ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2021; 28(**1**): 37-44
ISSN 2299-9590
DOI: 10.23829/TSS.2021.28.1-5

Arrowhead agility test in elite U-19 soccer players: positional differences and relationships with other performance tests

YIANNIS MICHAILIDIS[1], CHRISTOS KARYDOPOULOS[1], DIMITRIOS KAPRALOS[1], MICHALIS MITROTASIOS[2], IOANNIS ISPIRLIDIS[3], KONSTANTINOS MARGONIS[3], THOMAS METAXAS[1]

Abstract

Introduction. **Change of direction (COD) is an important prerequisite in soccer. Therefore, a large number of tests have been developed aiming to assess the COD of athletes. The test most commonly used in soccer include the Illinois test (ICODT), the T test, the 505 test, and the Arrowhead COD test (ACODT).** **Aim of Study.** **The aim of this study was to investigate relationships between ACODT and other field tests (ICODT, 0-10 m sprint, 0-30 m sprint, countermovement jump, squat jump) in Greek elite under-19 soccer players. Comparisons were also drawn between different field positions (central defenders, side defenders, central midfielders, side midfielders, forwards).** **Material and Methods.** **Forty Greek elite male soccer players (under 19; U-19) participated in this study and were classified into the following groups: forwards, central-midfielders, side-midfielders, central-defenders, and side-defenders. Anthropometric variables of participants (height, weight, body mass index (BMI), % body fat) and anaerobic physiological parameters (10 m and 30 m sprint, squat jump, countermovement jump, Illinois COD test, Arrowhead COD test) were measured.** **Results.** **There were no significant differences between the position groups for any of the performance tests or the anthropometric measurements. There were significant correlations between ACODT for both sides (left and right) and 0-10 m time, 0-30 m time, and ICODT time. There were no significant correlations between ACODT and any of the jump performance tests.** **Conclusions.** **The lack of differences between positional roles is in contrast with other studies that addressed professional older soccer players. This fact indicates that the specification of the training may produce differences between positional roles as the performance level of the players is increasing. Greater sprinting and acceleration speed could augment ACODT performance.**

KEYWORDS: anthropometrics, change of direction, playing position, anaerobic profile.

Received: 30 July 2020
Accepted: 29 December 2020

Corresponding author: ioannimd@phed.auth.gr

[1] Aristotle University of Thessaloniki, Department of Physical Education and Sports Sciences, Laboratory of Evaluation of Human Biological Performance, Thessaloniki, Greece
[2] National and Kapodistrian University of Athens, Department of Sport Science, Athens, Greece
[3] Democritus University of Thrace, Department of Physical Education and Sports Sciences, Komotini, Greece

Introduction

Soccer is an intermittent-type of sport that incorporates actions with low and high intensity and duration. A soccer player during a match covers on average about 9 to 14 km, and performs considerably more than 1.000 activities in a match, such as e.g. accelerations, decelerations, jumps, changes of direction, etc. [20]. The ability to move at high speed and quickly execute changes of direction (COD) is crucial for successful match performance [14]. Therefore, in soccer training numerous COD drills are included, which help players to become more economical in such actions.

Previous researchers mentioned the significance of COD for performance and they proposed a model to improve this ability. More specifically, Lloyd et al. [15] suggested that COD should be targeted during both prepubescence and adolescence. They mentioned that neural plasticity, which is associated with prepubescence, offers an ideal opportunity to develop motor control programs inclusive of a basic change of direction techniques. Recently, a group of researchers proposed a model for the development of agility during childhood and adolescence. They mentioned that during pre-puberty 25% of the training time should be focused on COD training, during circum-puberty 40%, and during post-puberty 20% of the time [15].

The use of a global positioning system (GPS) greatly facilitates the assessment of each athlete's physical demands (distance at specific speed ranges, average speed, acceleration, decelerations, and a maximum number of sprints) during matches and training sessions. Previous studies in soccer have noted that different field positions (e.g. defenders, midfielders, and forwards) encounter different dynamic actions during a match [3]. More specifically, it has been reported that in a high-level match the midfielders cover significantly more distance and make considerably fewer turns than defenders or strikers [3, 7, 30]. It has also been found that strikers do significantly more sprints than defenders and midfielders, while defenders cover the shortest distance of all players with the ball [7].

