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Vertical Jump and Relative Strength are Strongly Associated with Change of Direction in Professional Male Basketball Players

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ABSTRACT

Purpose: The aim of this study was to examine the predictors of change of direction (COD) in highly trained/national level male basketball players using field assessments.

Methods: Eight professional male basketball players (age: 24.0 ± 5.5 years; body mass index (BMI): 24.1 ± 1.6 kg·m^{-2}) volunteered for participation in this study. All the evaluations were carried out during 2 sessions as follows: First day_1) body composition, 2) unilateral and bilateral squat jump (SJ) and countermovement (CMJ), and 3) Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1); Second day_1) COD performance, and 2) one repetition maximum (1RM) hang clean (HC) and bench press (BP). A linear regression was performed to evaluate the determinants of COD amongst all other measured variables. Furthermore, we applied Pearson correlation coefficient and in the case of non-normally distributed variables, Spearman's correlation coefficient for the selected variables.

Results: The linear regression indicated that only SJ height was a significant determinant of COD (R^2 = 58.8%, p = 0.016). Significant correlations were identified between COD test and SJ (r = -0.75, p = 0.034; very large), and relative HC 1 RM (r = -0.74, p = 0.038; very large).

Conclusions: The associations found between COD performance and physical parameters should be considered when developing athletic conditioning programs. Especially, the vertical jump height could explain the greatest variability in COD performance.

Keywords: Team sports; field testing; muscular power; agility; anaerobic performance; elite athletes.

INTRODUCTION

Time-motion analyses in basketball games identified a large number of high speed multidirectional movements in a relatively small playing area, with changes in action pattern reported to occur every 1–3 seconds 1. Thus, basketball competitions are characterized by frequent transitions between low intensity activities and intense bursts of linear sprinting, changes of direction (COD), dribbling, shuffling and jumping 1. Moreover, it is important to consider that game demands vary according to competition levels, with higher level players showing greater intermittent workloads than lower level players [2, 3]. The observed intermittent nature of elite basketball suggests that the ability to rapidly accelerate, decelerate, and COD is essential to adequately prepare players transitioning to world class level [4]. In this context, COD performance discriminates between competition levels (first vs. second level teams) and playing roles (starters vs. non-starters) [4, 5].

Given the importance of speed and COD qualities in basketball performance, it is crucial to adopt physical assessment practices that allow discriminate between the most important physical factors of success in basketball [4]. Change of direction was defined as a closed skill consisting in rapidly changing direction (i.e. pre-planned agility), that depends essentiality on muscular strength, speed, technique and coordination; while reactive agility complements a cognitive component to these elements [6,7]. Despite the growing interest in quantifying power-related determinants of COD in the literature (e.g. jump performance, lineal sprint, etc.) across different playing levels or age categories [8-18]; according to a recent systematic review [4], only 9 studies quantified relationships between COD and several performance tests in professional male basketball players. These studies indicate equivocal relationships between performance during the COD and jump capacity, for example: 5 jump test: r = -0.61, p = 0.02; squat jump (SJ): r = -0.11, p = 0.37; countermovement jump (CMJ): r = -0.35, p = 0.15 [11]; and CMJ: r = -0.59; SJ: r = -0.47, p < 0.05 [12]; and broad jump: r = -0.54, p ≤ 0.05; reactive strength index: r = -0.64, p ≤ 0.05 [13]; and CMJ: r ≥ -0.44, p < 0.05; drop jump: r ≥ -0.45, p < 0.05; reactive strength index: r ≥ -0.42, p < 0.05 [14]. Using others physical assessment approaches, Barrera-Domínguez et al. [14] and Chaouachi et al. [11] observed a significant negative correlation between COD performance, theorical maximal force F-V profile (r ≥ -0.55, p < 0.001) and maximum oxygen consumption ($\dot{V}O_{2max}$) (r = -0.72, p = 0.01), respectively. Furthermore, given the complexity of factors contributing to multidirectional movement proficiency [7], Chaouachi et al. [11] have also examined the relationship between COD performance and strength, showing non-significant associations (squat: r = 0.18, p = 0.29; bench press (BP): r = 0.27, p = 0.21). On the other hand, Pehar et al. [13], Lockie et al. [15], Scanlan et al. [16], and Sekulic et al. [17], evaluated the associations between COD skill and reactive agility finding divergent results. For example, Lockie et al. [15] detected a moderate non-significative correlation (i.e. r ≤ 0.44) between COD and reactive agility in 20 male adults' basketball players (i.e. 10 semiprofessional and 10 recreational). Inversely, Sekulic et al. [17] exhibited a significative correlation between COD and reactive agility (i.e. r ≥ 0.40) in 110 high-level male basketball players. Also, the associations between COD time and sprint time are not clear in elite male basketball players [11, 12, 15, 16, 18]. Although, these previous studies provide important insight into the relationships between COD and performance tests, equivocal findings of COD determinants make the information limited.

