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Age-Related Variation in Change-of-Direction Performance and Deficit Among Late Childhood Boys

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ABSTRACT

Effective coaching strategies for enhancing change-of-direction (COD) ability in older elementary school boys require innovative assessment approaches due to the pivotal role of this skill in motor control programs. We aimed to (a) conduct a cross-sectional comparison of differences in COD total time (CODT) and COD deficit (CODD) according to chronological age among boys aged 10–12 years and (b) investigate the association of CODT and CODD with height, body mass, and jumping ability. Seventy-eight Japanese boys with chronological age 10–12 years (10.0–10.9 years, n=26; 11.0–11.9 years, n=26; 12.0–12.9 years, n=26) performed 20-m sprint, 505COD, counter-movement jump (CMJ), and rebound jump (RJ) tests; their height and body mass were recorded. Unpaired one-way ANOVA was used to compare each variable between the three groups. CODT ($F(2, 75) = 6.21$, $p = 0.003$) and 10-m time ($F(2, 75) = 9.49$, $p = 0.001$) were significantly shorter in 12-year-olds than in 10-year-olds; however, no significant differences were observed in CODD, CMJ, and RJ-index. Regarding partial correlation coefficients, CODT showed a significant positive correlation with CODD and 20-m time ($r = 0.67$ to 0.76, $p = 0.001$) and a significant negative correlation with CMJ, RJ-index, and RJ-height ($r = -0.43$ to -0.53, $p = 0.001$). CODD demonstrated a significant positive correlation with height ($r = 0.29$, $p = 0.011$), body mass ($r = 0.30$, $p = 0.008$), and sprint momentum ($r = 0.28$, $p = 0.013$). These findings suggest that regarding CODD, the development of COD ability did not vary with age, indicating its association with morphological growth. Therefore, COD training should be provided according to children's morphological and linear sprint speed development.

Keywords: COD development, COD deficit, linear sprint speed, elementary school children

INTRODUCTION

The agility required in field and court sports is defined as a rapid whole-body movement with a change of velocity or direction due to visual stimuli (30). Agility includes perceptual, decision-making, and change-of-direction (COD) ability. COD ability is regarded as the physical and technical foundation of agility development (14, 22). COD ability is the physical skill of slowing, turning, changing direction, and reaccelerating under preplanned conditions, regardless of stimuli response (12, 14). Previous research has highlighted the significance of COD in talent identification in junior rugby (8) and junior soccer (10, 27). Given COD's role in various sports, a structured theoretical approach for childhood and puberty development is required (18).

Research into COD ability development has focused on the 11 to 17 year old age range. In a study involving male soccer players aged 11-16 years, Vänttinen et al. (34) discovered that Figure-8 test performance improved with age, with the most significant progress occurring during years 13–14 (contributing to 3.8% of peak development). Similarly, Philippaerts et al. (26) observed that 10 × 5-m shuttle run times peaked during the 13–14-year age bracket, aligning with peak height velocity (PHV). Although several semi-longitudinal studies have examined COD ability development, they focused on total COD test time (CODT), neglecting its strong correlation with linear sprint speed (21). The Figure-8 test and 10 × 5-m shuttle run test are "maneuverability assessments" involving multiples CODs, 5 or 20 times, and have extended test durations of 7 or 22 seconds, respectively. Thus, an extremely strong bias towards linear speed is anticipated. To accurately assess COD speed, test should be shorter in duration, typically with only one or two turns (13, 21).

Generally, COD ability is assessed using the total time required for a COD test. However, due to the strong correlation between CODT and linear sprint speed (9, 22, 23), relying on total time may over estimate the COD ability of individuals with fast linear sprint speed. This approach also does not isolate direction-changing ability (21). The term "direction-changing ability" specifically denoted the capacity to change direction independently of one's sprinting. To address this limitation, Nimphius et al. (22) introduced the COD deficit (CODD) by subtracting straight-line running time from COD test time. CODD has been employed to assess COD ability among cricket (22) and football players (20, 23). However, no study has investigated CODD-based COD ability development in prepubescent children aged 10- to 12, (known as the older elementary schoolchildren in Japan). Lloyd & Oliver (17) suggested that prepubescence is a critical period for motor control program development due to heightened neural plasticity. However, their report lacks substantial COD ability data for prepubescent children.