It is also stated that anthropometric characteristics, such as body weight, height and body mass index, may vary depending on the position of the soccer player [31]. As regards the changes of direction, in a study carried out in the Premier League it was established that players perform on average more than 700 changes of direction [3]. This high frequency shows the important role of the ability to change direction in soccer performance. The same study also found that there is a difference in direction changes depending on the players' position with midfielders performing the least compared to the other pitch positions [3].

Characteristics such as age, biological maturity, coaching age and anthropometric characteristics can affect the physical performance of players [5]. At younger developmental ages, the match rate is lower [29], and therefore it affects all the other variables such as the total distance covered.

The COD seems to depend on many factors such as strength, power, technique and anthropometric characteristics [15, 17]. Recent studies in developmental age players have shown that strength and power training programs have also improved performance in the COD. More specifically, Keiner et al. [10] reported that after a long program of strength training, the COD ability improved. Michailidis et al. [19] mentioned that after a 6-week plyometric training program the COD ability improved. In addition, previous studies have reported significant correlations between anthropometric characteristics and performance in the ability to change direction [17].

As mentioned above, COD is an important prerequisite in soccer. Therefore, a large number of tests have been developed aiming to assess the COD in athletes and most of them have been applied to soccer players. Distances in these tests ranged from 10 to 60 m including 1 to 9 directional changes of 45° to 270° [1]. The tests most commonly used in soccer include the Illinois test (ICODT), the T test, the 505 test and the Arrowhead COD test (ACODT). A recent study showed that ACODT is reliable to measure COD in soccer players [22].

Therefore, this study investigated relationships between ACODT and other field tests (ICODT, 0-10 m sprint, 0-30 m sprint, countermovement jump, squat jump) in Greek elite under-19 soccer players. Comparisons were also drawn between different field positions (central defenders, side defenders, central midfielders, side midfielders, forwards).

Material and Methods

Subjects

Fifty-three soccer players from elite male U-19 soccer teams were approached to participate in this study, but only 44 accepted the invitation (age 18.2 ± 0.8 years). The inclusion criteria to participate in the study were as follows: 1) not to have musculoskeletal injuries for ≥6 months prior to the study, 2) having participated in ≥95% of training sessions, 3) not to be taking any medication. Forty soccer players met the inclusion criteria and completed the study. All participants and their parents were informed about the potential risks and benefits of the study and signed consent was obtained. The local Institutional Review Board approved the study, in accordance with the Helsinki Declaration.

Experimental approach to the problem

In order to study the correlation of the ACOD with the selected field tests and to study potential differences between the different filed positions, the following design was followed. Field players were stratified into central defenders (n = 8), side defenders (n = 7), central midfielders (n = 11), side midfielders (n = 5), and forwards (n = 9). The players performed the subsequent field tests: the ACOD test, the Illinois test, 0-10 m sprint, 0-30 m sprint, countermovement jump and squat jump. The dependent variables for this study were: 0-10 m and 0-30 m sprint times; ACODT time from the left and from the right side, Illinois test time, as well as CMJ and SJ height.

Procedures

All players were familiar with the tests, because these tests were previously used by the teams' training staff to evaluate players' performance. Testing was incorporated within the team's gym (jump tests) and field (running field tests) training sessions that were held across two weeks in a season. At the beginning of each testing session, soccer players performed a 10-minute warm-up and at the end a 10-minute cool-down period. In the gym, after the warm-up, the players executed the CMJ test and then the SJ test. In the field, the players executed the sprint tests, followed by the ACODT and Illinois tests. Each test was performed twice and the best performance was used for statistical analysis. A 3-minute period was provided between trials. Testing was performed under identical conditions and the players avoided intense exercise in the preceding 24 hours. The field tests were performed on a soccer field with synthetic grass. Before the first gym testing session, the player's body mass, height, body fat and age were recorded.

