Contributing Factors to Change-of-Direction Ability in Professional Rugby League Players

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Abstract

Delaney, JA, Scott, TJ, Ballard, DA, Duthie, GM, Hickmans, JA, Lockie, RG, and Dascombe, BJ. Contributing factors to change-of-direction ability in professional rugby league players. *J Strength Cond Res* 29(10): 2688–2696, 2015—Rugby league is an intermittent team sport in which players are regularly required to accelerate, decelerate, and change direction rapidly. This study aimed to determine the contributing factors to change-of-direction (COD) ability in professional rugby league players and to validate the physical and physiological components of a previously proposed COD ability predictor model. Thirty-one male professional rugby league players (age: 24.3 ± 4.4 years; height: 1.83 ± 0.06 m; body mass: 98.1 ± 9.8 kg) were assessed for anthropometry, linear speed, various leg muscle qualities, and COD ability. Change-of-direction ability was assessed for both the dominant (D) and nondominant (ND) legs using the 505 test. Stepwise multiple regression analyses determined the combined effect of the physical and physiological variables on COD ability. Maximal linear speed (SpMax) and relative squat strength (squat:BM) explained 61% of the variance in 505-D performance, whereas measures of mass, unilateral, and bilateral power contributed 67% to 505-ND performance. These results suggest that the 505-ND task was heavily dependent on relative strength and power, whereas the 505-D task was best predicted by linear sprint speed. Second, the physical component of the COD predictor model demonstrated poor correlations ($r = -0.1$ to -0.5) between absolute strength and power measures and COD ability. When made relative to body mass, strength and power measures and COD ability shared stronger relationships ($r = -0.3$ to -0.7). Change-of-direction ability in professional rugby league players would be best improved through increases in an athlete's strength and power while maintaining lean muscle mass.

Key Words team sports, power, agility, linear speed, relative strength, stretch-shortening cycle

Introduction

The movement patterns of rugby league are unique because they involve large quantities of nonlocomotor activities, such as pushing, pulling, and tackling, in combination with accelerations, decelerations, and direction changes throughout a match (15,27). Many of these efforts are performed in response to an opponent's actions, and due to the required cognitive involvement, can be classified as agility-based movements (36). Previously, Sheppard and Young (36) proposed a deterministic model of agility in which it was presented as a combination of both cognitive (perceptual and decision-making factors) and physical (change-of-direction [COD] ability) subcomponents (Figure 1). The validity of this model has been demonstrated among various team sport athletes, with a strong focus placed on the physical and physiological factors that contribute to COD ability, as COD ability strongly contributes to agility performance (3,6,22,43).

Although technique has been shown to contribute to COD ability, previous research has typically concentrated on the physical and physiological contributing factors to COD performance (3,6,22,31,39,40,42) because of the considerable financial burden and logistical constraints associated with the quantification of technique among elite and professional team sport athletes. For example, Chaouachi et al. (6) identified that linear sprint acceleration, muscular strength, and body composition were the strongest predictors of COD ability among professional soccer players. In contrast, several authors have indicated measures of relative eccentric, concentric, and dynamic strength to be best related to COD performance among female basketball athletes (31,39). Recently, Keiner et al. (23) investigated this relationship longitudinally among elite male soccer players, reporting improvements in relative front and back squat strength to be significantly correlated to changes in COD performance ($r = 0.39$–0.70, $p \le 0.05$). However, this

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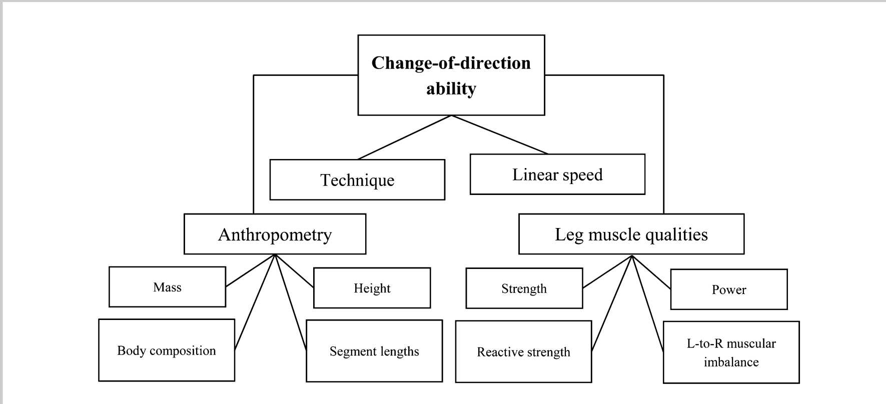

