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Change of Direction Ability

Change of Direction Performance and its Physical Determinants Among Young Basketball Male Players

by

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The main aim of the present study was to examine the effects of the age group (U-15, U-17 and U-19) on change of direction (COD) performance and its specific physical determinants among young basketball male players. Thirty-one young male basketball players (13–18 years) volunteered to participate in this study. The sample was divided into 3 age groups (U-15, U-17, U-19). All the evaluations were carried out in the same order in 3 sessions as follows: 1) body composition, self-reported sexual maturation, COD performance, and intermittent endurance capacity; 2) reactive strength index (RSI), 15-m sprint, and repeated sprint ability (RSA) test; 3) vertical and horizontal jumps and lower-limb strength. The results showed significant differences between groups for age, sexual maturation, endurance capacity, horizontal and vertical jump performances, RSI, COD, RSA, and lower-limb strength ($p < 0.05$). Significant correlations were identified between COD performances and some physical determinants such as jumping ability and RSA performance ($-0.43 < r < 0.85$; $p \leq 0.05$). In conclusion, there are age effects on COD performance and its specific physical determinants among young basketball male players. The associations between COD performance and its determinants should be considered by practitioners when programing athletic talent development for this population.

Key words: *team sports; athletic talent; adolescence; field testing; basketball.*

Introduction

Time-motion analyses in basketball have shown that players perform many intermittent forward, backward, and lateral high-speed movements during games (Abdelkrim et al., 2007; Petway el al., 2020; Stojanović et al., 2018). In this context, previous studies have reported that basketball is characterized by intermittent high-intensity actions such as changes of direction (CODs), sprints and jumps which are considered main factors for specific performance (Abdelkrim et al., 2007; Ari et al., 2021; Petway el al., 2020; Stojanović et al., 2018). Furthermore, recently it has been suggested that repeated CODs can be considered a key ability for team sports such as basketball (Brini et al., 2020a, 2021). In this regard,

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several recent studies have described the importance of implementing COD, power, as well as acceleration and deceleration exercises for the evaluation and training of both young and senior basketball players (Brini et al., 2020a, 2021; Mancha-Triguero et al., 2019; Ramos et al., 2020; Stojanović et al., 2019).

Previous studies have analyzed the determinants of performance in rapid linear sprinting and jumping with COD and have developed specific methods for testing and training in basketball (Scanlan et al., 2021; Spiteri et al., 2015; Zagatto et al., 2017). However, the relationships among jumps, linear sprinting and sprinting with COD (Chaouachi et al., 2009; Haj-Sassi et al., 2011; Young et al., 2002) are not consistent in literature. Furthermore, Little et al. (2005) analyzed the relationship between maximum sprinting speed, COD, and acceleration capacity and concluded that these three capacities are relatively independent. On the contrary, Sturzik et al. (2017) reported a significant strong relationship between vertical jump and COD performance in young basketball players. Therefore, while it seems that repeated COD sprints are important for basketball players, it still needs to be determined how it is related to specific performance factors.

The ability to perform fast COD is also considered a valid criterion for talent identification and preparedness in basketball (Ramos et al., 2020; Sisic et al., 2015; Stojanović et al., 2019; Scanlan et al., 2021; Torres-Unda., 2013). However, there are only few studies in literature with young players which have evaluated some physical and morphological differences among age categories (Calleja-González et al., 2018; Fort-Vanmeerhaege et al., 2016) or playing positions (Ivanović et al., 2022), but not the factors related to COD ability. Therefore, it would also be important to verify the changes in this key capacity for players of different age, and if other components of fitness in addition to muscle power (Scanlan et al., 2021), would be involved in its improvement throughout the formative years.

Thus, the main aim of this study was to compare 3 age groups of young basketball male players (U-15, U-17 and U-19) with respect to COD ability and their specific physical determinants. Following the current literature, it was hypothesized that COD performance would improve with age and physical fitness (Abdelkrim et al., 2010).

Methods

Participants

Thirty-six male basketball players aged 13–18 years volunteered to participate in this study. Players had a minimum of 3 years of training experience. All of them belonged to the same team competing in the sub-elite series of the Uruguayan Basketball Federation (FUBB). All players trained 5 times a week, with sessions lasting ~2 h. Players maintained their usual training schedules during the procedures at the pre-season period. Participants were asked not to modify any aspect of their daily life (sleep, diet, etc.), and to rest properly between evaluations. The inclusion criteria were: 1) be preparing for the 2020 league; 2) not having any musculoskeletal injury or any pain or discomfort during the time of the study; 3) not having any cardiometabolic disease; 4) not taking any supplements or drugs. Prior to recruitment, participants and their parents were informed of the objectives, potential risks and benefits of the study, and signed an informed written consent form. This study was carried out in accordance with the Declaration of Helsinki (World Medical Association 2013) following the update of Fortaleza 2013.