Research addressing this gap would provide guidance in understanding the complexity of the factors contributing to COD ability in professional basketball players. Therefore, the main aim of this study was to investigate the relationships between COD ability with jump performance, maximal strength and intermittent endurance capacity in highly trained/national level male basketball players. According to the current literature, it was hypothesized that COD performance would be related with jump ability.

METHODS

Participants

Eight, highly trained/national level [19] male basketball players (age: 24 ± 5.5 years; body height: 189.4 ± 8.5 cm; body mass: 91.3 ± 9.8 kg) volunteered to participate in this study. The players had a minimum of 12 years of training experience and 4 years at elite level. All the participants trained 6 times/week (twice a day), for a duration of ~2 h per session, completing a total of 11 to 12 sessions/week. All of them belonged to the same team competing in the first division of the *"Federación Uruguaya de Básquetbol" (FUBB)* (http://www.fubb.org.uy/). Players were asked to not modify any aspect of their lifestyle (sleep, nutrition, transport, diet, etc.). Inclusion criteria were: 1) no musculoskeletal injuries or discomfort during the execution of the study tasks; 2) no cardiometabolic risk factors; 3) no consumption of nutritional supplements, nicotine or drugs.

Procedures

All athletes were evaluated during two different days of a first preseason week, separated by 72 h to ensure adequate recovery. In addition, players were asked not to consume any type of stimulants (e. g. coffee, mate, energy drinks, etc.) in the morning preceding each evaluation. All sessions were held at the same time of day (08:00–1:00 PM), season (winter), and environmental conditions (~15 °C temperature;