Figure 1. Demonstration of the variables and their proposed role in contributing to change-of-direction ability. Adapted from Sheppard and Young (34). Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

current body of literature has examined such relationships among primarily ectomorphic populations. Specific to rugby league, a higher body mass is necessary for the development of greater impact forces throughout the frequent contact situations (14). Therefore, such findings might be limited in their application to largely mesomorphic athletes such as rugby league players.

The ability to change direction depends largely on sufficient eccentric braking capabilities to halt momentum in 1 direction, before acceleration in a new direction occurs (38,39). It could be proposed that athletes possessing greater musculature and body mass face a greater task in overcoming the inertia encountered during the deceleration phase of a COD movement (20). This has implications for team sports that require a large range of anthropometric profiles between positions, such as rugby league (13). The assessment and training of COD ability is common among professional rugby league clubs (15,16). Previously, Gabbett et al. (16) investigated the relationship between COD ability and linear sprint speed among subelite rugby league players, reporting large significant correlations ($r = 0.52–0.58$, $p < 0.01$). Potentially, because of the considerable proportion of lean mass among rugby league players, the extra force that is required to overcome may be negated by the extra muscle mass, in theoretical contrast to the ectomorphic cohorts recruited in previous research. However, this study did not provide an indication of body composition, and therefore, this suggestion requires support from further research. To date, no research has investigated the physical factors that contribute to COD ability, specifically in high-level rugby league players.

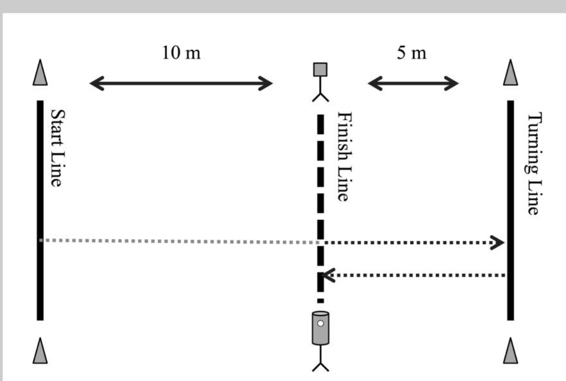

Figure 2. Schematic illustration of the 505 test (11).

During locomotive directional changes, the central nervous system uses 2 mechanisms, foot placement and trunk lean, to reorientate the center of mass into the new direction of movement (33). Among male soccer players, Sasaki et al. (35) observed a strong significant relationship between displacement of the trunk and time to complete a 180° COD task ($r = 0.61$, $p = 0.04$). Furthermore, during treadmill running, Myers and Steudel (30) observed a higher energetic cost associated with a more distally distributed mass. Although such energetics may differ from those of a COD movement, it could be suggested that an athlete possessing considerable peripheral mass may face a greater task in reorientating their limbs and torso.

Although great importance has been placed on COD ability among team sport athletes, there is a paucity of literature examining the contributing factors to COD ability, specifically in mesomorphic team sport athletes such as rugby league players. Therefore, the purpose of this study was to examine the relationships between various physical and physiological variables to COD ability among professional rugby league players. Furthermore, this study aimed to validate the physical and physiological components of the COD ability predictor model of Sheppard and Young (36) among professional rugby league players. It was hypothesized that the unique mesomorphic physique of these athletes will have an impact on the contributing factors to COD ability.

