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Section III – Sports Training

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Assessing Change of Direction Ability in a Spanish Elite Soccer Academy

by
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The aims of the study were: a) to analyze the reproducibility of the Modified Agility Test (MAT) according to two types of displacement (i.e. constrained [MATtop] vs. free [MATfree]), b) to examine the explanatory capacity of anthropometric characteristics and neuromuscular performance on the ability to change the direction (CODA), c) to look into the practical consequences of the types of displacement from the perspective of an elite soccer academy. 118 male soccer players (age: 16 (13-25) years old) from the same elite Spanish soccer academy (U13 to senior) were tested twice on two versions of the MAT (MATtop and MATfree), with 48 hours between testing sessions. Moreover, they were tested on linear-sprint performance, over 5 m (S5m) and 15 m (S15m), and the vertical jump (VJ) (countermovement jump with [ACMJ] and without an arm swing [CMJ]). The main findings were: a) the type of displacement did not affect the reliability of the CODA test; b) weight, S15m, ACMJ and CMJ variables explained close to 60% of CODA performance; c) MATtop (i.e. constrained displacement) and MATfree (i.e. free-displacement) CODA tests could show different profiles of development along the age groups; and d) the impact of the task's constraints was relatively higher in U16 and U17 groups. CODA seems to have a variable meaning depending on the characteristics of the test and the age of the participants.

Key words: *agility, test, youth, soccer, athletics.*

Introduction

Several authors have suggested that the change of direction ability (CODA) is an essential quality for soccer players, who, in an endurance context, are required to turn, sprint and change pace during matches (Stølen et al., 2005). Specifically, Reilly (1990) reported about 1000 changes of pace and direction during a game and Bloomfied et al. (2007a, 2007b) recorded an average of 9.3 decelerations every 15 minutes and more than 700 changes of direction per game in professional matches. CODA tests are habitually included in the batteries that try to describe and assess the physical fitness of soccer players (Brughelli et al., 2008; Fiorilli et al., 2017; Pojskic et al., 2018) or seek to distinguish between elite and sub-elite young soccer players (Gil et al., 2007; Hachana et al., 2014; Reilly et al., 2000; Trecroci et al., 2018a, 2018b).

Operationally, CODA is understood as the performance (i.e. time scored) over pre-planned sprint courses (Brughelli et al., 2008; Young and Willey, 2010). Among the numerous tests used to assess CODA, the T-Test (Chaouachi et al., 2012; Little and Williams, 2005; Sporis et al., 2010) designed by Seminick (1990) and its later modified versions (MAT) (Sassi et al., 2009; Silva

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et al., 2011) have been proposed as valid and reliable, having been widely used in order to assess CODA in soccer. Being originally designed for basketball players, the T-Test and its modifications require 4 changes of direction and the combination of frontal (forward and backward) and lateral (without crossing feet) displacements. The modified versions of the T-Test (MAT) shortened the pre-planned sprint course from 36.576 m to 20 m, trying to adapt the original protocol to the reported CODA activity during soccer and other games (Sassi et al., 2009). However, similarly to the T-Test, the MAT still involves elements that are not soccer specific (i.e. hand-touching of course lines and sideward and backward sprinting) for outfield players (Bloomfield et al., 2007c; Little and Williams, 2005; Strøyer et al., 2004). Several years ago two new versions of the MAT have been proposed with the aim of adapting it to the specificity of soccer: MATtop (Yanci et al., 2013) allows the players to touch the highest part of the cone, while MATfree (Yanci et al., 2014) imposes no constraints in terms of displacement or cone-touching. MATfree could be considered the most specific one because the players are not required to touch the ground with the hand nor to apply backward and lateral (without crossing feet) displacements as in other sports (i.e., basketball and racquet sports) (Bloomfield et al., 2007c; Little and Williams, 2005; Strøyer et al., 2004).

Because of its complex nature, multiple factors (i.e., technique, straight sprinting speed, leg muscle qualities, anthropometry and so on) can condition this ability (Sheppard and Young, 2006). Consequently, the characteristics of the tests (i.e., time to complete the test, the number of CODs, primary application of force throughout the entire test) determine the importance attributed to those factors (Brughelli et al., 2008; Chaouachi et al., 2012) and the definition of the CODA itself. Therefore, the aim of this study was to look into the practical consequences that certain changes in the measurement test (i.e. free displacement) can have on performance from the perspective of an elite soccer academy. Our research questions were whether the CODA tasks' constraints affected their applicability and their ability to discriminate between groups and players in a professional soccer academy in Spain. Hypothetically, we assumed that players' performance would not be affected by the lack of constraints in the definition of the task.