Design and Procedures

The procedures were carried out in March of 2020 during the last 2 weeks of the pre-season. A week before data collection, players were fully familiarized with all the tests during regular training. Physical fitness evaluations were selected from the systematic review by Mancha-Triguero et al. (2019) who considered aerobic capacity, anaerobic capacity, jump capacity, linear speed and agility as important physical fitness components for basketball players.

All athletes were evaluated over 15 days during 3 different sessions lasting ~2 h each, separated by four to five days to ensure adequate recovery. In addition, their coaches were asked to avoid intense activities, while players were asked not to consume any type of stimulants (e.g., coffee, mate, etc.) 48 h before evaluations. All the tests were carried out on the same official basketball court and were separated into 3 sessions as follows: 1) body composition evaluation, self-reported sexual maturation evaluation (Tanner stage), COD, and intermittent endurance test; 2) reactive strength index (RSI), 15-m sprint, and repeated sprint ability (RSA) test; 3) jumps and lower-limb strength. Throughout all the tests, players were instructed to perform their maximum effort and were verbally encouraged by the research team. The standardized warm-up in all testing sessions consisted of 5 min of self-selected submaximal running, two submaximal sprints over 12 m, and two maximal sprints over the same distance.

Measures

First day

Body Composition

The collected measurements were: body height (cm) using a stadiometer (2096 PP, Toledo do Brazil, São Paulo, Brazil), body mass (kg), body mass index (BMI), and body fat (%) using a digital body composition monitor (HBF 514, OMRON, Kyoto, Japan).

Tanner stage

The self-administered questionnaire validated by Morris (1980) was used to evaluate the sexual development of participants. For this purpose, participants were asked to respond with a number from 1 to 5, to identify the maturational stage they considered to meet at the moment of the study.

Change of direction (COD)

The modified T-test (Haj-Sassi et al., 2009) was used to assess COD ability. This test was performed with four cones forming a T, and a set of photocells with accuracy of 0.01 s (Chronojump Bosco system®, Barcelona, Spain) (de Blas et al., 2012). Photocells were placed at the beginning of the test which coincided with the end. Athletes were asked to stand with their front foot 50 cm behind the starting line. This adapted test requires sprinting, lateral shuffling, and backpedaling with 4 directional changes representing the typical movements of basketball (Haj-Sassi et al., 2009). COD ability was evaluated twice with a passive recovery of 2 min between attempts, and the mean was used for further analyses. The ICC value obtained for this test was 0.91 (0.83–0.96, 95% CI).

Intermittent endurance capacity

The 30–15 intermittent fitness test (IFT) which consists of alternating 30-s bouts of increasing running speed with passive recovery periods of 15 s, was used to assess specific endurance capacity. The initial speed was 8 km·h and it was increased by 0.5 km·h each stage. The test ended when the player was exhausted or when could not make the 2-m zone at the time of the "beep" for three consecutive times. The test version used was the one specifically modified for basketball (Buchheit, 2010). The peak velocity in the IFT (VIFT) was recorded and then maximum oxygen uptake (VO_{2max}) was estimated according to a validated formula (Buchheit, 2010).

Heart rate measured during the IFT

Players were monitored during the IFT with a heart rate (HR) chest strap (Firstbeat Technologies® Ltd, Jyväskylä, Finland). The HR data were subsequently exported to Firstbeat Sports software (v4.7.3.1, Firstbeat Technologies Ltd, Jyväskylä, Finland) to record the peak HR (HR_{peak}). Athletes were asked to rest for 2 min on the court in the supine position immediately after the end of the IFT to record the HR recovery % delta at the 2nd min (HRRΔ 2 min) (Benítez-Flores et al., 2021).

Second day

Reactive strength index

The RSI was assessed utilizing the 10 rebound jump test (10/5 RJT) (Comyns et al., 2019). This measure was recorded with a portable device (v2.0, PUSH Inc., Toronto, Canada) secured with a waist belt placed on the low back. This sensor with a triaxial accelerometer and a gyroscope has previously shown acceptable validity and reliability to monitor kinematic variables in different power exercises (Montalvo et al., 2021; Pérez-Castilla et al., 2019). During the evaluation, players were instructed to keep their hands on hips, jumping and landing with their legs extended during 10 repetitions on the same spot, maximizing jump height and minimizing the ground contact time. Then, the five best jumps from a single attempt were considered for analyses.

