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PREDICTORS OF AGILITY IN YOUTH SOCCER PLAYERS: CONTEXTUALIZING THE INFLUENCE OF BIOLOGICAL MATURITY

NAPOVEDNIKI GIBLJIVOSTI PRI MLADINSKIH NOGOMETAŠIH: KONTEKSTUALIZACIJA VPLIVA BIOLOŠKE ZRELOSTI

ABSTRACT

This study aimed to evaluate factors that influence soccer-specific change-of-direction speed (SSCODS) and reactive agility (SSRAG) in youth soccer players, taking into account their biological-maturity. The sample comprised 41 youth soccer players (14-15, height: 167.1±8.7 cm, mass: 56.1±4.9 kg) tested on anthropometrics, 10m-sprint, countermovement jump, reactive-strength-index, 20-yard generic test [20-yard], SSCODS and SSRAG. The biological-maturity was calculated on the basis of peak-height-velocity and expressed as maturity-offset (MO). The significant correlations between MO with remaining variables were evidenced, and the highest correlations were noted for CMJ and the 20-yard generic CODS test (Pearson's $r = 0.61$ and -0.63, $p < 0.01$; respectively). Multiple regression analyses were performed for 20-yard, SSCODS, and SSRAG as criteria. Predictors explained 66% percent of the 20-yard- and 40% of the SSCODS-variance (both $p < 0.05$). The biological-maturity has a minimal influence on performances where coordination, cognitive and perceptual capacities are important determinants of achievement.

Keywords: agility, change of direction speed, sport specific tests, generic tests, football

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IZVLEČEK

Cilj študije je oceniti dejavnike, ki vplivajo na hitrost spreminjanja smeri (SSCODS) in na gibljivost (SSRAG) pri nogometaših - mladincih, ob upoštevanju njihove biološke starosti. V vzorec smo vključili 41 mladinskih nogometašev (starost 14 in 15 let, višina: 167,1 ± 8,7 cm, masa: 56,1 ± 4,9 kg). Izvedli smo antropometrične teste, 10-metrski šprint, skok z nasprotnim gibanjem, generični test na 20 jardov, test hitrosti spreminjanja smeri, test reaktivne gibljivosti ter izračunali indeks relativne moči. Biološka zrelost je bila izračunana na podlagi najvišjega prirastka višine ter izražena kot zamik dozorevanja (MO). Ugotovili smo značilne korelacije med MO s preostalimi spremenljivkami. Najvišje korelacije opažamo pri testu skok z nasprotnim gibanjem in generičnim testom na 20 jardov (r = 0,61 in -0,63, p <0,01;). Za kriterij generičnega testa na 20 jardov, testa spreminjanja hitrosti in testa reaktivne gibljivosti, smo izvedli multiplo regresijsko analizo. Napovedniki pojasnjujejo 66% odstotkov skupne variance za generični test teka na 20 jardov in 40% skupne variance na hitrost spreminjanja smeri (oba p <0,05). Biološka zrelost ima minimalen vpliv na izvedbo, kjer so koordinacijske, kognitivne in zaznavne sposobnosti pomembne determinante dosežkov.

Keywords: okretnost, sprememba smeri hitrosti, specifični športni testi, nogomet, generični testi.

INTRODUCTION

Agility as motor ability can be defined as a rapid change of speed and direction of movement as a reaction to stimulus (Sheppard & Young, 2006). Agility depends on a number of motor factors, such as speed, power and stability (Okur, Taskin, & Taskin, 2019; Sekulic, Spasic, & Esco, 2014). Two relatively independent forms of agility (agility components) exist: change of direction speed or pre-planned agility/closed skill agility (CODS) and reactive or non-planned/closed skill agility (RAG). In brief, CODSinvolves an active change of direction speed as an athlete knows the pattern of movement in advance. On the other hand, in RAG the direction and speed of movement changes due to an external stimulus and athlete needs to anticipate and recognize the new situation and respond to it in a timely and correct manner (Sekulic et al., 2017). Anticipation in sport is defined as the capability of the athlete to use information from their environment to predict an opponent's action and respond on it with to achieve their task or goal (Brenton & Müller, 2018). Regardless of some differences, the importance of both CODS and RAG on achieving top sports results and performances has been frequently confirmed (Coh et al., 2018; Pojskic et al., 2018; Sekulic et al., 2014).

Soccer is social and cultural phenomenon and a highly complex polystructural team sport played by two teams characterized by changing dynamics and multistructural movements (Gardasevic & Bjelica, 2018). The actions during a game involve running at different speeds; high velocity movements through large ranges of motion; changes in movement patterns, such as running in all directions, sprinting, accelerating and decelerating; and numerous ball activities (Clemente et al., 2019). Although low-intensity activities account for 76.3% to 85.2% of soccer players' performance, the most important defensive and offensive movements are performed with maximum running speed and changing direction of movement (Faude, Koch, & Meyer, 2012). These changes of direction in soccer are usually influenced by some external influence, such as a teammate, opponent or ball, and represent a soccer-specific type of agility (Krolo et al., 2020).

The importance of agility in competitive team sports, including soccer, has been the subject of numerous studies in previous years (Sheppard & Young, 2006; Dos' Santos, McBurnie, Thomas, Comfort, & Jones, 2020; Hammami et al., 2018; Pojskic et al., 2018; Sekulic et al., 2017; Trecroci, Longo, Perri, Iaia, & Alberti, 2019). In general, this motor ability is considered as the crucial component of technical-tactical efficacy and one of the most important determinants of achieving top performance (Hammami et al., 2018; Sekulic et al., 2017). With regard to soccer, some investigations are particularly interesting.