Methods

Participants

One hundred and eighteen male soccer players volunteered to participate in the study. They all were players from the same soccer academy belonging to a club that took part in the Spanish First Division League. These young soccer players belonged to 7 different age categories: senior-professional (the second team of the club that competed in the Spanish Second division B), junior (Under-19 and Under-17), cadets (Under-16 and Under-15) and child category (Under-14 and Under-13). The players' physical and anthropometric characteristics are presented in Table 1. Before the beginning of the study, written informed consent was obtained from the players and/or their legal guardians. The study was conducted according to the Declaration of Helsinki and in agreement with the guidelines of the Institutional Review Committee of the Sports and Youth Institute of Navarre.

Procedures

Two CODA tests (i.e., MATtop and MATfree) were included in the battery habitually used in the soccer academy to assess physical fitness of players. The collection of data was made in the last period of physical evaluation of the season (i.e., May) over three sessions with the following distribution of tests: a) Session 1: three performances of MATtop and MATfree randomly distributed, b) Session 2: three additional performances of MATtop and in MATfree randomly distributed, and c) Session 3: linear-sprint performance over 5 m (S_{5m}) and 15 m (S_{15m}) and two vertical jump (VJ) tests (countermovement jump with (ACMJ) and without an arm swing (CMJ)). Anthropometric measures were made before the first session. All the players were familiarized with the MAT tests in a previous session and had a rest interval of 48 hours between testing sessions. The players were fully acquainted with the rest of the tests.

Testing took place indoors on a synthetic court. Before each session a standardized warm-up, consisting of 3 min self-paced low-intensity running, skipping and scalping exercise, strides, and two acceleration drills, was performed. Strong verbal encouragement was provided to the players during all the tests to elicit maximal efforts.

In this study, the quality of the data of both tests (I.e., MATtop and MATfree) was assessed using relative and absolute reliability methods (Atkinson and Nevill, 1998; Bland and Altman, 1995; Hopkins et al., 2009; Sassi et al., 2009) considering a short term re-test design (48 h apart). In order to check the construct of the CODA we considered the differences in performance between age groups and the association between the performance in the CODA tests and the rest of the independent variables (Sheppard et al., 2006): sprint performance (S_{5m} and S_{15m}), VJ performance (CMJ and ACMJ) and anthropometrical values. In order to evaluate the global practical information provided by each test we calculated the intra-group correlation between both tests by means of the Kendall rank association coefficient.

Change of direction ability (CODA)

MATtop: Modified Agility Test touching the top of the cone. In fulfilment of the protocol of the Modified agility test (MAT) outlined by Pauole et al. (2000) and Sassi at al. (2009) the participant began with both feet behind the starting line A. At their own discretion, participants sprinted forward to cone B and touched it with their right hand. Facing forward and without crossing feet, they shuffled to the left to cone C and touched it with their left hand. The players then shuffled to the right to cone D and touched it with their right hand, shuffling back immediately after to the left to cone B to touch it. Finally, participants ran backward as quickly as possible returning to line A (Sassi et al., 2009). The only difference was that the players were allowed to touch the top of the cone (30 cm) instead of its base (Yanci et al., 2013).

MATfree: Modified Agility Test without indications about how to displace or which part of the cones to be touched. The only change with respect to the protocol of the MATtop was that in MATfree players were not required to move sideways and backwards at any time (Yanci et al., 2014). Table 2 shows the characteristics and the comparison of the MAT, MATtop and MATfree procedures.

Each player randomly completed three maximal performances of each of the CODA tests (i.e., MATtop and MATfree) interspersed with 3 min of passive recovery. The player's CODA performance was considered to be the shortest time needed to cover the set protocol distance in both tests. Any attempt that did not meet the considered requirements was excluded and repeated. Scores were recorded with photocell-beams set on tripods approximately 0.40 m above the floor level (Yanci et al., 2014) and positioned 2 m apart on either side of the starting line (DSD Laser System, Barcelona, Spain).

Sprinting (S_{5m} and S_{15m})

Each player performed an acceleration test consisting of three maximal sprints over 15 m, with 2 min of passive recovery between each sprint (Los Arcos et al., 2014). Players were placed 0.30 m away from the starting line and began the test when they felt ready (Los Arcos et al., 2014). Sprint times were collected with accuracy of ±0.001 s using photocell beams (DSD Laser System, Barcelona, Spain) set at 0, 5 and 15 m from the starting line, placed 0.4 m above the ground. The timer was activated automatically as the participant passed through the first gate at the 0.0 m mark recording split times for 5, 10 and 15 m sprints.