15-m sprint

Participants were instructed to run twice at maximum speed over a distance of 15 m. Between the sprints there was a passive recovery period of 2 min. The lap times were recorded with photocells with accuracy of 0.01 s (Chronojump Bosco system, Barcelona, Spain) (De Blas et al., 2012) located at the starting and the end line. Players were asked to stand with the front foot 50 cm behind the starting line. The mean of these two sprinting times was used for further analyses. The ICC value obtained was 0.93 (0.86–0.97, 95% CI).

Repeated sprint ability (RSA)

For RSA testing we used the protocol proposed by Nabli et al. (2016) which consists of 5 sprints of 30 m (15+15 m) with a COD of 180° and 25 s of passive recovery between efforts. Participants were asked to run at maximum speed to the line located at the 15th m, step on it, change direction 180° and return as fast as possible to the starting line. The times of each sprint were recorded with photocells with accuracy of 0.01 s (Chronojump Bosco system, Barcelona, Spain) located at the starting line. The following variables were subsequently calculated: RSA total time (s), defined as the sum of the five sprinting times; RSA best time (s), calculated as the best time among all repetitions; and the RSA fatigue index (FI) according to the following equation: FI = [Σ total time/ (best time × n° sprints) × 100)] - 100 = % (Fitzsimons et al., 1993).

Third day

Vertical and horizontal jumps

Vertical jump performances were evaluated using a portable device (v2.0, PUSH Inc., Toronto, Canada) as previously described. The jumps considered were the unilateral and bilateral countermovement jumps (CMJ). Two attempts of the bilateral CMJ and one of the unilateral CMJ (left: CMJL and right: CMJR) were allowed. Participants started with both feet together and were asked to jump as high as possible. The depth of the CMJ was self-selected and players were asked to land at the same place of the take-off (Markovic et al., 2004). Jump height and mean power were recorded for further analyses. The average of two attempts of the bilateral CMJ were used for further comparisons. The ICCs values were: 0.96 (0.92–0.98 95% CI) and 0.91 (0.82–0.96 95% CI), for jump height and power, respectively.

The unilateral and bilateral standing broad jump (BJ) performances (Artero et al., 2011) were evaluated with a measuring tape. Players were asked to keep their hands on the waist as during the CMJ. We only recorded those jump attempts in which participants were able to stand in the final position without losing balance. Two executions of the bilateral BJ and one of the unilateral BJ (left: BJL and right: BJR) were carried out, with the mean used for further analyses. The ICC value for BJ distance was 0.90 (0.80–0.95 95% CI).

Lower-limb strength

Following a previous study (Pareja-Blanco et al., 2017), athletes performed a progressive load test in the free squat exercise. A free eccentric velocity was allowed until the thighs were below the horizontal plane and then they were asked to move at maximum concentric velocity. Three repetitions per load were performed with 2 min of recovery between sets. The mean velocity of each repetition was controlled and only the best repetition in the set was recorded for further analyses (v2.0, PUSH Inc., Toronto, Canada). Twenty kilograms were taken as the initial load and subsequently the load was progressively increased by 10 kg, until the mean velocity reached was ~0.95 $m \cdot s^{-1}$. This mean velocity has been associated with maximum power production (Sánchez-Medina et al., 2017).

Statistical Analyses

Data are presented as mean ± SD and 95% confidence intervals (CI). Reliability for each test was calculated by determining the intraclass correlation coefficient (ICC) using a custom-made Excel® spreadsheet. Acceptable reliability was determined at an ICC ≥ 0.8 (Hopkins, 2000). Normality was assessed by means of standard distribution measures, visual inspection of *Q*–*Q* plots and box plots, and the Shapiro-Wilk test (<50). Additionally, variance homoscedasticity was assessed using the Levene's test variables. Where normalization was not possible, for some variables (age, HR_{peak} and lower-limb strength), non-parametric methods were used. Mean differences among groups were conducted using one-way ANOVA with Bonferroni's post hoc paired comparisons. For non-normal variables, intergroup comparisons were evaluated using the Kruskal-Wallis test and pairwise analyzes by the Mann-Whitney U test. Effect sizes were calculated using η_p^2 in order to examine the magnitude of the differences between the three groups and Cohen's *d* (for normal variables) or $r = z/\sqrt{N}$ (for non-normal variables) for paired comparisons. Threshold values for effect size were 0–0.2 trivial, >0.2–0.6 small, >0.6–1.2 moderate, >1.2– 2.0 large, and >2.0 very large (Hopkins et al., 2009). The Pearson´s correlation coefficient (r) was used to assess the relationships between selected variables with the following thresholds: ≤0.1, trivial; >0.1–0.3, small; >0.3–0.5, moderate; >0.5–0.7, large; >0.7–0.9, very large; and >0.9–1.0, almost perfect (Hopkins et al. 2009). For non-normal variables, a *Spearman's correlation* coefficient was used. The statistics were performed with IBM SPSS Statistics® software (v23.0, IBM Corporation, Armonk, New York, USA). All graphics were made with Graph Pad Prism (v6.0, Graph Pad Software, San Diego, CA, USA). The alpha level was set at $p < 0.05$.