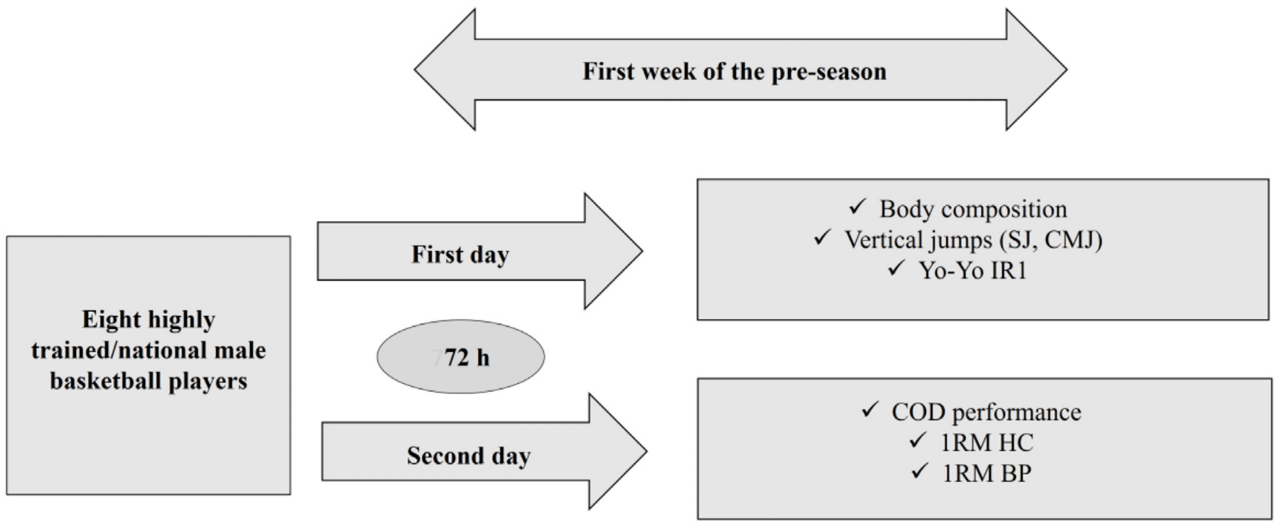

Figure 1. Testing schedule SJ, squat jump; CMJ, countermovement jump; Yo-Yo IR1, Yo-Yo intermittent recovery test level 1; HC, hang clean exercise; BP, bench press exercise; 1RM, one repetition maximum; COD, change of direction.

~78% humidity). The assessments were carried out on an official basketball court during two sessions as follows: First day_1) body composition, 2) vertical jumps, and 3) Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1); Second day_1) COD performance, and 2) one repetition maximum (1RM) hang clean (HC) and BP. Testing schedule is illustrated in Figure 1. Players were instructed to produce a maximal effort and were verbally encouraged by the research team. The warm-up consisted of 5 min of self-selected submaximal running, two submaximal sprints over 12-m, and two maximal sprints over the same distance, 5 SJ and 5 CMJ.

Assessments

First day

Body Composition

Participant's' height (cm) was recorded using a stadiometer (2096 PP, Toledo do Brazil, São Paulo, Brazil), and body mass (kg), body mass index (BMI), and body fat (%) was assessed employing a digital body composition monitor (HBF 514C, OMRON®, Kyoto, Japan) [20].

Vertical jumps

Vertical jumps were performed on a valid and reliable contact mat connected to a microcontroller that estimated vertical jump height from flight time (Chronojump-Boscosystem®, Barcelona, Spain) [21]. Four types of jumps were considered, namely unilateral and bilateral SJ and CMJ. These SJ and CMJ are the most commonly used measures to determine the external power in basketball players [4]. For the SJ, athletes jumped from a semi-squatting position without any countermovement, and for the CMJ, athletes were allowed to perform a countermovement with the lower limbs before jumping [22]. The depth of all the jumps was self-selected and players were asked to land on the same point as take-off [22]. A very high reliability has been show for both measures (SJ: ICC = 0.97 and CMJ: ICC = 0.98) with low CV (~ 3 %) [22]. Two repetitions of the bilateral SJ and CMJ and two repetitions for unilateral SJ and CMJ (left: SJL, CMJL and right: SJR, CMJR) were executed with one minute of recovery. Participants were asked to jump "as high as possible". The jump height was recorded for further analyses and the average of the two attempts was calculated [23].

Yo-Yo intermittent recovery test level 1

For the assessment of endurance capacity, the Yo-Yo IR1 was undertaken. This test is a valid approach to estimate VO_{2max} [24] and is highly used in basketball players [25]. Players were required to complete 2 × 20 m shuttles at a progressively increasing pace (controlled by audio signals), interspersed with a 10 second period of jogging around a marker placed 5 m behind the finish line. The test ended when the participant chose to terminate it, or when the players could not complete the distance run on two consecutive occasions. Participants' VO_{2max} was estimated based on their performance during the Yo-Yo IR1, using the following equation [24]: VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) = IR1 distance (m) × 0.0084 + 36.4. All individuals were verbally encouraged to exercise to exhaustion, following two criteria to classify the effort as maximum: 1) CR10-RPE ≥ 8; and 2) volitional exhaustion.

Second day

Change of direction (COD)

The 5+5 test was used to assess COD ability. In this test the players ran as fast as possible for 10 meters with a 180° COD after 5 meters. This test was selected because it closely reproduces the distance and duration of basketball actions [1]. Previously, it was indicated that this test has good test-retest reliability [26]. A set of photocells with an accuracy of 0.01s connected to a specific software (Chronojump-Boscosystem®, Barcelona, Spain), was placed at the starting line of the test which coincides with the finish. Athletes were asked to stand with their front foot 50 cm behind the starting line. The test was performed twice, with a passive recovery of 2 minutes between attempts, and the average was used for further analyses.