Vertical jump performance (CMJ and ACMJ)

Soccer players' vertical jumps (VS), countermovement jumps (CMJ) and arm swing countermovement jumps (ACMJ) were tested using infrared bars (Opto Jump Next, Microgate, Bolzano, Italy) according to the procedures proposed by Bosco et al. (1983). Players performed three CMJs and three ACMJs with at least a 3 min rest interval. Resting time between attempts was 20 s. In CMJs the hands were placed on the hips during take-off, flight, and landing phases and the maximal flexion of the knees during the take-off phase was required to be approximately ~90° (Bosco and Komi, 1979). In addition, a minimal flexion of the trunk during the take-off was permitted (Bosco and Komi, 1979). In comparison to CMJs, players were not obliged to place the hands on the hips during take-off, flight, and landing phases. Any jump that did not meet the considered requirements was repeated.

Anthropometric profile

All anthropometric measures were made in the afternoon by the same expert technician. Firstly, body mass and stature of each player were measured (Seca 799 and Seca 220, Hamburg, Germany). Next, skinfold measurements were carried out at four sites using a skinfold caliper (Holtain Ltd., Crymych, UK): triceps, subscapular, abdominal and suprailiac. Each measurement was made 3 times according to the recommendations of the Spanish International Group of Kinanthropometry and International Standards for Anthropometric Assessment (ISAK) and the average value was considered for each skinfold. Finally, the body fat percentage was estimated using the equation proposed by Faulkner (1968): body fat (%) = ∑skinfolds (tríceps + subscapular + suprailiac + abdominal) · 0.153 + 5.783.

Statistical Analysis

The results are presented as mean ± standard deviation (SD). The normality of the data was confirmed using the Shapiro-Wilk test. We used custom-made spreadsheets to analyse the magnitude of the differences in CODA performance from the test to retest (Hopkins, 2006) and between categories. Practical significance of the differences was assessed by calculating the Cohen's d effect size (Cohen, 1988). Effect sizes (ES) between <0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, and 2.0-4.0 were considered as trivial, small, moderate, large and very large, respectively (Hopkins et al., 2009). Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile difference or change (0.2 multiplied by the between-subject SD, based on the Cohen's effect size principle). Quantitative chances of higher or lower differences were evaluated qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; > 99%, almost certain. If the chances of having higher or lower values than the smallest worthwhile difference were both >5%, the true difference was assessed as unclear. Reliability calculations were made for MATtop and MATfree considering the value of the best attempt. The relative reliability was assessed using the Intraclass Correlation Coefficient (ICC) (Hopkins et al., 2009) and the magnitude of the effect for the ICC analysis (90% confidence limits) was provided according to the arbitrary categorization scale suggested by Coppieters et al. (2002). The absolute reliability was assessed calculating the Typical Error of the Measurement (TEM) (Hopkins et al., 2009). The coefficient of variation (CV) was calculated for all variables to determine the stability of the values between trials (CV =[SD/mean] x 100) (Atkinson and Nevill, 1998). The construct validity was assessed using an ANOVA design (inter-groups design) with the Bonferroni post-hoc test. Association between the considered to be independent variables and CODA test performances was evaluated using a backwards steps wise multiple regression approach. Kendall's tau correlation coefficients were calculated for each group in order to assess the intragroup performance level of each player according to each test. The analyses were performed using the SYSTAT 13 statistical software. Significance was set a priori at 5%.

Results

Test-retest differences were trivial for MATtop (5.63 ± .35 vs 5.60 ± .35, ES = -0.13 ± 0.08, likely) and MATfree (5.16 ± 0.31 vs 5.12 ± 0.29, ES = -0.17 ± 0.07, likely). ICC, TEM and CV values were 0.97, 0.19 and 10.1 for MATtop and 0.92, 0.30 and 10.7 for MATfree.

Table 3 shows the overall and age specific results for all the tests of physical fitness.