Results

No injuries were recorded over the course of the study. Five participants did not attend the three days of assessments and therefore they were excluded. Thus, the final sample consisted of 31 athletes (U-15 = 10, U-17 = 12 and U-19 = 9).

Intergroup differences

Significant differences among groups were noted for age, Tanner stage, VIFT, VO_{2max}, HR_{peak}, CMJ height, CMJ absolute power, CMJL absolute power, CMJR height, CMJR absolute power, BJ distance, RSI, COD, RSA total time, RSA best time and lower-limb strength ($p < 0.05$). No significant differences were detected among groups for body height, body mass, BMI, body fat, HRRΔ 2min, CMJ relative power, CMJL height, CMJL relative power, CMJR relative power, BJL distance, BJR distance, 15-m sprint time and RSA FI ($p > 0.05$) (Tables 1–3 and Figure 1).

Correlations

Correlations between COD and all the remaining performance variables are shown for each age group and for the whole sample in Table 4. Significant correlations between COD performance and some physical determinants such as jump and RSA performances were identified, especially among U-15 and U-17 (moderate to very large; -0.43<r<0.85; $p \le 0.05$).

Discussion

The main aim of the present study was to examine differences between age groups (U-15, U-17 and U-19) in COD performance and its specific physical determinants among basketball male players. The main findings showed that age, Tanner stage, VIFT, VO_{2max}, HR_{peak}, CMJ height, CMJ absolute power, CMJL absolute power, CMJR height, CMJR absolute power, BJ distance, RSI, COD, RSA total time, RSA best time and lower-limb strength differentiated between age groups. However, other physical determinants such as VIFT, VO_{2max}, CMJ and BJ variables, RSI, COD, and RSA performance did not exhibit any significant difference between U-17 and U-19 categories. Moreover, our results showed a significant correlation between COD performance and some physical determinants such as VIFT, CMJ and BJ (bilateral and unilateral), and RSA, especially in the U-15 and U-17 groups.

Table 1. *Body composition and cardiorespiratory performances.*

Variable	U-15 (n = 10)	U-17 (n = 12)	U-19 (n = 9)	Post-hoc analyses (p value and effect size)		
				U-15 vs. U-17	U-15 vs. U-19	U-17 vs. U-19
Age (years)	13.30 ± 0.5 (12.9 to 13.6)	15.7 ± 0.7 (15.2 to 16.2)	17.7 ± 0.7 (17.1 to 18.2)	0.000# 0.87	0.000# 0.87	0.000# 0.80
Height (cm)	171.3 ± 7.9 (165.7 to 176.9)	175.7 ± 8.6 (170.2 to 181.1)	177.3 ± 5.4 (173.2 to 181.5)	0.584 0.53	0.291 0.88	1 0.22
Body mass (kg)	65.6 ± 16.2 (54 to 77.2)	71.4 ± 15.7(61.4 to 81.3)	76.90 ± 14 (66.1 to 87.7)	1 0.36	0.364 0.75	1 0.37
BMI	22.2 ± 4.5 (19 to 25.5)	22.9 ± 3.2 (20.8 to 24.9)	24.5 ± 4.5 (21 to 27.9)	1 0.18	0.701 0.51	1 0.41
Body fat (%)	17.1 ± 11.2(8.4 to 25.7)	17.9 ± 7.8 (12.9 to 22.9)	20.9 ± 8.9 (14.1 to 27.8)	1 0.08	1 0.38	1 0.36
Tanner stage	3.3 ± 0.8 (2.7 to 3.9)	4.6 ± 0.52 (4.3 to 4.9)	4.2 ± 0.8 (3.6 to 4.9)	0.001# 1.93	0.023* 1.13	0.823 0.59
VIFT (km·h^{-1})	17 ± 1.5 (15.9 to 18.1)	18.9 ± 1.4 (18 to 19.8)	19.3 ± 1.2 (18.3 to 20.2)	0.012* 1.31	0.005# 1.69	1 0.31
$VO_{2}max$ (mL·kg^{-}	44.8 ± 3.1 (42.6 to 47)	48.9 ± 3.1 (46.9 to 50.8)	50.1 ± 2.9 (47.9 to 52.3)	0.013* 1.32	0.002# 1.77	1 0.40
HR_{peak} (beats·mi	206.4 ± 3.8 (203.7 to 209.1)	200.2 ± 6.3 (196.2 to 204.1)	198.4 ± 11.2 (189.8 to 207)	0.012* 0.54	0.268 0.25	0.859 0.04
HRRΔ 2min (%)	33.3 ± 7.9 (38.9 to 27.7)	33.9 ± 4.9 (37.1 to 30.9)	34.8 ± 4.1 (38 to 31.7)	1 0.09	1 0.24	1 0.20