Methods

Experimental Approach to the Problem

Using a cross-sectional descriptive design, a group of well-trained professional rugby league players were assessed for a range of physical and physiological

TABLE 1. Descriptive statistics of all physical factors ($n = 31$).*

	Mean	*SD*	95% CI
505-D (s)	2.21	0.07	2.19–2.24
505-ND (s)	2.23	0.08	2.20–2.25
Torso (cm)	96.6	3.5	95.4–97.8
Leg (cm)	86.2	3.9	84.8–87.6
LMI	55.6	5.3	53.7–57.4
SpAcc ($m \cdot s^{-2}$)	3.48	0.20	3.41–3.55
SpMax ($m \cdot s^{-1}$)	8.78	0.42	8.63–8.93
RSI ($JH \cdot CT^{-1}$)	1.04	0.23	0.96–1.11
Squat (kg)	122.0	9.5	118.4–125.1
LJ-D (cm)	194.2	18.6	187.6–200.7
LJ-ND (cm)	195.8	17.4	189.7–201.9
CMJ40 PP (W)	5,580.0	891.7	5,266.1–5,893.9
Squat:BM ($kg \cdot kg^{-1}$)	1.34	0.10	1.30–1.37
LJ-D:BH ($cm \cdot cm^{-1}$)	1.06	0.10	1.03–1.10
LJ-ND:BH ($cm \cdot cm^{-1}$)	1.07	0.10	1.04–1.11
CMJ40 PP:BM ($W \cdot kg^{-1}$)	56.9	7.4	54.3–59.5

*D = dominant leg; ND = nondominant leg; LMI = lean mass index; SpAcc = average acceleration; SpMax = average maximal velocity; RSI = reactive strength index; JH = jump height in meters; CT = contact time in seconds; LJ = lateral jump test; BH = body height; CMJ40 = countermovement jump loaded with 40 kg; PP = peak power.

capacities to assess contributions to COD ability, as well as validating the physical component of the model of Sheppard and Young (36), in which COD ability was the dependent variable. As per this model, test scores for anthropometry, linear sprinting speed, lower body strength, and reactive strength and power were analyzed for their contribution to COD ability. Left-to-right muscular imbalance was included (6). Change-of-direction ability was assessed using the 505 test (11). According to Barnes et al. (3), team sport athletes are most commonly subjected to such sharp CODs during sprints of approximately 5 m. Therefore, the 505 test exhibited considerable validity to the study population. In addition to this, the study aimed to differentiate between the contribution of the plant (PL) leg and the push-off (PO) leg during the 505 test.

Subjects

Thirty-one ($n = 31$) full-time professional rugby league players (age: 24.3 ± 4.4 years; height: 1.83 ± 0.06 m; body mass: 98.1 ± 9.8 kg) from the same National Rugby League (NRL) club were recruited for this study and consisted of 17 forwards and 14 backs. All players had at least 2 years of training experience with an NRL club and were familiar with all testing procedures from previous preseason testing batteries. During these 2 years, players trained on average between 3 and 5 days per week (for approximately 60–90 minutes per session), across a combination of resistance, aerobic, anaerobic, speed, and skills/tactical training. The subjects in this study were deemed to be elite athletes, as they were in full-time training for the highest level of rugby league competition. Ethical approval was granted by the institutional ethics committee. All subjects provided written consent before start of the study and were older than 18 years (age range: 19–34 years).

Procedures

To standardize training content and to fit within the schedule of the professional NRL team, 3 separate testing sessions were completed within 3 days. To limit the circadian effect on performance, testing sessions were conducted at a similar time of day to which the players were accustomed (field sessions from approximately 7–9 AM, resistance sessions from approximately 1–3 PM). Testing procedures were performed during the general preparation phase of the season. During the 48-hour preceding testing,

TABLE 2. Correlation coefficients (*r*) between change-of-direction ability and measures of anthropometry, linear speed, reactive strength, and left-to-right imbalance.*

	Mass	Height	Torso	Leg	LMI	SpAcc	SpMax	RSI	LJ%
505-D	0.41†	0.39†	0.45†	0.18	0.41†	−0.25	−0.63‡	−0.44†	0.12
505-ND	0.53‡	0.39†	0.45†	0.21	0.54†	−0.53‡	−0.52‡	−0.45†	−0.23

*LMI = lean mass index; SpAcc = average acceleration; SpMax = average maximum velocity; RSI = reactive strength index; LJ% = lateral jump percentage differences; D = dominant leg; ND = nondominant leg.
†Significant at $p \leq 0.05$.
‡significant at $p < 0.01$.

