even though HS and JS have been shown to be effective exercises to improve both sprint and jump abilities (Loturco et al., 2016, 2017a; Seitz et al., 2014), it appears that they do not equally translate into reduced COD deficits.

To successfully decelerate and re-accelerate the body during a COD maneuver, an athlete needs to quickly apply substantial forces onto the ground, in both horizontal and vertical directions (Condello et al., 2016; Dos' Santos et al., 2017;

Havens and Sigward, 2015; Schreurs et al., 2017). As such, it is unquestionable that soccer or rugby players must possess high levels of relative strength and power to be able to rapidly change direction (or velocity). The issue becomes, then, "how" to properly employ these superior capabilities to present faster COD speeds and, at the same time, lower COD deficits. Cormie et al. (2011) stated that, to maximize the transference of strength and power to performance, training practices should reflect the neuromechanical characteristics of the sport-specific task (i.e., movement patterns, loads, and velocities). Consequently, it has been suggested that more diversified and tailor-made methodologies could conceivably reduce COD deficits in team-sport athletes (Loturco et al., 2018a). In particular, for example, training strategies focused on optimizing the application of vertically- and horizontally-oriented forces during COD drills through concentric (i.e., propulsive) and eccentric (i.e., braking) actions might potentially yield positive adaptations (De Hoyo et al., 2016; Dos' Santos et al., 2018a; Havens and Sigward, 2015; Rodríguez-Osorio et al., 2019) which could, ultimately, result in players "spending less time" when changing direction.

In the abovementioned scenario, using alternative equipment such as weighted vests, might allow more adequate overload on the lower-body muscle groups during specific COD maneuvers and emphasize the eccentric phase of the movement (by increasing sprint momentum) (Rodríguez-Osorio et al., 2019), which would be an advantageous stimulus from a mechanical perspective (Chaabene et al., 2018; De Hoyo et al., 2016; Spiteri et al., 2013). Furthermore, this strategy could improve the ability to tolerate faster entry velocities in different COD tasks (De Hoyo et al., 2016; Dos' Santos et al., 2018a), and thus develop athletes who are more efficient at changing direction (Loturco et al., 2019). Interestingly, promising results supporting the use of weighted vests to enhance COD performance have recently been published (Rodríguez-Osorio et al., 2019). However, no data other than COD test completion time was presented by the authors, which emphasizes the need for additional research on the effects of loaded COD training.

In summary, we revealed that stronger and more powerful team-sport players were able to sprint faster and jump higher than their weaker peers; nevertheless, they displayed greater COD deficits. These data indicate that athletes with superior strength-power capacity tend to be less efficient at changing direction, relative to their maximum speed, which could possibly be related to an inability to cope with greater entry (and exit) velocity during directional changes (Dos' Santos et al., 2018a) and mechanical consequences associated with this issue (i.e., higher momentum and, hence, inertia) (Freitas et al., 2018, 2019; Loturco et al., 2019). The main limitation of the present study was its cross-sectional nature which precluded the determination of any causal relationship between the different variables. In addition, technical outcomes (e.g., joint angles or contact times of the plant and push-off legs) that could possibly help better understand the COD deficit differences identified between the high and low strength-power groups were not assessed. Future research is warranted to investigate whether this phenomenon is also observed in COD tests with less aggressive directional changes (i.e., with angles ≤ 45º) in which deceleration is limited, and velocity maintenance is key (Dos' Santos et al., 2018a; Havens and Sigward, 2015). Moreover, it would be of great interest to investigate the short- and long-term effects of multifaceted training schemes on COD ability and deficit in different team-sports. Finally, studies focused on examining the internal structure of the movements (e.g., muscle activation patterns during specific COD actions) are required, as this may provide important and novel information regarding COD efficiency (Golas et al., 2017a, 2017b).

Conclusions

Stronger and more powerful soccer and rugby players are prone to sprint faster and jump higher than their weaker peers, but also, to be less efficient at changing direction. Therefore, coaches and sport scientists are encouraged to rethink and reorganize their strength and power training approaches, at least when the main objective is to enhance COD performance. Multidimensional programs with an emphasis on eccentric training and unilateral strength-power exercises, containing technique-oriented drills and acceleration-deceleration tasks under different loading conditions (by utilizing, for instance, weighted vests), may potentially be a suitable option to decrease COD deficits in faster and more powerful athletes. However, further research on these topics is needed given that, to date, it remains unknown whether an adequate training stimulus may lead to increased efficiency when changing direction or, on the contrary, more powerful athletes will consistently present higher COD deficits due to the mechanical consequences of being faster (i.e., higher inertia).

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