The performance level in MATtop correlated with body mass (r = 0.690, $p < 0.001$), body height (r = 0.639, $P < 0.001$), S_{5m} (r = 0.602, $P < 0.001$), S_{15m} (r = 0.673, $p < 0.001$), CMJ (r = 0.703, $p < 0001$) and ACMJ (r = 0.696, $p < 0.001$). Multiple regressions for MATtop showed the best fit (60% of explained variance) when including body mass, S_{15m} and CMJ variables. The performance level in MATfree was statistically significant with body mass (r = 0.685, $p < 0.001$), body height (r = 0.660, $p < 0.001$), S_{5m} (r = 0.609, $p < 0.001$), S_{15m} (r = 0.720, $p < 0.001$), CMJ (r = 0.698, $p < 0.001$) and ACMJ (r = 0.721, $p < 0.001$). Multiple regressions for MATfree showed the best fit (62% of explained variance) when including body mass, S_{15m} and ACMJ variables.

Significant ($p < 0.05$) and most likely large/very-large differences (ES = 1.74–2.45) were found between MATtop and the MATfree scores (MATfree < MATtop) in all categories. The mean improvement ranged from a maximum of 9.82% (U-14) to a minimum of 7.32% (U-16).

Tables 4 and 5 show the pairwise ANOVA comparisons between age groups for MATfree and MATtop, respectively, showing significant differences between U13 (MATfree: ES = 1.16–3.23; MATtop: ES = 1.03–3.59) and the rest of the groups and between U14 players (MATfree: ES = 1.28–1.92; MATtop: ES = 1.86–2.33) and the rest of categories except for U15 players. The U15 group happened to be slower than any older group in MATtop, but not in all cases in MATfree.

The Kendall ranked correlation test between MATfree and MATtop showed the following intragroup tau values: Senior (tau = 0.65, p < 0.000), U-19 (tau = 0.53, p < 0.003), U-17 (tau = 0.28, p < 0.200), U-16 (tau = 0.41, p < 0.036), U-15 (tau = 0.50, p < 0.008), U-14 (tau = 0.48, p < 0.002) and U-13 (tau = 0.53, p < 0.002).

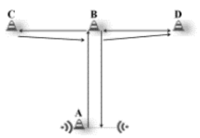
Table 1

Participants' characteristics according to their playing category.
The data are mean ± standard deviation.

	Senior (n = 19)	**U-19 (n = 12)**	**U-17 (n = 15)**	**U-16 (n = 15)**	**U-15 (n = 17)**	**U-14 (n = 22)**	**U-13 (n = 18)**	**Total (n = 118)**
Age (years)	22.1 ± 2.0	18.3 ± 0.7	17.1 ± 0.3	16.3 ± 0.3	15.2 ± 0.2	14.2 ± 0.2	13.2 ± 0.2	16.5 ± 3.0
Body mass (kg)	72.8 ± 6.0	74.1 ± 6.1	72.1 ± 4.9	67.1 ± 5.8	64.9 ± 9.5	55.4 ± 6.4	50.1 ± 6.3	64.4 ± 10.9
Body height (cm)	179.3 ± 6.7	182.2 ± 5.3	180.0 ± 5.2	178.2 ± 4.5	174.7 ± 7.6	169.0 ± 5.6	161.6 ± 8.3	174.4 ± 9.3
Body fat (%)	11.1 ± 1.1	10.4 ± 0.8	11.1 ± 1.0	10.3 ± 0.6	11.2 ± 1.4	10.4 ± 0.9	11.1 ± 1.7	10.8 ± 1.2

Table 2

Different T-design test characteristics (previous and present study).

<table>
<tr><th>Agility Test</th><th>Distance to cover</th><th>Test design</th><th>Displacement mode</th><th>End of displacement</th><th>Turns</th></tr>
<tr><td>T-Test (27)</td><td>36.57 m</td><td rowspan="4">
</td><td rowspan="3">A➞B forwards
B➞C Lateral, legs uncrossed
C➞D Lateral, legs uncrossed
D➞B Lateral, legs uncrossed
B➞A backward</td><td rowspan="2">Touch base of the cone</td><td rowspan="4">0-90º and 90-180º</td></tr>
<tr><td>MAT (26)</td><td rowspan="3">20 m</td></tr>
<tr><td>MATtop present study</td><td rowspan="2">Touch top of the cone (30 cm)</td></tr>
<tr><td>MATfree present study</td><td>A➞B➞C➞D➞B➞A Free</td></tr>
</table>

MAT = Modified Agility Test; MATfree = Modified Agility Test Free.

Table 3

Physical performance results according to the playing category.
The data are mean ± standard deviation.