TABLE 3. Correlation coefficients (*r*) between change-of-direction ability and measures of absolute and relative strength and power.*

	Absolute variables				Relative variables			
	Squat	LJ-D	LJ-ND	CMJ40 PP	Squat:BM	LJ-D:BH	LJ-ND:BH	CMJ40 PP:BM
505-D	−0.28	−0.20	−0.28	−0.13	−0.52‡	−0.34†	−0.42†	−0.47‡
505-ND	−0.21	−0.51‡	−0.43†	−0.12	−0.56‡	−0.65‡	−0.56‡	−0.48‡

*LJ, lateral jump; D, dominant leg; ND, nondominant leg; CMJ40, countermovement jump loaded with 40 kg; PP, peak power; BM, body mass; BH, body height.
†Significant at $p \leq 0.05$.
‡significant at $p < 0.01$.

players refrained from high-intensity training or heavy lifting. The first testing session was performed on the morning of testing day 1 and consisted of an anthropometric assessment and linear and COD speed measurement. During the speed testing, subjects wore rubber-soled shoes and training attire and changed into their football boots for the COD testing, which was performed on a grass surface. After a 4-hour unsupervised break during which subjects were instructed to avoid any strenuous activity, subjects returned for the second testing session, which required completion of a weighted countermovement jump (CMJ) and single-leg maximal lateral jumps (LJ). Forty-eight hours later, subjects completed a third testing session to assess lower body strength through 3 repetition maximum (3RM) testing of the back squat exercise.

Anthropometry. Body mass was measured to the nearest 0.1 kg, using calibrated electronic scales (Tanita, Kewdale, Australia). Both standing height and seated height (on a 0.45-m box) were recorded to the nearest 0.01 m using a calibrated stadiometer (HART Sport and Leisure, Aspley, Australia). A Σ7 skinfold profile was performed using calibrated Harpenden calipers (British Indicators Ltd., St Albans, England) by a trained anthropometrist (typical error of measurement, TE = 2.6%), as per Norton and Olds (32). Lean mass index (LMI) was calculated using methods described previously (37).

Linear Speed. All speed and COD tasks were timed to the nearest 0.001 seconds using telemetric electronic timing lights (Fusion Sport, Coopers Plains, Australia) that possess acceptable reliability (intraclass correlation coefficient [ICC] = 0.87–0.96, TE = 1.3–1.9%) (16). Linear sprinting speed was assessed over a distance of 40 m on an outdoor synthetic track. A 0- to 10-m split provided a measure of average acceleration (SpAcc), and the 30- to 40-m split represented maximum linear speed (SpMax) (24). Three repeat trials were completed, separated by a rest period of 3 minutes, with the fastest 40-m sprint time and corresponding split times selected for analysis.

Change-of-Direction Ability. Subjects' COD ability was assessed using the 505 test as originally proposed by Draper

TABLE 4. Forward stepwise multiple regression summary of the deterministic model.*

Step	Variable	Beta	B (*SE*)	*p*	R^2
505-D					
1	SpMax	−0.59	−0.10 (0.02)	<0.001	0.40
2	Squat:BM	−0.46	−0.22 (0.06)	0.001	0.61
505-ND					
1	LJ-D:BH	−0.43	−0.44 (0.10)	0.002	0.42
2	Mass	−0.65	−0.01 (0.00)	<0.001	0.57
3	CMJ40 PP:BM	−0.42	−0.00 (0.00)	0.006	0.67