One repetition maximum

The 1RM test is considered as the gold standard for dynamic muscular strength assessment and presented good to excellent test–retest reliability [27]. The following steps were undertaken following previous recommendations [28]:

1. Warm up, with 40 to 60% of perceived 1RM (5 to 10 repetitions).
2. After 1 min of rest, with 60 to 80% of perceived 1RM (3 to 5 repetitions).
3. After 3 min rest, with ~90% of perceived 1RM (1 repetition).
4. After 3 min rest, conservative increases in load were applied until the athlete perform only 1RM (3 min rest for each load).
5. 1RM value it was recorded as the heaviest load that the player successfully completed.

Hang clean

A hang clean (HC) is an alternative option for the full clean exercise that skips the first pull given that the barbell starts at the mid-thigh position. From this initial position, with their hands about one thumb distance from hips, athletes were instructed to explosively move the barbell upward to be received at his shoulder height [29]. This exercise as derivative is optimal tools to promote power development, and the technique is relatively easy to learn compared with other weightlifting exercises. Weightlifting derivatives are an optimal tool to promote power development and produce greater neuromuscular gains than traditional resistance training [30]. In addition, the HC 1RM has been significantly associated with COD, CMJ and sprint performance in team sports athletes [31].

Bench press

The BP it is a traditional exercise in strength training programs for various sports. To perform the BP, participants used the standard five-point body contact technique (head, upper back, and buttocks on the bench with both feet flat on the floor). Players started the exercise holding the barbell with their elbows fully extended and using a self-selected grip keeping it throughout the test. In addition, participants were required to lower the barbell until it touched the chest at the level of the sternum and subsequently lift the barbell as fast as possible until elbow extension [32]. The BP 1RM was significantly discriminates between competition levels in basketball players [33].

Statistical Analyses

Data are presented as mean ± SD and 95% confidence intervals (CI). Normality was assessed by means of standard distribution measures, visual inspection of *Q–Q* plots and box plots, and the Shapiro-Wilk test (<50). Pearson´s correlation coefficient (r) was used to assess the relationships between selected variables with the following thresholds: 1) ≤ 0.1, trivial; 2) > 0.1–0.3, small; 3) > 0.3–0.5, moderate; 4) > 0.5–0.7, large; 5) > 0.7–0.9, very large; and 6) > 0.9–1.0, almost perfect. In the case of non-normal variables, a Spearman's correlation coefficient was used. A linear regression was performed to evaluate the determinants of COD amongst all other measured variables. The statistics were performed with the software IBM SPSS Statistics (v23.0, IBM Corporation®, Armonk, New York, USA). The alpha level was set at $p < 0.05$. Post-hoc power analyses were calculated for all significant correlations using G*Power version 3.1.9.7 (Dusseldorf University, Düsseldorf, Germany): 1) alpha-value of 0.05; 2) correlation value found for each analysis; 3) number of participants of 8.

RESULTS

Physical characteristics are presented in Table 1 and correlations coefficients are presented in the Table 2. Regarding the associations between jump and COD performance, there was a significant negative correlation between SJ height and time spent during COD test (r = -0.75, $p = 0.034$; very large, post-hoc statistical power = 88%), and a

Table 1. Physical characteristics of professional male basketball players.

Outcome measures	Mean ± SD	95% CI
Age (years)	24 ± 5.6	[20.9 to 28.4]
Body mass (kg)	91.3 ± 9.8	[85.1 to 97.1]
Height (cm)	189.4 ± 8.5	[183 to 194]
BMI (kg.m^{-2})	24.1 ± 1.6	[23.0 to 25.0]
% Fat mass (%)	15.4 ± 2.4	[13.9 to 17.0]
SJ (cm)	31.4 ± 3.4	[29.1 to 33.5]
Right SJ (cm)	15.6 ± 2.0	[14.4 to 16.9]
Left SJ (cm)	15.6 ± 2.6	[13.9 to 17.1]
CMJ (cm)	35.3 ± 3.8	[33 to 37.6]
Right CMJ (cm)	16.6 ± 3.6	[14.4 to 19.0]
Left CMJ (cm)	17.0 ± 3.1	[14.9 to 18.8]
Distance Yo-Yo IR1 (m)	1640 ± 226	[1520 to 1800]
Predicted VO_{2max} Yo-Yo IR1 (mL.kg.min^{-1})	50.2 ± 1.9	[49.2 to 51.5]
HC 1RM (kg)	63.6 ± 8.0	[58.4 to 68.9]
Relative HC 1RM (kg/ body mass)	0.7 ± 0.1	[0.63 to 0.76]
BP 1RM (kg)	86.8 ± 6.3	[83.0 to 91.3]
Relative BP 1RM (kg/ body mass)	0.95 ± 0.13	[0.88 to 1.05]
COD time (s)	2.07 ± 0.08	[2.02 to 2.12]