Considering the average age at PHV for Japanese boys its 13.05 ± 0.94 years (32), the study focused on boys aged 10 to 12, who experience rapid physical changes during this period. Focusing on boys aged 10–12 years enabled us to assess development pre-PHV. Prior to the onset of PHV, linear sprint speed progresses more than muscle strength and power (24). Given that linear sprint speed, concentric strength, power, and reactive strength all contribute to COD ability (3, 30), the slower muscle development observed in older elementary schoolchildren suggests there will be limited CODD growth during this phase, reflecting COD itself.

Detecting observable differences in COD ability among 10–12 year-old children, based on age could guide coaching strategies aimed at enhancing COD ability in line with growth. Additionally, linking CODD with variables such as height, body mass, or jumping ability could inform effective training regiments to boost COD ability in this age group. Therefore, our aim is twofold: 1) To cross-sectionally compare CODT and CODD differences by age among boys aged 10–12 years, and 2) explore the association of CODT and CODD with height, body mass, and jumping ability in this cohort. We hypothesize that CODD will remain consistent despite age-related CODT differences among boys aged 10–12 years and that CODD will exhibit a significant negative correlation with jumping ability, including counter-movement jump (CMJ) and rebound jump (RJ).

METHODS

Subjects

The study participants included 78 Japanese boys with chronological age of 10–12 years (10.0–10.9 years, n = 26; 11.0–11.9 years, n = 26; 12.0–12.9 years, n = 26). The mean height and body mass of each age group were as follows: 1.38 ± 0.06 m and 33.3 ± 6.1 kg, 1.46 ± 0.07 m and 37.9 ± 6.5 kg, and 1.49 ± 0.07 m and 37.9 ± 6.3 kg, respectively. The sample size was estimated using the G*Power software (version 3.1.9.7), with an alpha level set at 0.05, a power of 80%, and a large effect size (f = 0.4). Thus, a minimum of 66 subjects (22 subjects per group) were satisfactory for an unpaired one-way ANOVA. All boys were members of an athletics or soccer club and underwent training sessions 2–3 times weekly. Before the measurements, a written explanation of the study's purpose and methods, along with information on personal data handling, was provided to both the participants and their parents or guardians, from whom consent was obtained. This study was approved by the Research Ethics Review Committee of Fukui University of Technology (approval number: human-2016-04).

Procedures

The 505 COD, 20-m sprint, CMJ, and RJ tests were all conducted during a single test session; measurements were obtained each year from December to February during the 2018–2021 period. Prior to data collection, the participant's height and body mass were recorded. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Seca Nihon, Japan). Body mass was measured to the nearest 0.1 kg using a professional weighing scale (WB-260A, Tanita Corporation, Japan). Prior to the measurements, the participants completed a 20-min warmup consisting of 5 min of jogging, 5 min of dynamic stretching, and 10 min of preparatory exercises comprising skipping (forwards and sideways) and sprint drills. After this warmup, measurements were conducted in the following order: 20-m sprint, 505 COD, CMJ, and RJ tests. All measurements were performed on an indoor track, ensuring no impact from rain or wind.

20-m Sprint Test

The 20-m sprint time was measured to the nearest 0.01 s using a dual-timing lights system (WITTY, Microgate, Italy). The photocells were adjusted such that the lower of the dual-timing gates was at the height of the participant's lower back and placed at the starting point (0 m), midpoint (10 m), and finishing point (20 m). The starting method involved a two-point position standing start, with the tips of the toes of the front foot aligned with a line 30 cm behind the starting point. This 30-cm distance from the starting point was used according to the starting position recommended by Altmann et al (1). The participants decided when to start running and were instructed to run as fast as they could until they were 1 m past the finishing point. The parameters analyzed were the 20-m time from the start to the finishing point and the 10-m time from the start to the midpoint. In addition, sprint momentum ($kg{\cdot}m^{-1}{\cdot}s^{-1}$) was calculated by multiplying the subject's body mass by the velocity achieved in the 0-10m section in the 20-m sprint test (2). The test was conducted twice, with a recovery time of approximately 3 min in between; the better of the two 20-m times was used. The intra-session intraclass correlation coefficient (ICC) was 0.937 and the coefficient of variation (CV) was 5.1%.