*Step = forward stepwise regression variable inclusion step; SpMax = average maximal velocity; BM = body mass; BH = body height; LJ = lateral jump; D = dominant leg; ND = nondominant leg; CMJ40 = countermovement jump loaded with 40 kg; PP = peak power; R^2 = coefficients of determinations.

and Lancaster (11) using 1 electronic timing gate. The structure of the test is shown in Figure 2. The cohort was familiar with the test, as per previous testing sessions. Briefly, the test involved one 180° COD and a total of 10 m of linear running. Change-of-direction ability was measured as the time taken (to the nearest 0.001 s) for an athlete to decelerate over 5 m, perform a single directional change by playing 1 foot (PL) on or over a marked line, before accelerating a further 5 m back to the start line. Each subject was required to perform 3 successful trials using both their dominant (D) and nondominant (ND) leg as the PL, with the opposite leg being defined as the PO leg. The fastest trial for each leg was used for data analysis. The D leg was defined as the subjects' preferred kicking leg (12,18), and all subjects were able to identify this.

Jump Testing. Before jump testing, subjects completed a standardized dynamic warm-up, which included submaximal familiarization with the jumping protocol. Lower body power in the vertical direction was assessed using a weighted (40 kg total; 20-kg barbell loaded with an additional 20 kg) CMJ40, using methods typical for rugby league and rugby union players (2,8). The CMJ40 jump was selected for use in this study because of its classification as a slow stretch-shortening cycle (SSC) movement (contraction time >0.25 seconds) (19).

A linear position transducer (LPT; Kinetic Performance Technology, ACT, Australia) was attached to the left hand side of the barbell, 0.6 m from the bar's midpoint, to track peak instantaneous power (PP; in watts) during the concentric phase of the movement (7), in line with the model of Sheppard and Young (36). Three trials were completed, and the jump that elicited the highest PP value was selected for data analysis. Peak power was selected to account for the interaction of force and velocity, not otherwise accounted for by the chosen strength and linear speed tests. The validity and reliability of LPT devices for measuring both displacement and kinetic variables during such movements have been established (ICC = 0.98, cross-validation [CV] = 2.1–2.9%) (9).

Unilateral power was assessed using an LJ test for distance (ICC = 0.94, CV = 4.4%), which provided an indication of power in the medial direction (28). This test was selected to indirectly assess unilateral power, as it resembles the COD movement pattern required within the 505 test. Subjects were required to perform 3 maximal efforts of the LJ on each leg. In line with previous research, arm movement was not restricted, and the furthest jump for each leg was selected for analysis (34). Additionally, the LJ test was used to calculate left-right muscular imbalance, as a percentage difference (% diff) between legs ([D leg − ND leg]/D leg × 100) (6).

Reactive Strength. The drop jump (DJ) test was administered as a measure of reactive strength, because of the short duration (<0.25 seconds), and fast SSC function of the contraction (19). The reactive strength index was calculated as the ratio of jump height (in meters) to contact time (CT; in seconds) (26). These variables were assessed using an Optojump photoelectric cells system (Optojump; Microgate, Bolzano, Italy) that has previously been shown to be a valid and reliable (ICC = 0.99, CV = 2.2%) (17).

For the DJ test, subjects were required to stand with both feet on a platform raised 0.3 m above the ground as used previously in sprint athletes (19,43). A broomstick was held across the shoulders in the back squat position to negate the contribution of arm swing. Subjects were instructed to step off the platform and land on 2 feet. On contact with the ground, the instruction was given to jump to maximize height and minimize ground CT (26). The highest jump was used for analysis, provided the CT of the jump was less than 0.25 seconds, to ensure that the jump was an appropriate measure of a fast SSC movement.

Lower Body Strength. The 3RM test of the back squat exercise was chosen to quantify lower body strength, in line with previous research among rugby league athletes (1,7). Before testing, subjects completed 3 submaximal warm-up sets of the back squat, comprising of 8, 5, and 3 repetitions at an increasing load. The load was estimated from the season's training history of the player and maximum testing scores conducted within the NRL club. After this, the weight was progressively increased until a 3RM score was attained, using established procedures (1). Subjects wore rubber-soled shoes throughout testing, and no supportive garments (i.e., weightlifting belts, knee wraps) were permitted.