Anthropometric measurements

Body mass was measured accurate to the nearest 0.1 kg using an electronic digital scale with the participants in their underclothes and barefoot. Standing height was measured to the nearest 0.1 cm (Seca 220e, Hamburg, Germany). Body fat percentage was estimated based on the sum of four (biceps, triceps, suprailiac, subscapular) skinfold thicknesses measured with a specific caliper (Lafayette, Ins. Co., Indiana) on the right side of the body by the equation of Siri (1956) [25].

Speed testing

A 30 m sprint test with 10 m splits (0–10 m was measured as well) was used to measure speed performance. After a 5-second countdown the participants ran in front of three infrared photoelectric gates (Microgate, Bolzano, Italy) that recorded times at each gate. The participants sprinted from a standing starting position with the toe of the front foot approximately 0.3 m behind the first gate. Photocells were placed 0.6 m above the ground (approximately at the hip level) to capture the movement of the trunk rather than a false signal due to a limb motion. The coefficient of variation for test–retest trials was 3.2%.

Vertical jump testing

The participants performed two jump tests: (a) SJ: participants, from a stationary semi-squatted position (90° angle at the knees), performed a maximal VJ; (b) CMJ: participants, from an upright standing position, performed a fast preliminary motion downwards by flexing their knees and hips followed by an explosive upward motion by extending their knees and hips. Both tests were performed with the arms akimbo. The VJ height was measured with Chronojump Boscosystem (Chonojump, Spain). The coefficients of variation for test–retest trials were 2.9 and 3.7% SJ and CMJ, respectively.

Arrowhead COD test

The participants stood behind the starting line in a sprint starting position. At their discretion, each subject ran as fast as possible from the starting line to the middle marks (A), turned to run through the side marks (C), through the far marks (B), and back through the start/finish line (Figure 1A). The participants completed two trials, one to the left and one to the right, having at least 5 minutes of recovery between them. The time was recorded in seconds to the nearest two decimal places for each direction. The coefficient of variation for test–retest trials was 4.3%.

Illinois COD test

The ICODT was set up with four markers forming a square area of 9.3 × 7.2 m. The start and finish gates were positioned at two consecutive angles of a square area, while two markers were positioned on the opposite side to indicate the two turning points. Four other markers were in the center, with an equal distance apart (3.1 m). Each participant had to run as quickly as possible from the start gate, follow a planned route, and slalom through the markers without knocking them down or cutting over them. From a standing position, each athlete sprinted 9.3 m on command and returned to the starting line, then had to swerve in and out of the markers, perform another sprint of 9.3 m, and complete the test by running to the finish gate. The photocells at the start and finish gates recorded the test time. The better time of two attempts was considered the ICODT score. A graphic representation of the test is shown in Figure 1B.

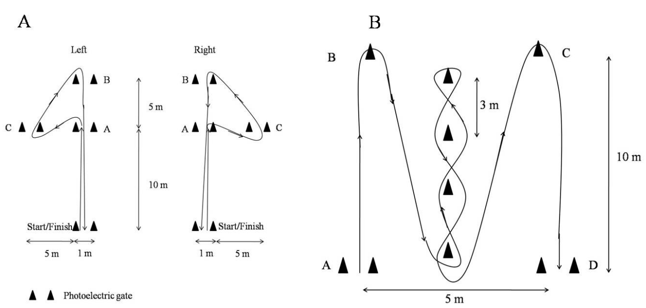

Figure 1. Graphic representation of COD tests: A. Arrowhead change of direction test (ACODT); B. Illinois change of direction test (ICODT)