505 Change-of-Direction Test

The 505 COD test was conducted following the measurement method described by Nimphius et al (22). Figure 1 shows the 505 COD setup. The participants commenced by sprinting for 15 m from the starting point, made a 180° turn at the 15-m point, and sprinted back for 5 m in a straight line. They were instructed to either step over or touch the line with the outside foot and touch the ground with the fingers of their outer hand when changing direction. For example, if their upper body was faced left during the COD, their right foot should touch the line while their right hand touched the ground. The tester supervised the process, ensuring that both foot and fingers touched the line and ground; failure to do so resulted in an invalid test, prompting a repeat measurement. The starting position was a standing start, with the tips of the toes of the front foot aligned with a line 30 cm behind the starting point. The dual-timing lights system (WITTY, Microgate) was positioned at the starting point and 10-m point. The time from the start to the 10-m point (approach time) and the time taken to make the 180° turn from the 10-m point and to run 5 m back [a total of 10 m (CODT)] were measured to the nearest 0.01 seconds. The test was conducted twice, each with the right and left feet touching the turnaround point and with a recovery time of approximately 3 min in between; the best CODT of the four tests was used for analysis. Due to the strong correlation between CODT and linear sprint ability, CODD was calculated according to the method described by Nimphius et al (22). It involved subtracting the 10-m time measured in the 20-m sprint test as the time from the starting point to the 10-m midpoint. The intra-session ICC was 0.790 or 0.726 when it was the right or left foot, respectively, that touched the

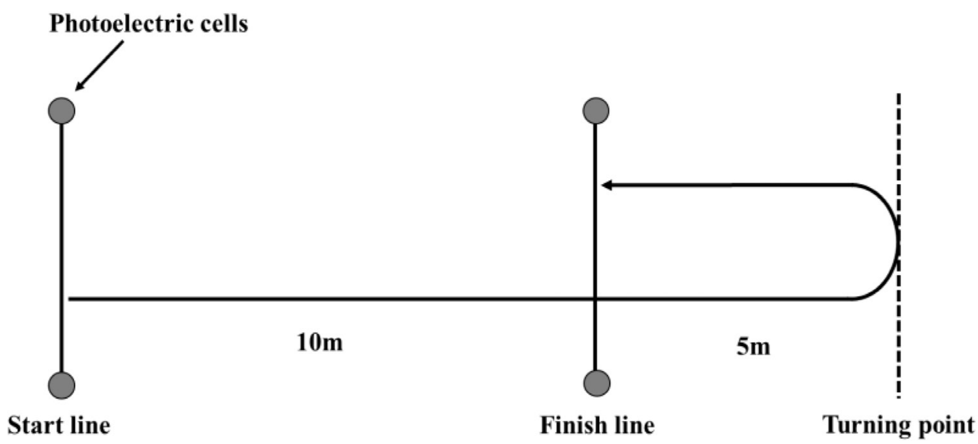

Figure 1. Equipment setup for the 505 change-of-direction test (505COD)

turnaround point. The CV was 6.0% and 6.2% when it was the right or left foot, respectively, that touched the turnaround point.

Counter-movement Jump and Rebound Jump Tests

CMJ involves a jumping movement using a counter-movement from a standing position (33), while RJ involves a ballistic jumping movement in which the participants continuously jump in place 6 times (16, 29, 33). The CMJ test was conducted based on the method described by Tauchi et al (33), and the RJ test adhered to the procedure outlined by Tauchi et al (33) and Kariyama (16). During the CMJ test, the participants were instructed to jump as high as possible and to land in an extended position. In contrast, during the RJ test, they were instructed to jump as high as possible 6 times continuously while keeping their feet on the floor for as short as possible. Both jumping exercises were conducted with the hands on the hips to eliminate the effect of arm swinging.