Statistical Analyses

Data are presented as mean ± *SD*, and analysis was performed using SPSS software, version 19.0 (SPSS, Inc., Chicago, IL, USA). Each variable was initially tested for normality using the Shapiro-Wilk test. Relationships between variables were established using Pearson's product-moment correlation coefficient ($p \le 0.05$). Coefficients were qualitatively ranked by magnitude, according to Hopkins (21). The strength of correlation coefficients was defined as trivial $r < 0.1$, small $0.1 < r < 0.3$, moderate $0.3 < r < 0.5$, large $0.5 < r < 0.7$, very large $0.7 < r < 0.9$, almost perfect $0.9 < r < 1.0$, and perfect r = 1.0. The physical component of the deterministic model of Sheppard and Young (36) was analyzed for validity on the significance of the relationships established. Paired-sample *T*-tests were also used to determine any significant ($p \le 0.05$) difference between legs for the 505 and LJ tests.

To determine the combined effect of the chosen variables on COD ability, a forward stepwise regression model was used. A forward model was used to identify the fewest variables that could predict COD ability, given the intended practical application of the findings. Two variations of the model were used to permit the determination of contributing factors to 505-D and 505-ND independently. The CMJ40 and the 3RM squat were both reported as an absolute measure and relative to body mass due to account for the large range in body masses. Similarly, the LJ test was reported relative to body height (BH) to prevent bias towards taller athletes. Coefficients of determinations (R^2) were used to indicate the goodness of fit of the predictor models with either the 505-D or 505-ND test as the independent variable. Statistical significance was set at $p \leq 0.05$.

Results

Data for all physical testing are presented in Table 1. No significant difference was observed between legs for the 505 test or the LJ test ($p = 0.21$ and 0.36, respectively). Leg length was the only anthropometric variable that was not significantly correlated with either 505-D ($r = 0.18$, $p > 0.05$) or 505-ND performance ($r = 0.21$, $p > 0.05$). Average acceleration was significantly related with the 505 test, but only when the test was performed using the ND leg as the PL leg ($r = -0.53$, $p < 0.01$). Large significant correlations were observed between average maximal velocity and both the 505-D ($r = -0.63$, $p < 0.01$) and 505-ND ($r = -0.52$, $p < 0.01$). No significant relationships were observed between COD ability and left-to-right imbalance ($p > 0.05$) (Table 2). The LJ was the only absolute strength or power test to significantly correlate with COD ability, but only when the 505 test was performed on the ND leg ($r = -0.43$ to -0.51, $p \leq 0.05$) (Table 3). When strength and power measures were made relative to body size, moderate-to-strong correlations ($r = -0.42$ to -0.65, $p \leq 0.05$) were observed with 505-D and 505-ND performance.

The 505-D model (Table 4) reached its best fit after 2 steps ($R^2 = 0.61$, adjusted $R^2 = 0.59$, $F = 22.21$, $p = 0.001$). Average maximal velocity was entered first into the model, explaining 40% of the variance in 505-D performance. Lower body relative strength was the second best predictor, contributing a further 21% to the model, which allowed the combined model to account for 61% of the overall variance for the D leg.

When 505-ND was selected as the dependent variable (Table 4), the model also assumed its best fit after 3 steps ($R^2 = 0.67$, adjusted $R^2 = 0.64$, $F = 18.60$, $p < 0.001$). The LJ-D relative to BH inputted the model first, explaining 40% of the variance in 505-ND performance. Second, body mass explained a further 14% of the variance. Finally, CMJ40 PP relative to body mass added 10% to the 505-ND model, accounting for a combined total of 64% of 505-ND performance.