Statistical analysis
Descriptive statistics (mean ± standard deviation, SD) were calculated for each parameter. Data normality was verified with the Kolmogorov–Smirnoff test. A one-way analysis of variance (ANOVA) was used to compute any differences in the subject characteristics and the performance test data between the position groups (central defenders, side defenders, central midfielders, side midfielders, forwards). Pearson's two-tailed correlation analysis determined relationships between ACODT and ICODT, CMJ, SJ, 0-10 m sprint test, and 0-30 m sprint test. The level of significance was set at $p = 0.05$. A power analysis was performed to estimate the smallest acceptable number of participants to analyze the interaction between groups and time points of measurements. The SPSS version 18.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results
Anthropometric characteristics are presented in Table 1. There were no significant differences in age, body mass,

Table 1. Participants' anthropometric characteristics

	F	CD	CM	SD	SM
Age (y)	18.4 ± 0.8	18.6 ± 0.9	17.9 ± 0.6	17.8 ± 1.1	18.2 ± 0.5
Height (m)	1.80 ± 0.05	1.79 ± 0.07	1.76 ± 0.06	1.77 ± 0.04	1.76 ± 0.09
Weight (kg)	72.8 ± 6.9	72.6 ± 8.8	69.4 ± 5.7	69.8 ± 4.7	69.1 ± 7.2
BMI	22.4 ± 1.2	22.5 ± 1.7	22.5 ± 1.3	22.2 ± 1.5	22.2 ± 0.8
Body fat (%)	11.7 ± 3.8	11.1 ± 2.2	13.5 ± 3.7	11.3 ± 2.8	9.7 ± 3.1

Note: Data are presented as means ± SD; F – forward; CD – central defender; CM – central midfielder; SD – side defender; SM – side midfielder