*Data are Mean ± SD (95%CI). BMI = body mass index; VIFT = peak velocity in 30–15 intermittent fitness test; HR_{peak} = heart rate peak; VO_{2max} = maximum oxygen uptake; HRRΔ 2 min = hearth rate recovery % delta at 2 min * $p \le 0.05$ and # $p \le 0.01$.*

Table 2. *Jump performances.*

Variable	U-15 (n = 10)	U-17 (n = 12)	U-19 (n = 9)	Post-hoc analyses (p value and effect size)		
				U-15 vs. U-17	U-15 vs. U-19	U-17 vs. U-19
CMJ height (cm)	28.8 ± 5.6 (24.8 to 32.9)	35.3 ± 7.2 (30.7 to 39.8)	36.7 ± 3.2 (34.2 to 39.1)	0.044* 1.01	0.019* 1.73	1 0.25
CMJ absolute power (W)	1544.9 ± 304.2 (1327.4 to 1762.5)	2063.4 ± 601.1 (1681.5 to 2445.4)	2103.4 ± 328.8 (1850.6 to 2356.1)	0.036* 1.09	0.035* 1.76	1 0.08
CMJ relative power (W·kg^{-}	25.1 ± 8 (19.4 to 30.9)	30.6 ± 11.9 (23.1 to 38.1)	28.5 ± 8.3 (22.2 to 34.9)	0.603 0.54	1 0.42	1 0.20
CMJL height (cm)	15.3 ± 5.2 (11.6 to 18.9)	19.5 ± 4.3 (16.7 to 22.2)	19.8 ± 2 (18.3 to 21.4)	0.074 0.88	0.07 1.14	1 0.09
CMJL absolute power (W)	2860.8 ± 200.4 (717.5 to 1004.1)	1037.6 ± 214.4 (901.4 to 1173.8)	1086.2 ± 145.8 (974.2 to 1198.3)	0.122 0.85	0.05* 1.29	1 0.27
CMJL relative power (W·kg^{-}	14 ± 5.1 (10.4 to 17.7)	15.2 ± 4.9 (12.1 to 18.3)	14.7 ± 4.1 (11.6 to 17.9)	1 0.24	1 0.15	1 0.11
CMJR height (cm)	15.5 ± 3.9 (12.7 to 18.2)	19.8 ± 3.7 (17.5 to 22.1)	20 ± 1.7 (18.7 to 21.3)	0.014* 1.13	0.017* 1.50	1 0.07
CMJR absolute	816.4 ± 165.5 (698 to 934.8)	1031.3 ± 166.2 (925.7 to 1136.9)	1039.4 ± 145.3 (927.7 to 1151.2)	0.012* 1.30	0.016* 1.43	1 0.05
CMJR relative power (W·kg^{-}	13 ± 3.6 (10.5 to 15.6)	15 ± 3.9 (12.6 to 17.5)	14.1 ± 3.8 (11.1 to 16.9)	0.671 0.53	1 0.30	1 0.23
BJ distance (cm)	130.9 ± 17.8 (118.2 to 143.6)	152.2 ± 20.7 (139 to 165.3)	164.5 ± 8.3 (158.1 to 170.9)	0.021* 1.10	0.001# 2.42	0.334 0.78
BJL distance (cm)	103.8 ± 21 (88.8 to 118.8)	123 ± 23.3 (108.2 to 137.8)	110.4 ± 22.1 (93.5 to 127.4)	0.16 0.87	1 0.31	0.633 0.55
BJR distance (cm)	114 ± 23.3 (97.36 to 130.64)	123.4 ± 22.3 (109.3 to 137.6)	114.5 ± 14.4 (103.4 to 125.6)	0.89 0.41	1 0.03	1 0.47
RSI (m·s^{-1})	0.97 ± 0.33 (0.74 to 1.21)	1.36 ± 0.46 (1.06 to 1.65)	1.43 ± 0.21 (1.27 to 1.59)	0.057 0.97	0.028* 1.66	1 0.20