	Senior (n = 19)	U-19 (n = 12)	U-17 (n = 15)	U-16 (n = 15)	U-15 (n = 17)	U-14 (n =22)	U-13 (n = 18)	Total (n = 118)
MATtop (s)	5.39 ± 0.23	5.28 ± 0.17	5.33 ± 0.18	5.35 ± 0.19	5.66 ± 0.22	5.84 ± 0.23	6.07 ± 0.21	5.60 ± 0.35
MATfree (s)	4.98 ± 0.18	4.83 ± 0.12	4.92 ± 0.14	4.96 ± 0.21	5.15 ± 0.17	5.27 ± 0.22	5.52 ± 0.20	5.12 ± 0.29
S_{5m} (s)	0.96 ± 0.03	0.96 ± 0.04	1.00 ± 0.05	1.00 ± 0.04	1.05 ± 0.07	1.08 ± 0.06	1.08 ± 0.06	1.02 ± 0.07
S_{15m} (s)	2.30 ± 0.07	2.32 ± 0.07	2.34 ± 0.07	2.37 ± 0.07	2.48 ± 0.14	2.55 ± 0.13	2.58 ± 0.13	2.43 ± 0.15
CMJ (cm)	42.4 ± 5.5	45.4 ± 4.3	45.9 ± 5.3	46.2 ± 5.1	39.3 ± 4.8	36.7 ± 4.4	32.6 ± 3.9	40.5 ± 6.7
ACMJ (cm)	50.0 ± 6.0	51.9 ± 4.9	51.3 ± 5.6	52.7 ± 5.1	45.9 ± 4.4	43.2 ± 5.7	37.9 ± 4.8	46.8 ± 7.2

MAT = Modified Agility Test; MATFREE = Modified Agility Test Free; S_{5m}= acceleration in a 5 m test; S_{15m}= acceleration in a 15 m test; CMJ = height of a counter movement jump; ACMJ = height of an arm swing counter movement jump.

Table 4

ANOVA pair wise comparison with the Bonferroni adjustment between the MATfree and the players' category.

	Senior	U-19	U-17	U-16	U-15	U-14	U-13
Senior							
U-19	NS						
U-17	NS	NS					
U-16	NS	NS	NS				
U-15	NS	*	*	NS			
U-14	*	*	*	*	NS		
U-13	*	*	*	*	*	*	

** = significant difference, $p < .05$; NS = no significant differences; MATF = Modified Agility Test Free.*
Effect Size (ES) and probabilities
U-13 vs U-14/U-15/U-16/U-17/U-19/Senior: ES = -1.16 - -3.23, most-likely moderate/very large
U-14 vs U-16/U-17/U-19/Senior: ES = -1.28 - -1.92, most-likely large
U-15 vs U-17/U-19: ES = -1.26 - -1.72, most-likely large

Table 5

ANOVA pair wise comparison with the Bonferroni adjustment between MATtop and the players' category.

	Senior	U-19	U-17	U-16	U-15	U-14	U-13
Senior							
U-19	NS						
U-17	NS	NS					
U-16	NS	NS	NS				
U-15	*	*	*	*			
U-14	*	*	*	*	NS		
U-13	*	*	*	*	*	*	

** = significant difference, p < .05; NS = no significant differences; MATF = Modified Agility Test Free.*
Effect Size (ES) and probabilities
U-13 vs U-14/U-15/U-16/U-17/U-19/Senior: ES = -1.03 - -3.59, very/most-likely moderate/very-large
U-14 vs U-16/U-17/U-19/Senior: ES = -1.86 - -2.33, most-likely large/very-large
U-15 vs U-16/U-17/U-19/Senior: ES = -1.26 - -1.72, most-likely large

Discussion

The aim of the study was to assess the applicability of two specific T-design CODA tests (i.e., MATtop and MATfree) in an elite soccer academy. The main findings were: a) both tests were reliable in order to produce scientifically and practically valid data when assessing the CODA in young soccer players; b) body mass, S15m and ACMJ variables explained 62% of the common variance for MATfree, while body mass, S15m but CMJ variables explained 60% for MATtop; c) MATfree and MATtop could show different profiles of development along the age groups, and d) the impact of the task's constraints was relatively higher in U16 and U17 groups.

Similarly to the MAT (i.e., touching the base of the cone with lateral and backwards displacements) (Sassi et al., 2009) and to the MATtop (i.e., touching the top of the cone and lateral and backwards displacements), we found trivial test-retest differences (ES = 0.13-0.21) and high reliability scores for the MATfree. Therefore, the requirement of touching the top of the cone and the involvement of free movement did not affect the quality of the data.