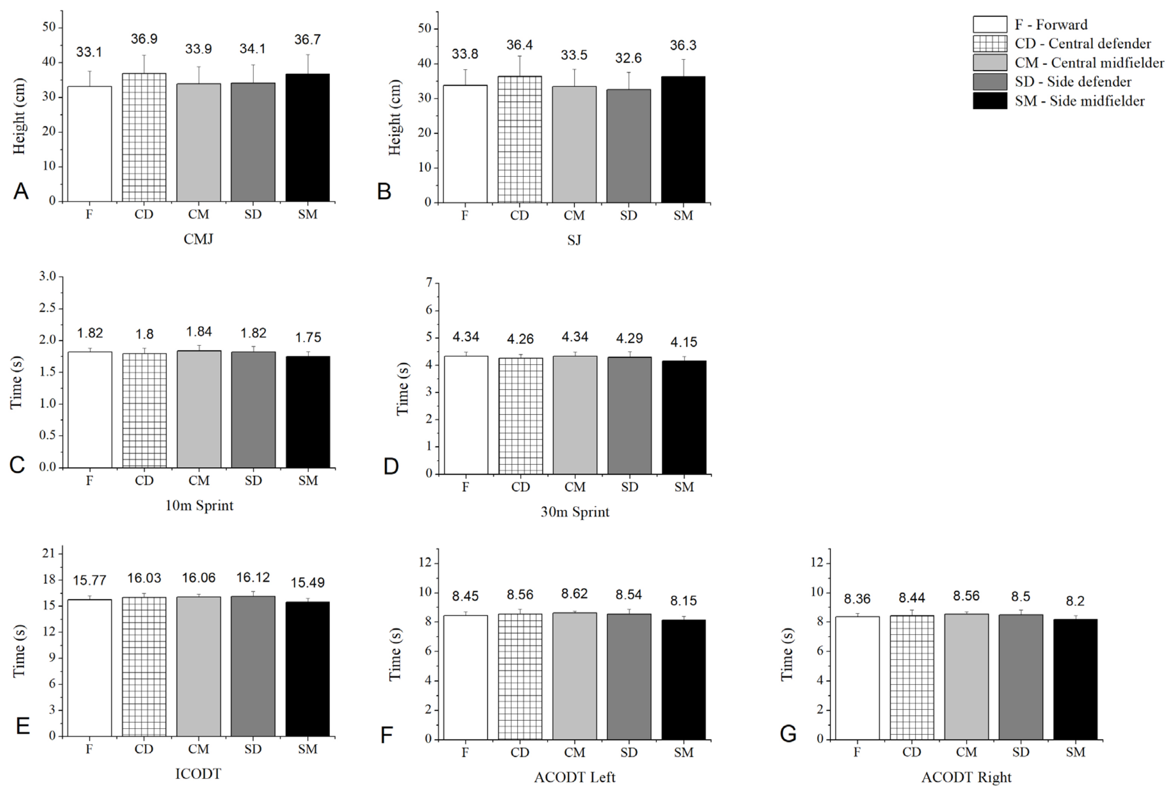

Figure 2. The comparison of obtained results according to playing positions: A – countermovement jump; B – squat jump; C – acceleration times (10 m); D – sprint times (30 m); E – Illinois COD test times; F – arrowhead COD times for the left side; G – arrowhead COD times for the right side

Table 2. Correlation between performance and anthropometric variables

		Height	Weight	BMI	% BF	SJ	CMJ	10 m	30 m	ICODT	ACODT left	ACODT right
% BF	r	–0.199	–0.152	0.474		–0.352	–0.352	0.181	0.355	0.325	0.330	0.209
	p	0.219	0.348	0.002**		0.026*	0.026*	0.262	0.025*	0.041*	0.077	0.195
SJ	r	0.159	0.142	0.052	–0.352		0.944	–0.267	–0.541	–0.397	–0.227	–0.159
	p	0.326	0.381	0.748	0.026*		0.001**	0.096	0.001**	0.011*	0.158	0.327
CMJ	r	0.092	0.091	0.048*	–0.352	0.944		–0.312	–0.594	–0.317	–0.218	–0.104
	p	0.574	0.578	0.771	0.026*	0.001**		0.050	0.001**	0.046*	0.177	0.521
10 m	r	0.268	0.152	–0.062	0.181	–0.267	–0.312		0.759	0.539	0.490	0.441
	p	0.094	0.350	0.703	0.262	0.096	0.050		0.001**	0.001**	0.001**	0.004**
30 m	r	0.240	0.066	–0.162	0.355	–0.541	–0.594			0.588	0.592	0.400
	p	0.136	0.684	0.319	0.025*	0.001**	0.001**			0.001**	0.001**	0.011*
ICODT	r	0.141	0.050	–0.095	0.325	–0.397	–0.317				0.869	0.800
	p	0.385	0.758	0.559	0.041*	0.011*	0.046*				0.001**	0.001**
ACODT left	r	0.141	0.022	–0.134	0.330	–0.227	–0.218					
	p	0.386	0.892	0.409	0.077	0.158	0.177					
ACODT right	r	0.225	0.141	–0.044	0.209	–0.159	–0.104					
	p	0.162	0.386	0.788	0.195	0.327	0.521					

Note: BMI – body mass index; % BF – percentage of body fat; SJ – squat jump; CMJ – countermovement jump; ICODT – Illinois change of direction test; ACODT – arrowhead change of direction test
* significance level <0.05; ** significance level <0.01

height, body fat and BMI between the positional groups. The performance test data are shown in Figure 2. The one-way ANOVA analysis indicated no significant differences between the positional groups for any of the performance tests.

The correlations between the ACODT and the other field performance tests are presented in Table 2. There were significant correlations between ACODT for both sides (left and right) and 0-10 m time, 0-30 m time, and ICODT time. All the correlations were positive, indicating that a lower time in the above tests was related to a lower time in ACODT. There were no significant correlations between ACODT and any of the jump performance tests.

Discussion

The aims of this study were a) to investigate relationships between ACODT and other field tests (ICODT, 0-10 m sprint, 0-30 m sprint, countermovement jump, squat jump), and b) to establish the anthropometric and anaerobic profile of Greek elite under-19 soccer players according to their playing positions (central defenders, side defenders, central midfielders, side midfielders, forwards). The major finding of this study is that anthropometric characteristics did not differ depending on playing positions. Additionally, there are no positional differences in anaerobic performances.