*Data are Mean ± SD (95%CI). CMJ = countermovement jump; CMJL = countermovement jump left; CMJR = countermovement jump right; BJ = broad jump; BJL = broad jump left; BJR = broad jump right; RSI = reactive strength index. * $p \leq 0.05$ and # $p \leq 0.01$.*

Table 3. *Change of direction (COD), speed and strength performances.*

Variable	U-15 (n = 10)	U-17 (n = 12)	U-19 (n = 9)	Post-hoc analyses (*p* value and effect size)		
				U-15 vs. U-17	U-15 vs. U-19	U-17 vs. U-19
COD time (s)	6.75 ± 0.59 (6.32 to 7.18)	6.15 ± 0.41 (5.89 to 6.41)	5.99 ± 0.36 (5.72 to 6.27)	0.017* 1.18	0.005# 1.56	1 0.41
Sprint 15 m time (s)	2.72 ± 0.25 (2.54 to 2.89)	2.61 ± 0.17 (2.50 to 2.71)	2.55 ± 0.15 (2.43 to 2.67)	0.586 0.51	0.21 0.82	1 0.37
RSA total time (s)	34.42 ± 2.86(32.2 to 36.6)	30.89 ± 1.67 (29.76 to 32.01)	30.68 ± 1.34 (29.44 to 31.92)	0.003# 1.51	0.005# 1.67	1 0.14
RSA best time (s)	6.65 ± 0.55 (6.25 to 7.04)	6.08 ± 0.35 (5.86 to 6.30)	6.01 ± 0.22 (5.84 to 6.18)	0.007# 1.23	0.005# 1.53	1 0.24
RSA FI (%)	2.5 ± 1.2 (1.5 to 3.4)	2.3 ± 1 (1.6 to 2.9)	1.4 ± 0.9 (0.5 to 2.2)	1 0.18	0.136 1.03	0.286 0.95
Lower-limb strength (kg)	25 ± 8.5 (18.9 to 31.1)	36.7 ± 8.9 (31 to 42.3)	50 ± 16.6 (37.2 to 62.7)	0.006# 0.59	0.001# 0.74	0.047* 0.43

*Data are Mean ± SD (95%CI). COD = change of direction; RSA = repeated sprint ability; FI = fatigue index. * $p \leq 0.05$ and # $p \leq 0.01$.*

Table 4. *Intercorrelation matrix between change of direction (COD) and the remaining performance variables*

Variable	COD time (s) correlation level and *p* value			
	U-15	U-17	U-19	Total
Age (years)	0.038	-0.011	-0.292	-0.490
	0.917	0.972	0.446	0.005#
Height (cm)	-0.170	0.531	-0.348	-0.121
	0.639	0.076	0.359	0.515
Body mass (kg)	0.112	0.571	0.363	0.093
	0.758	0.052	0.337	0.617
BMI	0.167	0.512	0.459	0.152
	0.645	0.089	0.214	0.415
Body fat (%)	0.305	0.475	0.576	0.226
	0.392	0.119	0.104	0.221
Tanner stage	-0.191	-0.268	0.050	-0.415
	0.597	0.399	0.898	0.020*
VIFT (km·h^{-1})	-0.620	-0.888	-0.441	-0.784
	0.056	0.000#	0.235	0.000#
$VO_{2}max$ (mL·kg^{-1}·min^{-1})	-0.574	-0.874	-0.456	-0.769
	0.083	0.000#	0.217	0.000#
HRRΔ 2min (%)	-0.507	0.569	-0.508	-0.101
	0.134	0.054	0.163	0.590
CMJ height (cm)	-0.697	-0.716	-0.417	-0.746
	0.025*	0.009#	0.265	0.000#
CMJ absolute power (W)	-0.550	-0.610	-0.010	-0.599
	0.100	0.035*	0.979	0.000#
CMJ relative power (W·kg^{-1})	-0.264	-0.685	-0.130	-0.435
	0.460	0.014*	0.739	0.014*
CMJL height (cm)	-0.777	-0.656	-0.477	-0.763
	0.008#	0.021*	0.194	0.000#
CMJL absolute power (W)	-0.769	-0.483	-0.316	-0.678
	0.009#	0.112	0.407	0.000#
CMJL relative power (W·kg^{-1})	-0.447	-0.661	-0.275	-0.445
	0.195	0.019*	0.474	0.012*
CMJR height (cm)	-0.627	-0.669	-0.271	-0.717
	0.052	0.017*	0.480	0.000#
CMJR absolute power (W)	-0.894	-0.430	-0.303	-0.721
	0.000#	0.163	0.428	0.000#
CMJR relative power (W·kg^{-1})	-0.618	-0.657	-0.280	-0.529
	0.057	0.020	0.465	0.002#
BJ distance (cm)	-0.448	-0.661	-0.192	-0.672
	0.194	0.019*	0.621	0.000#
BJL distance (cm)	-0.567	-0.757	-0.380	-0.576
	0.087	0.004#	0.313	0.001#
BJR distance (cm)	-0.542	-0.694	-0.497	-0.519
	0.106	0.012*	0.174	0.003#
RSI (m·s^{-1})	-0.445	-0.267	-0.408	-0.527
	0.197	0.402	0.276	0.002#
Sprint 15 m time (s)	0.814	0.524	0.562	0.719
	0.004#	0.080	0.116	0.000#
RSA total time (s)	0.721	0.779	0.769	0.856
	0.029*	0.005#	0.043*	0.000#
RSA best time (s)	0.720	0.751	0.805	0.824
	0.019*	0.005#	0.009#	0.000#
RSA FI (%)	0.648	-0.110	0.068	0.362
	0.059	0.746	0.885	0.064
Lower-limb strength (kg)	-0.704	-0.370	0.068	-0.631
	0.023*	0.237	0.861	0.000#