Discussion

The primary aim of this study was to determine the contributing factors to COD ability among professional rugby league players. Because of the high-level nature of the recruited athletes, the research was limited to performance and correlational analysis, with no investigation of COD technique, although this approach has been used previously in the literature (6,22,31,39,42). The findings of this study suggest that physical and physiological variables can account for approximately 60% of the variance in 505 performance. This is in line with previous research, quantifying the contribution of such variables among Australian football (adjusted $R^2 = 0.57$, $p \leq 0.05$), soccer (adjusted $R^2 = 0.45$ to 0.48, $p \leq 0.05$), and rugby union (adjusted $R^2 = 0.60$ to 0.67, $p \leq 0.05$) athletes (6,40,42).

It has been observed that unilateral power, as measured by unilateral jumping tasks, contributes to COD ability (28). However, a limitation of the research by Meylan et al. (28) was that the unilateral jumping tasks were limited to the D leg for comparisons with COD ability on both the D and ND legs. As a consequence, it is difficult to determine the exact contribution of unilateral power to COD ability. This study identified the D leg as the preferred kicking leg, in line with previous research (12,18). Although this was not necessarily the leg on which subjects completed the test the fastest, interindividual differences in approach and reacceleration technique made defining a "dominant" COD leg difficult, and therefore, this method was chosen as the most appropriate. Interestingly, 18 of the 31 subjects completed the 505 test faster when using the ND leg as the PL leg. It is suggested that during the linear running phase of the task, a similar contribution between legs exists, and therefore, any differences in the predictor models between legs occur as a result of the COD phase of the test. Potentially, the PO leg may be required to generate concentric power in the new direction during the reacceleration phase of the movement (18). The findings of this study confirm this notion, with the LJ-D test relative to BH, explaining the greatest amount of variance in 505-ND performance ($R^2 = 0.42$).

Several studies have highlighted the importance of elastic muscle properties to linear sprinting (10,18,20,41). Green et al. (18) suggested that by increasing the SSC performance of athletes, COD ability might be also improved because of changes in the technique that results during performance, such as a decreased CT during a cut. This has previously been supported among young soccer players, with plyometric training resulting in improved COD ability (effect size: 1.3–1.5) as measured by the 505 test (41). This study was unable to determine a significant relationship between the 505 test and absolute CMJ40 PP. However, to account for the large differences in body mass among this cohort (range = 78–120 kg), this study also reported power output relative to body mass ($W{:}kg^{-1}$). As a result, relative CMJ40 PP contributed significantly to the 505-ND predictor model, explaining a further 10% of the variance in 505-ND performance ($R^2 = 0.67$). The study findings suggest that among professional rugby league players, relative power in the vertical direction may relate to COD ability more than absolute power, given the influence of a greater body mass on the movement of the body. This notion is further supported by the influence of body mass on the 505-ND predictor model.

During the eccentric braking phase of the COD movement, subjects are exposed to forces much greater than their own bodyweight because of the velocity of movement during deceleration (39). Both the CMJ40 and the COD task used in this study can be classified as slow SSC movements and share similarly small flexion of the hip, knee, and ankle joints (20). Furthermore, loaded jump squat training has been shown to relate to improvements in COD ability among physically active men (25). Taken together, it can be seen that the SSC conditions involved during a weighted CMJ may mimic that of the COD movement, explaining the transfer between the 2 tasks.

In contrast to the 505-ND, 505-D performance was best predicted by linear speed. It was hypothesized that SpAcc would share the greatest amount of transfer with the 505 test, given the requirement of subjects to accelerate over a distance of 5 m after the COD portion of the task. Interestingly, SpMax was the best predictor of the 505-D ($R^2 = 0.40$). Jones et al. (22) also reported strong correlations between the 505 test and maximal linear sprinting speed ($r = 0.78$, $p < 0.01$) among university students. It is possible that the muscle properties of athletes who were able to generate greater maximal linear speed may also allow them to change from an eccentric to a concentric contraction quickly during a COD movement. Alternatively, the static starting position of the acceleration task used in this study shares limited similarities with the acceleration phase of the 505 test, which is directly preceded by an eccentric loading phase.