The indices of jumping ability were jump height (m) for the CMJ test and the RJ-index (m/s), RJ-height (m), and RJ ground contact time (RJ-ct, s) for the RJ test. The jumping movements were conducted on a mat switch (Multi Jump Tester, PH-1260D, Q's fix, Japan) connected to a computer via an analog-to-digital converter, which measured flight time (s) and ground contact time (s). Jump height was calculated by inserting flight time into the following formula:

$$\text{Jump height} = (g \times Tf_{CMJ}^2)\ 8^{-1}$$

Here, g is the acceleration due to gravity (9.81m/s^2) and TfCMJ is the flight time in the CMJ or RJ test.
The RJ-index was calculated using the following formula (33).

$$\text{RJ-index (m/s)} = (g \times Tf_{RJ}^2)\ 8^{-1}/Tc$$

Here, Tf_{RJ} represents the flight time in the RJ test, and Tc represents the ground contact time in the RJ test. The CMJ and RJ tests were conducted twice, and the highest jump from the CMJ test and the highest RJ-index from the RJ test were used for the analysis. The intra-session ICC was 0.872 for the CMJ test and 0.905 for the RJ test. The CV was 13.6% for the CMJ test and 23.9% for the RJ index.

Statistical Analyses

Statistical analysis was performed using SPSS for Windows version 24 (IBM Corp, Armonk, NY, USA). The reliability of each test in the study was assessed by comparing the first and second measurements within a session, using the intra-class correlation coefficient (ICC) and the coefficient of variation (CV) calculated as SD / mean x 100. Measurement results are expressed as mean ± standard deviation. Equality of variance was evaluated using Levene's test. Unpaired one-way ANOVA was used to compare each variable between the 10-, 11-, and 12-year-olds. The effect size (partial eta squared: η_p^2) was categorized as follows: 0.01: small; 0.06: medium; and ≥0.14: large (28). If a significant difference was observed, multiple comparisons were conducted using Bonferroni's method. Pearson's correlation coefficients were calculated to investigate the association of CODT and CODD with age in months, height, body mass, jump performance, and linear sprint performance. Additionally, partial correlation coefficients were calculated, with age in months as the control variable. Correlation strengths were categorized as follows: <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: nearly perfect (25). Statistical significance was set at $p < 0.05$.

RESULTS

Table 1 displays the means and standard deviations of the measured values for the 10-, 11-, and 12-year-old boys. The results of one-way ANOVA indicated significant differences in height, body mass, CODT, approach time, 10-m time, 10–20-m time, 20-m time, sprint momentum, and RJ height between the three groups. However, no significant differences were observed in CODD, CMJ, RJ-index, or RJ-ct. Multiple comparisons using Bonferroni's method revealed that height, body mass, and sprint momentum were significantly greater in 12-year-old boys than in 10- and 11-year-olds. Additionally, CODT, approach time, and 10-m time were significantly shorter in 12-year-olds than in 10-year-olds. Moreover, the 10–20-m time, and 20-m time was significantly shorter in 12- and 11-year-olds than in 10-year-olds. RJ-height was significantly higher in 12-year-olds than in 10-year-olds.

Table 2 presents the partial correlation coefficients, with age as the control variable. When calculating partial correlation coefficients with age in months as a control variable, CODT showed a significant positive correlation with CODD and the times for 10-m, 10–20-m, and 20-m. Conversely, it exhibited