BMI = body mass index; VIFT = peak velocity in 30–15 intermittent fitness test; HR_{peak} *= heart rate peak;* VO_{2max} *= maximum oxygen uptake; HRRΔ 2 min = hearth rate recovery % delta at 2 min; CMJ = countermovement jump; CMJL = countermovement jump left; CMJR = countermovement jump right; BJ = broad jump; BJL = broad jump left; BJR = broad jump right; RSI = reactive strength index; COD = change of direction; RSA = repeated sprint ability; FI = fatigue index.*

** $p \leq 0.05$ and # $p \leq 0.01$.*

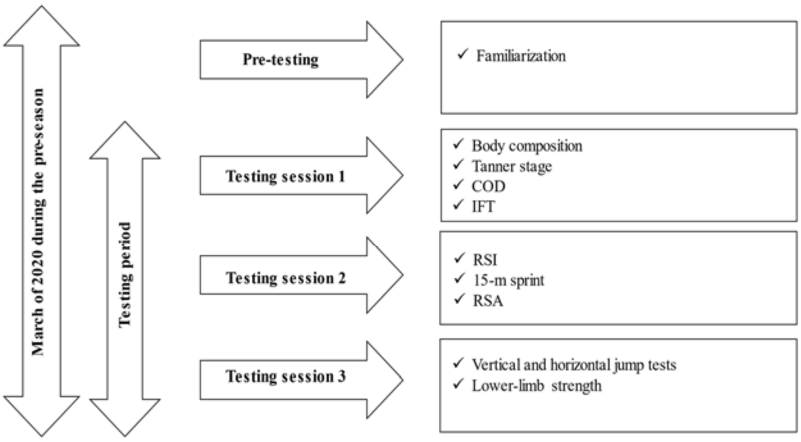

Figure 1. *Study design. COD = change of direction; IFT = intermittent fitness test; RSI = reactive strength index; RSA = repeated sprint ability*

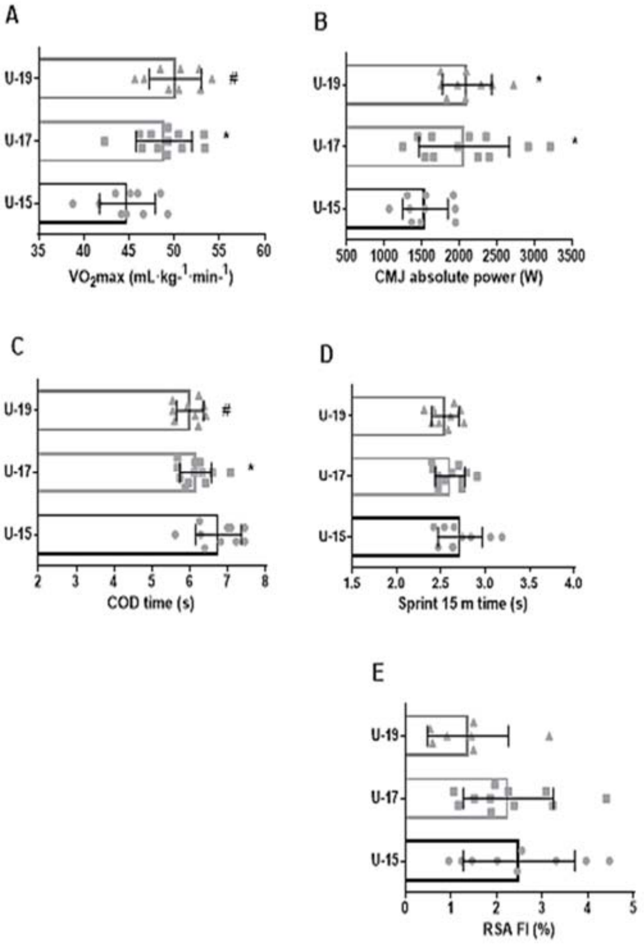

Figure 2. *Group and individual response for (A) VO_{2max}, (B) CMJ absolute power, (C) COD time, (D) 15-m sprint time, and (E) RSA FI. * $p \le 0.05$ differences vs. U-15. # $p \le 0.01$ differences vs. U-15.*