No differences were observed between the different playing positions in the two COD tests (ICODT and ACODT). This is in agreement with previous studies in collegiate soccer players [16]. However, previous researchers mentioned that agility could be used to distinguish elite from non-elite players within all positions [23]. Furthermore, elite Belgian male soccer forward players were faster in a shuttle-run COD speed test when compared to all the other position groups [4]. In view of the above, we find that in developmental ages and early adulthood there are no differences in the COD ability between playing positions as opposed to high-level adult soccer players. However, it should be noted that studies investigating the above relationship are limited. These findings suggest that when a young soccer player manages to compete at a high level, the long and specialized training followed when playing on a particular position could differentiate the player's performance in specific physical condition tests compared to the other positions. More simply, the specialization of the playing position probably causes differentiation in the tests' results.

The anthropometric characteristics and vertical jump performances did not correlate with the ACODT performance. It was surprising for us that, contrary to a previous study where minor relationships were found between CMJ and CODS ($p > 0.05$) [18], none of the vertical jump performances correlated with ACODT performance. However, both SJ and CMJ performances correlated with 30 m performance and Illinois COD test performance. Other earlier studies mentioned strong correlations between jumps and maximal velocity [18]. However, the correlations of ACODT with the sprint test and ICODT indicate that the use of ACODT is sufficient to evaluate the change of direction performance as it is with the Illinois test. It should be mentioned that the distance covered in ACODT is about 40 m, while in the ICODT it is about 60 m. This difference in the distance covered may make the ACODT a more appropriate test to assess the COD ability at developmental ages under 13 years of age, as the greater distance of the ICODT may adversely affect the COD ability of the participants. Weaker correlations ($r = 0.346$) were mentioned by Little and Williams (2005) [14] between 10 m performance with zig-zag agility test performance in a sample of professional male soccer players. Noted differences between the studies' results likely reflect the use of different COD tests and the different performance levels of participants.

The specialization of young soccer players in specific playing positions – concerning technical and tactical abilities – starts from the age of 13-14 years. However, the physical condition at these ages develops globally without differentiating between playing positions. In the last decade with the help of technology it has been found that during the match at the professional level there are differences in the running performance between playing positions. This differentiation probably indicates the need for personalized physical condition programs depending on the playing positions (e.g. SM runs more km than CD). This practice could lead to a greater improvement in the players' performance.

Numerous studies mentioned that professional soccer players exhibit positional differences regarding anthropometrical aspects such as body mass, height, body fat and body mass index [13]. More specifically, previous studies showed that CD were the heaviest and tallest players, while SD, SM, and F were the lightest and shortest [13]. Furthermore, the midfielders had a lower percentage of body fat than the other positional roles (defenders) [28]. However, other researchers mentioned no differences between positional roles [24]. This controversy in the literature could be due to the competitive level differences between soccer players. Another explanation for the differences between the results reported in various studies could be related with the design of individual studies, because some of them classified the players into three groups (defenders, midfielders, forwards) and others into five groups (CD, SD, CM, SM, F) except for goalkeepers. In our study we found no differences in anthropometric characteristics between the positional groups, but observed a trend for the CD and F to be heavier and taller than SD, CM, and SM.

It is known that vertical jump tests such as SJ and CMJ can determine the muscle power of the lower limbs in soccer players [26]. In the present study no positional differences were found in SJ and CMJ heights. These results are in agreement with previous studies [8, 13]. However, other researchers showed that explosive power is an important discriminate factor between the elite attackers from the other field positions [6], and in the case of underage soccer players it was mentioned that midfielders had the lowest jump height compared with forwards and defenders [29].

This study is in agreement with previous studies, which found no differences in running speed (10 m and 30 m sprint times) between soccer players depending on their playing positions [13]. In contrast, other studies showed that forwards were faster than defenders [8]. This contradiction could be explained by the competitive level of participating soccer players. As the competitive level increases and the trainings become more specific to a given soccer position, positional differences are observed and forwards seem to be faster than players of the other positions [27].