Chaouachi et al. (2012) were the first to analyse the alleged components of a T-design test in senior soccer players using the universal-model components for the CODA (Sheppard and Young, 2006). Using the T-Test as a dependent variable, their Stepwise multiple regression showed R2 of 0.45 obtaining significant effects ($p < 0.05$) for 5 m SS, height, QuadConc (quadriceps concentric isokinetic strength at 60º·s-1) and QuandEIm% (percentage difference of right vs left eccentric isokinetic strength, 60º·s-1, of quadriceps). In our study, body mass, S15m and ACMJ variables explained 62% of the common variance for MATfree, and body mass, S15m and CMJ variables explained 60% of the common variance for MATtop. Bearing in mind the age span of the groups of our study, and despite the important variations in body dimensions, no significant effect of body height was detected, in contrast to Chaouachi et al. (2012): body mass had significant effects ($p < 0.05$) for MATtop and MATfree, but not for the T-Test in Tunisian National Soccer League 1. Interestingly, while the CMJ and a quintuple horizontal jump test did not contribute to the T-Test performance for senior soccer players (Chaouachi et al., 2012), and no significant regreession equation could be found for NCAA woman Division I and II soccer players on the MATtop after considering, among others, vertical jumping as a factor (Lockie et al., 2018), the explanatory jumping factor varied from MATfree to MATtop in this study. That is, the primacy of a more open drill (i.e., ACMJ) for the free-displacement test and a closer drill (i.e., CMJ) for the constrained-displacement test can indicate the existence of slightly different CODA profiles, as far as lower limbs are concerned. These results suggest that, in addition to the characteristics of the players, the distance and the displacement mode of the T-design test (T-Test vs. MAT) determine the contribution of each factor to the performance.

Our results are congruent with previous studies that tested soccer players with MATfree. Yanci et al. (2014) conducted a study with 39 third division Spanish soccer players reporting a mean score of 4.89 ± .29 s, and Yanci et al. (2016) carried out an experimental study with a Spanish semi-professional team (2nd division B) reporting 4.92 ± .22 and 4.87 ± .25 scores in the pretest for both groups. These values, showing a slightly higher variance, are very similar to the results obtained by the groups older than U-16 in our research. In this sense, there are no differences between the four oldest groups (i.e. Senior, U-19, U-17 and U-16) in MATfree nor in MATtop, after the peak height velocity (Deprez et al., 2015; Mendez-Villanueva et al., 2011). Similarly, Loturco et al. (2019) did not find differences in change of direction speed between U17 (16.3 ± 0.2 years) and U20 (19.1 ± 0.4 years) players from top-level Brazilian soccer clubs. Moreover, senior soccer players showed a likely to very likely lower COD speed performance than U17 and U20 players (Loturco et al., 2019). In addition, Mujika et al. (2009) did not find differences between Spanish first division and junior players belonging to the same club in the 15 m CODA test. Among other factors (e.g. the characteristics of the tests), the absence of differences could be due to the reduction of individual variations in motor coordination that occurs in the mid-teenage years (Spencer et al., 2011), the effects of a prolonged exposure to "concurrent" training (i.e., high-volume of technical and tactical training in detriment to neuromuscular training) (Loturco et al., 2018), or the ineffectiveness of the neuromuscular training programs used in different stages of player's maturation (Loturco et al., 2019).

The effect of the aforementioned peak height velocity and its alleged impact on the CODA could appear at the bottom part of Tables 5 and 6 in relation to the absence or presence of differences between the U-15 group and the immediately preceding (U-14) or following (U-16) ones. In MATfree, apart from the surprising absence of differences between U-15s and seniors, there was no difference between consecutive groups from U-14 onwards; however, in MATtop there were large differences between U-15s and U-16s. U-15 appears to be the turning point of this CODA and further research is required to confirm or discard the existence of two separate logics of CODA development in relation to the definition of the CODA itself. Moreover, the intragroup Kendall ranked correlation tests between MATfree and MATtop show that the comparative performance level of a player can vary dramatically depending on the definition of the task with values of tau ranging from 0.28 (U-17 group) to 0.65 (Senior group).

Displacement constraints cannot be discarded as a relevant factor when assessing the CODA in elite young soccer players. Further research could consider the maturation level of the younger participants, the comparison with other team sports (i.e. basketball and handball) in which lateral and backwards displacement can be more specific than in soccer, and the collection of more data from different groups for a better management of the errors of measurement. The practical interest of testing the CODA in an elite soccer academy could be elucidated getting to know whether the differences found in this research in the younger groups were due to mere neuromuscular factors rather than coordination and agility issues.

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