Table 1. Anthropometric and Physical Characteristics of the Age Groups

	M ± SD of age groups			*F* Ratio	η_p^2
	10 years	11 years	12 years		
Age (months)	125.7 ± 3.4	137.0 ± 3.6	147.6 ± 2.2	316.78 *	0.89
Body height (m)	1.38 ± 0.06	1.46 ± 0.07	1.49 ± 0.07	17.07 *	0.31
Body mass (kg)	32.42 ± 5.18	37.90 ± 6.65	37.87 ± 6.31	7.00 *	0.16
CODT (s)	2.77 ± 0.15	2.70 ± 0.13	2.64 ± 0.10	6.21 *	0.14
CODD (s)	0.66 ± 0.11	0.65 ± 0.11	0.64 ± 0.07	0.36	0.01
AT (s)	2.18 ± 0.11	2.12 ± 0.12	2.07 ± 0.08	6.47 *	0.15
10-m time (s)	2.11 ± 0.09	2.06 ± 0.10	2.00 ± 0.07	9.50 *	0.20
10–20-m time (s)	1.65 ± 0.08	1.57 ± 0.09	1.53 ± 0.07	13.68 *	0.26
20-m time (s)	3.76 ± 0.16	3.63 ± 0.19	3.54 ± 0.13	12.29 *	0.25
SM ($kg·m^{-1}·s^{-1}$)	154.3 ± 26.2	185.1 ± 37.3	189.5 ± 34.3	8.79*	0.19
CMJ (m)	0.27 ± 0.03	0.29 ± 0.05	0.29 ± 0.03	1.63	0.04
RJ index (m/s)	1.45 ± 0.38	1.47 ± 0.37	1.55 ± 0.30	0.60	0.02
RJ height (m)	0.22 ± 0.04	0.24 ± 0.03	0.25 ± 0.04	4.15 *	0.10
RJ contact time (s)	0.16 ± 0.02	0.17 ± 0.02	0.17 ± 0.02	1.64	0.04

*Note. *: Significantly (p < 0.05) different between the age groups. CODT: Total time of the 505 change-of-direction test, CODD: COD deficit of the 505 change-of-direction test, AT: Approach time, SM: Sprint momentum, CMJ: Counter movement jump, RJ: Rebound jump.*

Table 2. Correlation between CODT, CODD, 10-m, 10–20-m, 20-m Sprint times, CMJ, RJ Index, RJ Height, RJ-ct, Body Height, Body Mass, and SM with CODT, CODD, and 20-m Sprint, using Age in Months as the Control Variable

Variable	CODT	CODD	10-m	10-20m	20-m	CMJ	RJ index	RJ height	RJ-ct	BH	BM	SM
CODT	—	0.76**	0.64**	0.63**	0.67**	-0.53**	-0.43**	-0.47**	0.16	-0.03	0.05	-0.08
CODD	—	—	-0.01	0.11	0.05	-0.15	-0.16	-0.15	0.09	0.29*	0.30**	0.28*
10-m	—	—	—	0.83**	0.95**	-0.64**	-0.46**	-0.54**	0.13	-0.38**	-0.26*	-0.46**
10-20-m	—	—	—	—	0.95**	-0.68**	-0.47**	-0.53**	0.18	-0.43**	-0.31**	-0.47**
20-m	—	—	—	—	—	-0.70**	-0.49**	-0.57**	0.17	-0.43**	-0.30**	-0.48**

*Note. *: Significant (p < 0.05) relationship between the two variables. **: Significant (p < 0.01) relationship between the two variables. CODT: Total time of the 505 change-of-direction test, CODD: COD deficit of the 505 change-of-direction test, SM: Sprint momentum, BH: Body height, BM: Body mass, CMJ: Counter-movement jump, RJ: Rebound jump, RJ-ct: Contact time of rebound jump.*

a significant negative correlation with CMJ height, RJ-index, and RJ-height. CODD was positively correlated with height, body mass, and sprint momentum. Additionally, the times for 10-m, 10–20-m, and 20-m were negatively correlated with CMJ height, RJ-index, RJ-height, height, body mass, and sprint momentum.

DISCUSSION

The results from the current study revealed that although the CODT, 10-m time, 20-m time, and RJ-height were all superior in 12-year-olds, as compared to those in 10-year-olds, no significant difference was observed in CODD between these age groups. In addition, the sprint momentum was significantly greater in 11- and 12-year-olds, than in 10-year-olds. When partial correlation coefficients were calculated with age in months as the control variable, the CODT correlated with 20-m time, CMJ, RJ-index, and RJ-height; however, CODD exhibited only slightly correlation with height, body mass, and sprint momentum. This demonstrates that in terms of CODD, the development of COD ability did not significantly vary with age. This result may be influenced by greater momentum due to increases in sprint speed and body mass.