The percentage of body fat was negatively correlated with performance in SJ and CMJ and positively with the performance in 30 m sprint and the Illinois COD test. A recent study showed similar results for the relationship between speed performances and the percentage of fat mass [21].

The COD tests include accelerations and decelerations, therefore the use of the stretch-shortening cycle (SSC) phenomenon is crucial in this performance. The SSC is typically characterized by an eccentric muscular contraction followed immediately followed by a concentric one. Utilizing a stretch immediately before a concentric contraction has been shown to augment the concentric phase, resulting in increased force production and power output [11]. The importance of the SSC in sprinting and jumping performance is well established [12]. It was mentioned that stronger correlations between SJ and acceleration may be due to the fact that an adequate starting strength is necessary to initiate acceleration and overcome inertia and it does not rely as heavily on the SSC due to a static starting position [9]. Before sprinting soccer players are usually already in motion, so the SSC is already contributing to force generation during a moving start. This means that the assistance of stored elastic energy in the CMJ is more similar to a maximal sprint. This could be an explanation why jump performances were correlated with ICODT, but not with ACODT. Perhaps the distance of the tests (60 m vs 37.07 m) is crucial for this difference. However, SSC effectiveness is influenced by the stiffness of the muscle tendon, the rate and magnitude of the stretch, as well as other factors [2].

Certain study limitations should be acknowledged. The sample for this study was relatively small (n = 40). Also, the heterogeneity was small, because only two U-19 Greek elite squads were tested. Additionally, the distribution of subjects between the positional groups was not equal, and this may have influenced the lack of significant differences found between positional groups.

Conclusions

The lack of differences between positional roles indicates that as the competitive level of the players increases, the specification of the training may produce differences between positions. More specifically, because the professional players reveal different positional profiles, U-19 soccer players have to participate in more position-oriented training sessions.

When we use tests to assess physical abilities it should be adequate to the soccer players' age. Although ACODT is proposed as a reliable and valid test to measure COD in soccer players, the data for similar young populations are limited. Additionally, there are no data for the relationships between ACODT and other field tests.

References

1. Altmann S, Ringhof S, Neumann R, Woll A, Rumpf MC. Validity and reliability of speed tests used in soccer: a systematic review. PLoS ONE. 2019;14(8):e0220982. https://doi.org/10.1371/journal.pone.0220982.
2. Anderson T. Biomechanics and running economy. Sports Med. 1996;22:76-89.
3. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different positions in FA Premier League soccer. J Sports Sci Med. 2007;6:63-70.
4. Boone J, Vaeyens R, Steyaert A, VandenBossche L, Bourgois J. Physical fitness of elite Belgian soccer players by player position. J Strength Cond Res. 2012;26(8):2051-2057.
5. Da Silva CD, Blommfield J, Martins JCB. A review of stature, body mass and maximal oxygen uptake profiles of U17, U20 and first division players in Brazilian soccer. J Sports Sci Med. 2008;7:309-319.
6. Deprez D, Fransen J, Boone J, Lenoir M, Philippaerts R, Vaeyens R. Characteristics of high level youth soccer players: variation by playing position. J Sports Sci. 2014; 7:1-12.
7. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. Analysis of high intensity activity in Premier League soccer. Int J Sports Med. 2009;30:205-212.
8. Gil SM, Ruiz F, Irazusta A, Irazusta J. Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process. J Strength Cond Res. 2007;21:438-445.
9. Henricks BA. A comparison of strength qualities and their influence on sprint acceleration. J Aust Strength Cond. 2014;22:77-84.
10. Keiner M, Sander A, Wirth K, Schmidtbleicher D. Long-term strength training effects on change-of-direction sprint performance. J Strength Cond Res. 2014;28(1):223-231.
11. Komi PV, Bosco C. Utilization of stored elastic energy in leg extensor muscles in men and women. Med Sci Sports Exerc. 1978;10:261-265.
12. Kubo K, Kanehisa H, Kawakami Y, Fukunaga T. Elasticity of tendon structures of the lower limbs in sprinters. Acta Physiol Scand. 2000;68(2):327-335.
13. Lago-Penas C, Casais L, Dellal A, Rey E, Domınguez E. Anthropometric and physiological characteristics of young soccer players according to their playing positions: relevance for competition success. J Strength Cond Res. 2011;25(12):3358-3367.
14. Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. J Strength Cond Res. 2005;19:76-78.
15. Lloyd RS, Read P, Oliver JL, Meyers Robert WM, Nimphius S, Jeffreys I. Considerations for the development of agility during childhood and adolescence. Strength Condit J. 2013;35(3):2-11.
16. Lockie RG, Moreno MR, Orjalo AJ, Stage AA, Liu TM, Birmingham-Babauta SA, et al. Repeated-sprint ability in Division I collegiate male soccer players: positional differences and relationships with performance tests. J Strength Cond Res. 2019;33(5):1362-1370.