SD, standard deviation; CI, confidence interval; %, percent; BMI, body mass index; SJ, squat jump; CMJ, countermovement jump; Yo-Yo IR1, Yo-Yo intermittent recovery test level 1; VO_{2max}, maximal oxygen consumption; HC, hang clean exercise; BP, bench press exercise; 1RM, one repetition maximum; COD, change of direction.

trend toward significant negative relation was found between CMJ height and time spent during COD test (r = -0.62, p = 0.1). Regarding the associations between maximal strength and COD time, there was a significant negative correlation between relative HC 1 RM and time spent during COD test (r = -0.74, p = 0.038; very large, post-hoc statistical power = 86%), and a trend toward significant negative association was found between relative BP 1 RM and time spent during COD test (r = -0.68, p = 0.064). Also, a significant correlation was exhibited between bilateral and unilateral SJ and CMJ height (r ≥ 0.70, $p < 0.05$; very large, post-hoc statistical power ≥ 82%). All other correlations were non-significant ($p > 0.05$), and varied from trivial to large. No relation was found between body composition and physical profile ($p > 0.05$).

The linear regression indicated that only SJ height was a significant determinant of COD, accounting for 58.8% of its variability (model statistics: R^2 = 0.589, Beta = -0.768; t: -3.168, p = 0.016).

DISCUSSION

The main aim of the present study was to examine the association between COD and physical parameters in highly trained/national level male basketball players using field assessments. This research provides data about the physical profile of Uruguayan first division basketball male players resulting a lower physical performance in vertical jump, maximal strength, and endurance capacity when compared with players from other leagues and countries. Moreover, we analyzed the correlations between maximal strength, jump ability, COD performance and intermittent endurance capacity. Thus, the main findings present large associations between jump performance and relative maximal strength with COD performance in professional basketball players.

Basketball games are characterized by anaerobic efforts and multidirectional activities development in small playing area [1]. Morrison et al. [4] highlighted the importance of COD, plyometric training,

Table 2. Correlation coefficients between different performance parameters of professional male basketball players.

	SJ (cm)	Right SJ (cm)	Left SJ (cm)	CMJ (cm)	Right CMJ (cm)	Left CMJ (cm)	Distance Yo-yo IR1 (m)	HC 1RM (kg)	Relative HC 1RM (kg/body mass)	BP 1RM (kg	Relative BP 1RM (kg/body mass)	COD time (s)
SJ (cm)	-	-	-	-	-	-	-	-	-	-	-	-
Right SJ (cm)	0.19	-	-	-	-	-	-	-	-	-	-	-
Left SJ (cm)	0.33	0.70*	-	-	-	-	-	-	-	-	-	-
CMJ (cm)	0.90**	0.43	0.65	-	-	-	-	-	-	-	-	-
Right CMJ (cm)	0.22	0.50	0.77*	0.40	-	-	-	-	-	-	-	-
Left CMJ (cm)	0.20	0.76*	0.53	0.34	0.60	-	-	-	-	-	-	-
Distance Yo-yo IR1 (m)	0.42	-0.40	-0.13	0.12	0.13	-0.12	-	-	-	-	-	-
HC 1RM (kg)	0.05	0.30	-0.03	-0.09	0.10	0.54	0.40	-	-	-	-	-
Relative HC 1RM (kg/ body mass)	0.28	0.42	0.25	0.29	-0.05	0.51	0.21	0.76*	-	-	-	-
BP 1RM (kg)	-0.22	0.36	-0.21	-0.15	-0.36	0.09	-0.83*	-0.21	-0.18	-	-	-
Relative BP 1RM (kg/ body mass)	0.43	0.48	0.35	0.58	-0.26	0.12	-0.36	-0.11	0.47	0.37	-	-
COD time (s)	-0.75*	-0.31	-0.13	-0.62	0.19	-0.23	-0.32	-0.44	-0.74*	0.05	-0.68	-