As expected, the better results in COD, jumps, and lower-limb strength performances recorded in the present study were in favor of U-19. One potential explanation, apart from maturational and physical differences, may be due to the fact that coaches did not focus on those abilities at earlier ages (i.e., U-15) with the majority of the training time devoted to improve players' individual (technical/tactical) performances. Thus, Dellal et al. (2013) previously reported that COD, interlimb coordination and RSA performance were not fully developed in younger players. Moreover, it should be noted that younger players may have experienced a higher decrease in COD and speed performances due to the deterioration of coordination associated with physical development during the rapid growth stage (Rommers et al., 2019) which occurs around the time of peak height velocity. Given that we did not consider this measure, further studies are required to appropriately test this hypothesis.

Regarding the better RSA performances recorded in U-17 and U-19 groups, it may be suggested that the higher estimated VO_{2max} recorded would favor a faster recovery between sprinting bouts thus improving RSA performance (Girard et al., 2011). In this context, Brini et al. (2020b) recently reported a significant correlation (r = 0.69) between RSA performance (total time) and maximal aerobic speed in adult male basketball players (age: 22.06 ± 2.8 years). In addition, it has been suggested that recovery in prepubertal children is affected by other factors different from cardiorespiratory fitness and, in fact, there are data showing that children have a faster recovery than adults (Hebestreit et al., 1993). Thus, other factors such as anaerobic work capacity could play a key role in RSA performance with increased age and the maturation stage (Beneke et al., 2007). Indeed, our data showed significant differences in the tanner stage between U-17 and U-19 vs. U-15.

Otherwise, the findings of the present study showed significant correlations between jumping ability (i.e., power, height and distance) and COD performance, especially in U-15 and U-17 groups. In accordance with the present study, Scanlan et al. (2021) recently showed a moderate correlation among COD performance with a standing long jump (r = -0.67), CMJ relative peak force (r = -0.63), isometric midthigh pull relative peak force (r = -0.55), and 10-m sprint times (r = 0.53) in young basketball players. However, our results did not show any significant correlation between COD and linear sprinting performance in U-15 and U-17 groups. Our findings are similar to previous studies with adult players reporting that COD is a multifactorial physical ability which can be influenced by strength, speed, and muscular coordination (Alemdaroğlu, 2012; Chaouachi et al., 2009). Chaouachi et al. (2009) found a negative correlation between COD and the 5J test (r = -0.61) in elite adult male basketball players, while Alemdaroğlu (2012) reported a significant correlation between CMJ height and COD (r = -0.59) in professional male basketball players. Therefore, strength and conditioning coaches should appropriately select those tests to monitor physical performance of athletes depending on their age.

On the other hand, aerobic capacity recorded in the present study was significantly better in U-17 and U-19 (effect size = 1.32 and 1.77, large) when compared with U-15 players. Our findings may be also explained by other factors that have been shown to be relevant in basketball players' performance such as weekly training loads, motivation during the test, and training status (Abdelkrim et al., 2010; Drinkwater et al., 2008; Geithner et al., 2004;). In the same context, Carvalho et al. (2013) reported that the accumulation of basketball-specific training loads through the years also appeared to have a positive independent effect on the development of aerobic-energy pathways in late adolescence. Previous studies reported that changes in body composition, hematological, and hormonal changes, which appear to improve markedly during adolescence, may influence aerobic trainability of younger players (Armstrong et al., 2011; Geinther et al., 2004). Thus, researchers and coaches should take into consideration all those aspects in order to prepare an adequate training strategy for young basketball players.

Limitations

Our study presents some limitations. The first refers to the limited sample size, with players competing in the same club. Secondly, participants of the present study were only grouped by chronological age. Finally, we examined only male basketball players and it is necessary that future studies examine performance of female basketball players to confirm if there are sex differences.

Conclusions

Our results show that that there are age effects on COD performance and its specific physical determinants among young male basketball players. Our results present a significant correlation between COD performance and some physical determinants such as jumping ability and RSA, especially among U-15 and U-17 players. These results should be considered by coaches when programing physical training sessions for young basketball players.

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