Studies on the development of COD ability have shown that its peak development occurs at age 13–14 years, which is also the PHV age (26, 34). Moreover, the only index of COD ability used in those studies was CODT (26, 34), which is the total time required to complete the COD test. To our knowledge, the present study is the first to investigate the development of COD ability in 10 to 12-year-olds using both CODT and CODD as indices. Comparisons between 10- and 12-year-olds revealed no difference in CODD; however, significant differences were observed in 10-m and 20-m time, suggesting that in older elementary schoolchildren, it is the improvement in linear sprint speed that contributes to the shortening of CODT, while there is no change in COD ability from the viewpoint of CODD. When partial correlation coefficients were calculated with age in months as the control variable, CODT was moderately correlated with 20-m time. In other studies using the 505 COD test, the CODT of the 505 COD test was moderately correlated with linear sprint speed in pubescent adolescents (9, 22). Therefore, the development of COD ability in older elementary schoolchildren may be affected by the development of linear sprint speed rather than the development of the ability to change direction in itself.

The CODD is considered to be an independent indicators of linear sprint speed (4, 21). In our partial correlation analysis using age in months as the control variable, we observed that CODD did not correlate with the 20-m time, suggesting that CODD may be used to assess COD ability independent of linear sprint speed in older elementary schoolchildren. The 505 COD test utilizes a 180° turn and involves changes in speed comprising deceleration, stopping, and acceleration. This requires motor skills that are involved in decelerating the velocity of the body's center of gravity to zero, immediately changing direction, and using the supporting foot to accelerate the center of gravity in the new direction of travel (15). Previous studies indicated that CODD is an indicator of the athlete's efficiency in direction change relative to their maximum sprint ability (7). Interestingly, our analysis of partial correlation coefficients using age in months as the control variable identified small positive correlations of CODD with height (r = 0.29) and body mass (r = 0.30) as well as moderate negative correlations of 20-m time with height (r = -0.43) and body mass (r = -0.30). These findings suggest that the linear sprint speed of the participants increased as a result of their increased height and body mass; nevertheless, when assessing COD ability using CODD, the observed ability was low. In 12-year-old boys specializing in basketball, body mass was weakly correlated with the zigzag agility drill time (r = 0.22) and 4 × 15-m agility run time (r = 0.21) (11); these values are remarkably similar to the partial correlation coefficients in this study. Several points regarding the relationship between morphology (height, body mass, body fat, limb length) and COD ability remain unclear; however, Sheppard & Young (30) indicated that height and body mass may be related to COD ability. For example, lowering the body's center of gravity determines deceleration and acceleration in the cutting maneuver (31), and lowering the height of the body's center of gravity after changing direction and reaccelerating by achieving impulse in the horizontal direction has also been shown to affect COD performance (15). This implies that individuals whose body has a low center of gravity may require less time than taller individuals to lower their center of gravity in order to change direction, enabling them to exert power more quickly in the horizontal direction (30).

Moreover, heavier body mass contributes to increases sprint momentum (i.e., body mass multiplied by sprint speed), and this has been suggested to also affect COD ability (7, 21). Prior research involving rugby players (7) indicated that faster and heavier athletes tent to possess greater sprint momentum, which influence their COD ability. Our study also reveals a slight positive correlation (r = 0.28, p = 0.013) between CODD and sprint momentum. Shortening the time taken to complete a COD while running and incorporating a 180° turn involves both a sufficient deceleration of velocity before changing direction and moving the body's center of gravity backward by leaning back during penultimate foot contact before changing direction (5,6), both of which affect COD performance. In our analysis of partial correlation coefficients with age in months as the control variable, CODD did not correlate with linear sprint speed, CMJ, and RJ-index. These measures indicate the ability to exert lower limb power, suggesting that CODD may be influenced by the technique involved in decelerating, changing direction, and reaccelerating at the point of changing direction. This suggests that although children who experienced significant growth in height and body mass exhibited improved linear sprint speed as a result of their morphological development, they might not have learned the technique necessary for effective reducing their velocity when changing direction or accepting the body mass of their body and switching it to a new direction of travel, which may have accounted for the absence of a difference in CODD between the different age groups. With respect to the effects of morphology and technique on CODD, further studies are required to compare the COD ability of children with different physiques and to conduct in-depth motion analysis of the period from deceleration until COD.