SD, standard deviation; CI, confidence interval; %, percent; BMI, body mass index; SJ, squat jump; CMJ, countermovement jump; Yo-Yo IR1, Yo-Yo intermittent recovery test level 1; VO_{2max}, maximal oxygen consumption; HC, hang clean exercise; BP, bench press exercise; 1RM, one repetition maximum; COD, change of direction.

*** $p < 0.01$*

** $p < 0.05$*

intermittent endurance capacity, and acceleration and deceleration drills for the improvement of performance in senior basketball players. Our findings show that the performance of Uruguayan male professional players was lower than that presented in a recent systematic review including ≥18 years of age male basketball players in variables such as; Distance Yo-Yo IR1 (1640 vs. 1815.6 m), SJ (31.4 vs. 38.3 cm), CMJ (35.3 vs. 44.5 cm), 1RM BP (86.8 vs. 92.9 kg) (only professionals) (Table 1) [4]. This result may be evident from the differences in the FIBA ranking 2023 between Uruguay (45 of 164 https://www.fiba.basketball/es/rankingmen) vs. all the studies selected.

On the other hand, it was established that the COD time during line agility test is an element that discriminated against the players drafted in the NBA in relation to those not recruited [34]. Furthermore, a recent review established that COD time is an important predictor of NBA game-play performance [35]. The COD ability depends of multifactorial physical attributes such as; muscular strength, speed, technique and coordination [7]; nevertheless, the relationship with physical condition factors has yet to be elucidated. Previously, Pérez-Ifrán et al. [9] showed that the COD performance in modified T-test was largely associated with unilateral and bilateral CMJ height (r ≥ - 0.66, $p < 0.05$) and indicators of repeated sprint ability (r ≥ 0.72, $p < 0.05$) in juniors basketball players. Alemdaroğlu [12] reported a significant correlation between CMJ height and COD ability (r= -0.59, $p < 0.05$) and SJ height and COD ability (r = -0.47, $p < 0.05$) in professional Turkish male basketball players. Barrera-Domínguez et al. [14] detected a significant relationship between CMJ and drop jump with COD ability (r = ≥ -0.44, $p < 0.05$) in Spanish national division players. Furthermore, Chaouachi et al. [11] established that the 5 jump test was one of the most factor associated with COD time across T-test in the Tunisian national basketball team. Besides, Pehar et al. [13], established that the reactive strength index (41%) and the broad-jump (29%) are the most important physical predictor of COD.

In this study, we detected a significant very large negative correlation between SJ height and COD time in 5+5 test (r = -0.75, $p = 0.034$), also a trend toward significant negative association between CMJ height and COD time in 5+5 test (r = -0.62, $p = 0.1$) (Table 2). Our results showed a stronger association between vertical jump and COD performance compared to previous studies. Also, we detected that SJ height was a significant determinant of COD (i.e. 58.8% of its variability). Previously, Scanlan et al. [8] shows that standing long jump distance shared the most variance (45%) with modified T-test performance and exhibited the largest difference between faster and slower male players. It is important to highlight that during basketball competitions different speed-strength qualities are necessary to meet the physical demands (e.g. reactive strength, short stretch-shortening cycle, speed-strength only concentric) [4]. Thus, SJ represent only concentric force production, while CMJ represent long-slow stretch shortening cycle force production [4]. Currently, the vertical jump and performance in COD has shown to improve as senior teams are elicited [33, 36] and also discriminates the competitive level of athletes [34, 36]. Agility is a very complex term that represents an open skill, which rapid movements of the whole body with a COD are completed in response to an external stimulus (i.e. perceptual and decision-making factors) [7]. On the other hand, COD ability is a closed skill that requires only interactions of physiological and biomechanical components (e.g. technique, straight sprinting time, reactive strength, muscular morphology, etc.) [7]; which concentric force production could explain part of the performance outcomes accomplished in COD testing [37]. Strikingly, we did not detect any association between COD performance and unilateral jumping ability. Previously, it was suggested that unilateral jumps might be more strongly correlated to pre-planned COD performance than bilateral jumps because of the characteristics (unilateral stance) of running [38]. Yet, it was not possible to replicate these findings in our study, perhaps due to the small sample size. Therefore, future studies should continue investigating the associations between COD performance and bilateral and unilateral jumping ability with larger samples.