17. Mathisen G, Pettersen SA. Anthropometric factors related to sprint and agility performance in young male soccer players. Open Access J Sports Med. 2015;6:337--342.
18. McFarland IT, Dawes JJ, Elder CL, Lockie RG. Relationship of two vertical jumping tests to sprint and change of direction speed among male and female collegiate soccer players. Sports (Basel). 2016;4(1): 11-17.
19. Michailidis Y, Tabouris A, Metaxas T. Effects of plyometric and directional training on physical fitness parameters in youth soccer players. Int J Sports Physiol Perform. 2019;14(3):392-398.
20. Mohr M, Krustrup P, Bangsbo J. Fatigue in soccer: a brief review. J Sports Sci. 2005;23:593-599.
21. Radzimiński Ł, Szwarc A, Padrón-Cabo A, Jastrzębski Z. Correlations between body composition, aerobic capacity, speed and distance covered among professional soccer players during official matches. J Sports Med Phys Fitness. 2019;60(2):257-262. doi:10.23736/S0022-4707.19.09979-1.
22. Rago V, Brito J, Figueiredo P, Ermidis G, Barreira D, Rebelo A. The arrowhead agility test: reliability, minimum detectable change, and practical applications in soccer players. J Strength Cond Res. 2020;34(2):483-494.
23. Rebelo A, Brito J, Maia J, Coelho-e-Silva MJ, Figueiredo AJ, Bangsbo J, et al. Anthropometric characteristics, physical fitness and technical performance of under-19 soccer players by competitive level and field position. Int J Sports Med. 2013;34(4):312-317.
24. Rienzi E, Drust B, Reilly T, Carter JE, Martin A. Investigation of anthropometric and work-rate profiles of elite South American international soccer players. J Sports Med Phys Fitness. 2000;40:162-169.
25. Siri WE. The gross composition of the body. Adv Biol Med Phys. 1956;4:239-280.
26. Slimani M, Chamari K, Miarka B, Del Vecchio FB, Cheour F. Effects of plyometric training on physical fitness in team sport athletes: a systematic review. J Hum Kinet. 2016;53:231-247.
27. Slimani M, Nikolaidis PT. Anthropometric and physiological characteristics of male soccer players according to their competitive level, playing position and age group: a systematic review. J Sports Med Phys Fitness. 2019;59(1):141-163.
28. Sporis G, Jukic I, Ostojic SM, Milanovic D. Fitness profiling in soccer: physical and physiologic characteristics of elite players. J Strength Cond Res. 2009;23(7):1947--1953.
29. Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. Sports Med. 2005;35:501-536.
30. Vardakis L, Michailidis Y, Mandroukas A, Mavrommatis G, Christoulas K, Metaxas T. Analysis of the running performance of elite soccer players depending on position in the 1-4-3-3 formation. Ger J Exerc Sport Res. 2019 Dec. https://doi.org/10.1007/s12662-019-00639-5.
31. Wong PL, Chamari K, Dellal A, Wisløff U. Relationship between anthropometric and physiological characteristics in youth soccer players. J Strength Cond Res. 2009;23: 1204-1210.