In this study, no significant age-related differences were observed among 10 to 12-year-olds in CMJ and RJ-index, which were used as indicators of lower-body power and reactive strength. Analysis of partial correlation coefficients with age in months as the control variable revealed that although CMJ and RJ-index showed a moderate negative correlation with CODT and 20-m time, they were not associated with CODD. Lockie et al (19) reported that among female university soccer players, CODT in the 505 COD test correlated with vertical jump height (r = -0.65 to -0.66), but no such correlation existed for CODD (r = –0.01 to 0.07). In terms of reactive strength, the 20-yard shuttle run test time demonstrated a correlation with jump height in the drop jump test (r = -0.31) (29). Our findings in this study, revealed that CODT was significantly correlated with jump height in both the CMJ and RJ tests, consistent with the findings of previous studies (19, 29), and support the results of Lockie et al (19) on the association with CODD. With respect to the association between CODD and jump performance, as described above, given that the CODD of a COD test incorporating a 180^{o} turn provides an assessment of performance ability that focuses only on COD independent of linear sprint speed, it is conceivable that the COD technique has a greater effect on CODD than lower-limb power or reactive strength.

This study had some limitations. The speed of the approach run is believed to have influence COD performance (21). Therefore, the approach time of 505 COD test and the 10-m time of the 20-m sprint test were compared using a paired t test. The approach times were significantly longer than the 10-m time in each group (10 years: $p < 0.001$, Cohen's d = 0.71; 11 years: p = 0.003, Cohen's d = 0.54; 12 years: $p < 0.001$, Cohen's d = 0.90). This suggests the participant's potential use of unconsciously pacing strategies during the 505 COD test. The CV for the CMJ and RJ tests were found to be high (CMJ: 13.6%, RJ: 23.9%). Despite instructions to maintain an extended posture during the jumps and landings, it is possible that the participants required further familiarization with the jump tests. Given that the study participants were affiliated with athletics or soccer club, exercising once or twice a week in addition to physical education classes at school. Therefore, our study results are more applicable to physically active children. Our study results were also obtained from a cross-sectional study comparing chronological age and have not been verified with respect to each participant's level of maturity from the perspective of PHV. Although data on sitting height would have provided an approximate estimate of biological maturity, it was not possible to measure sitting height in this study due to the experimental environment. Therefore, there might have been a mix of children with circa-PHV among the participants. Further studies are required to investigate the longitudinal development of height, body mass, COD ability, linear sprint speed, and lower-limb power.

PRACTICAL APPLICATIONS

Our findings indicates that CODD did not vary with age and this result may be influenced by increased momentum due to increased sprint speed and body mass. This suggests that for older elementary school-aged boys, experiencing significant changes in height and mass along with concurrent improvements in linear sprint speed, S&C coaches should emphasize teaching techniques on how to effectively reduce their speed before changing direction. For example, it is noted that in sharp angular change-of-direction, hip and knee joint flexion and ankle dorsi-flexion simultaneously act as a braking force for a longer time, lowering the center of mass for better stability (5). Lloyd & Oliver (17) suggest prepubescence as a prime time for motor control program development due to heightened neural plasticity. Therefore, S&C coaches who target older elementary school-aged boys for instruction may need to focus on penultimate foot contact techniques.

CONCLUSIONS

Our findings suggest that the inherent ability to change direction, as assessed by CODD, did not develop with age. Additionally, our results indicated a correlation between CODD and height, body mass, and sprint momentum all of which are indicative of morphological growth. Therefore, COD training should be provided according to children's morphological and linear sprint speed development.

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