Previously, it was suggested in a review article that the 1RM values of elite players may be higher than those of college players [36]. In fact, when the value of 1RM was compared in BP and squat between categories, the senior team completed a greater load than U-18 and U-20 [33]. Chaouachi et al. [11] found no significant associations between COD with 1RM in BP and squat exercise (r ≤ 0.27, $p > 0.05$) when recruiting players from Tunisian national team. Barrera-Domínguez et al. [14] reported a significant negative correlation between COD performance and theorical vertical maximal force (r = ≥ -0.55, $p < 0.001$) in elite male Spanish players. Townsend et al. [29] reported a significant correlation between absolute peak force mid-thigh pull and COD performance (r = -0.52, $p \leq 0.05$) in NCAA Division I men basketball players. Peterson et al. [39] showed with NCAA players that relative 1RM squat (i.e. adjusted for body mass) (r = -0.80, $p < 0.01$) was more highly related to COD performance than absolute 1RM squat (r = -0.78, $p < 0.01$). Likewise, Scanlan et al. [8] was showed that relative peak force of isometric midthigh pull it was associated with T-test COD time (r = -0.55, $p = 0.006$) in contrast to absolute peak force of isometric midthigh pull (r = 0.24, $p = 0.26$) with Australian national male young players. We observed a significant very large negative correlation between relative HC 1 RM and COD time (r = -0.74, $p = 0.038$), along with a strong trend toward significant negative association between relative BP 1 RM and COD time (r = -0.68, $p = 0.064$). Nevertheless, in reference to BP 1 RM and COD time association, a larger sample may be necessary to confirm this trend. Similar to previous studies, we observed the importance of relative force production for COD skills, given that few specific tests are used to assess this quality in basketball [4]. Therefore, we can speculate that the absolute force generation during dynamic actions in the vertical plane employs less influence on COD ability than force production normalized to body mass (i.e. relative force). Moreover, it was established that Weightlifting derivatives (e.g. hang clean) are optimal ways to improve neuromuscular function promoted physiological adaptations such as; motor units recruitment, rate coding, etc. [30]. In this context, the importance of power development is expressed when the players completed the COD, applying high forces against the ground before a rapid hip extension to start the movement in a new direction [8].

Our study presents some limitations. First, our COD test does not include specific basketball movements as previously suggested [6]. Besides, we did not incorporate any test that evaluate the horizontal force [40]. Also, we did not assess reactive agility like other authors [15-17]. Our proposal it was carried out at the beginning of the pre-season; therefore, the results cannot be extrapolated to other periods of the year. Our sample was small according post-hoc power analyses, nevertheless, the study population was highly trained/national level male players, so future studies should investigate similar issues at other levels of male and female players. We did not measure body composition with the gold standard (i.e. DEXA) like other studies [41]. Finally, the selected athletes show a lower physical aptitude than athletes from other leagues/countries, so the results should be interpreted with caution.

CONCLUSIONS

In summary, the vertical jump performance and maximal strength relative to body mass were strongly associated with COD performance, and vertical jump heigh was the main predictor. Considering the relevance of COD ability in the basketball game, this study brings new insights about the association of this outcome with others performance markers. This finding may help strength and conditioning coaches to prescribe players' physical training program in order to optimize different physical capabilities (i.e. jump performance, maximal strength and COD ability). Future studies should continue examining the associations between COD and physical components, including vertical and horizontal force-velocity profile and parameters of rate of force development.

CONFLICTS OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICAL APPROVAL

This study was performed in line with the principles of Declaration of Helsinki (World Medical Association 2013) and was approved for local Ethics committee [approval number: 2.903.811].

INFORMED CONSENT

Informed consent was obtained from all individuals participants.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FUNDING

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