This study observed no significant correlation between absolute lower body strength as measured by 3RM squat and COD ability on either the D or ND leg ($r = -0.28$ and -0.21, respectively). These findings support past data that did not find significant relationships between maximal lower body strength and COD ability (3,5). The full squat depth required by this study involved hip, knee, and ankle flexion of a greater magnitude than that of a COD movement, which may provide some explanation for the nonsignificant relationship (20). Among female basketball athletes, Spiteri et al. (39) reported very large significant relationships between the 505 test and a 90° back squat during dynamic ($r = 0.80$, $p < 0.001$), eccentric ($r = 0.89$, $p < 0.001$), and concentric conditions ($r = 0.79$, $p < 0.001$). Although this strong relationship may be partly due to the lesser squat depth required, it must be noted that these measures were reported relative to body mass. In this study, when squat strength was reported relative to body mass (3RM squat: BM), lower body strength accounted for a further 21% of the 505-D regression model ($R^2 = 0.62$). This is in support of the findings by Swinton et al. (40) who reported that relative 1RM lower body strength to be the best single predictor of 505 performance among subelite rugby union players (adjusted $R^2 = 0.51$). Taken together, these findings suggest a contribution of relative strength and power variables when considering COD ability.

A secondary aim of this study was to validate the physical and physiological components of the COD ability predictive model outlined by Sheppard and Young (36), specific to professional rugby league players who are largely a mesomorphic population. It was concluded that the COD model of Sheppard and Young (36) required subtle corrections to best suit professional rugby league players. Significant relationships were observed between measures of anthropometry, linear speed, and reactive strength. However, relative measures of lower body strength and bilateral and unilateral power significantly related with COD ability, whereas the absolute measures did not. As a result, the authors propose that the strength and power measures included in the model of Sheppard and Young (36) be expressed relative to body size to best suit population such as rugby league players.

Although only a moderate correlation was observed between body mass and COD ability, the impact of mass on the various strength and power measures seemed paramount. This highlights the importance placed on the strength and power to weight ratio among these athletes, as typical preparation programs of rugby league players emphasize the importance of increasing lean muscle mass while decreasing % body fat (29). As such, relative strength and power measures seem to be more valid in predicting COD ability when compared with absolute values. Moreover, the impact of the mesomorphic stature of professional rugby league players is further confirmed by the moderate-to-large correlations between COD ability and other anthropometric variables such as BH, torso length, and LMI.

Previously, Chaouachi et al. (6) suggested that both leg length and left-to-right muscular imbalance should be included in a COD predictive model. Although this study included such an assessment, it is unable to support this notion among professional rugby league players. Although no significant relationship existed between leg length and COD ability in this study, further research may benefit from investigating the impact of this measure on LJ. Throughout literature, inconsistencies exist regarding the most appropriate normalization variable for the LJ test. This study was limited to selecting 1 anthropometric variable, and therefore, future research may benefit from clarifying the interaction of selected anthropometrical factors with LJ performance.

This study observed that no significant difference was present between the D and ND legs for 505 time ($p = 0.21$). However, the different contributing factors between the 2 legs suggest that some degree of imbalance exists. However, only 2 subjects exhibited a muscular imbalance over a clinically accepted threshold of 10% (4). Therefore, differences in approach and reacceleration technique might explain the different contributing variables, although this requires support from future research.

Practical Applications

The data from this study highlight the importance of relative strength and power measures for COD ability among this population. Once a desired body mass is obtained, additional increases in strength and power while maintaining a constant body mass may benefit COD ability in high-level rugby league players, as it is the relative variable that more greatly influences performance. Intuitively, this improvement in the power to body mass ratio should allow an athlete to generate more force per unit of body mass through both the deceleration and acceleration phases of a COD task, resulting in a more mechanically efficient directional change. Additionally, this study has indicated the importance of the SSC during both maximal linear sprinting and the directional change phase of a COD task. These findings would need to be confirmed through a further analysis of the technical aspects of the 505 and whether they can be altered through specific strength and power training.

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