One study investigating field-based physical performance of under 16-year-old elite and subelite soccer players found better performance in agility tests (Slalom, S90, RAT) for the elite group (Trecroci et al., 2019). Supportively, a study performed on U17 and U19 soccer players of the highest national competitive rank found significant differences between age groups, indicating that newly developed tests of soccer-specific agility can differentiate U17 and U19 players (Pojskic et al., 2018). Although both previously mentioned studies highlighted importance of RAG and CODS for successful performance, it is important to note that the later study clearly evidenced better ecological validity of the agility testing protocols that involve sport-specific movement templates (sport-specific tests) compared with tests that measure agility components but do not involve sport-specific scenarios (generic tests) (Pojskic et al., 2018).

The overall importance of agility components in competitive sports has prompted studies where authors aimed to evaluate factors that influence agility (Köklü, Alemdaroğlu, Özkan, Koz, & Ersöz, 2015). In general, perceptual and cognitive capacities have been identified as significant predictors of RAG, while CODS performance was often associated with sprinting and jumping performances (Sattler et al., 2015; Scanlan, Humphries, Tucker, & Dalbo, 2014) which was also confirmed on studies done on soccer players (Köklü et al., 2015;Little & Williams, 2003). However, studies rarely investigated agility components in youth soccer players, and studies assessing predictors of soccer-specific RAG and CODS are particularly scarce.

In male adolescents, physical performance is related to biological maturation (Malina, Bouchard, & Bar-Or, 2004). Specifically, boys who are advanced in biological maturity are generally better performers then their later maturing peers. This notion often causes older and physically advanced individuals to be favored in team sports selections (Malina, 2003). To avoid these situations, peak height velocity (PHV) has been used to characterize changes in size, body composition and performance relative to the adolescent spurt in height. PHV represents the time at which an adolescent experiences fastest grow during the adolescent phase, and maturity offset (MO) is the time before or after PHV (Kozieł & Malina, 2018). Both measures can be calculated using numerous formulas. Although studies confirmed the influence of biological maturity on conditioning capacities in youth athletes, research demonstrating the association between biological maturity and different forms of agility is lacking. To the best of our knowledge, no study has investigated the association between biological maturity and soccer-specific agility.

Based on the literature overview presented above, it is clear that agility is an important component of success in soccer. Additionally, studies have investigated the associations that may exist between certain conditioning capacities and agility components in soccer players. However, studies that examined predictors of agility in youth soccer players, especially studies taking into account maturity status, are lacking. Additionally, to the best of our knowledge, no study to date has reported such associations for agility tests examining soccer-specific RAG and CODS. This study aimed to identify potential associations between important determinants of agility (sprinting and jumping capacities) and soccer-specific CODS and RAG in youth soccer players while taking into account possible influence of players' maturation status (biological age).

METHODS

Subjects

Subjects in this study included 41 young male soccer players (n = 41, age: 14.44 ± 0.5 years, body height: 167.1 ± 8.7 cm, mass: 56.1 ± 4.9 kg) who were members of three soccer clubs from Split region. All subjects competed in the same age category, were involved in soccer for at least 5 years, and train 4-5 times weekly. Their typical training regime in the period of the study consisted of 70-80% soccer training (technical and tactical training) and 20-30% conditioning training (mostly aerobic endurance, coordination and strength). At the time of testing, all subjects were healthy, and players who reported injury and illness in the two-week period before the study were not involved in the investigation.

The ethics board of the University of Split, Faculty of Kinesiology provided approval of the research experiment (Ethical Board Approval No: 2181-205-02-05-14-001) . All subjects were informed of the purpose, benefits and risks of the investigation. Since subjects are under 18, parents or legal guardian authorized participation by signing informal consent.

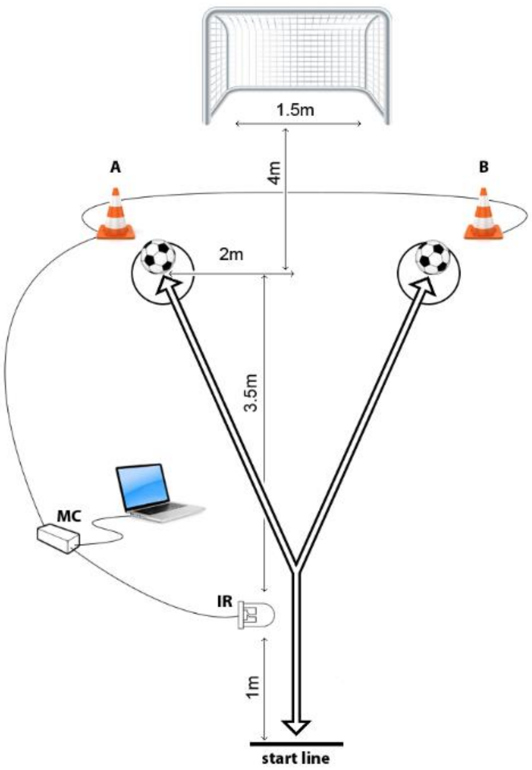
Procedures

In this study, we evaluated the following: (i) agility variables, including generic CODS 20-yard test (Eriksson, Johansson, & Bäck, 2015) and newly developed soccer-specific RAG (SSRAG) and soccer-specific CODS (SSCODS) tests (Krolo et al., 2020); (ii) sprinting and jumping capacities, including the countermovement jump test (CMJ), reactive strength index (RSI) derived from 15 seconds jump test; and 10-meter sprint (SPRINT-10m); (iii) biological age (maturity offset) and chronological age; and (iv) anthropometric indices (body height and mass). Included predictors were selected based on the findings from previous researches that have highlighted these motor capacities as those with the greatest impact on the manifestations of agility (Sheppard & Young, 2006).

Body height was assessed using a GPM anthropometer (Siber Hegner, Zurich, Switzerland), and a Tanita BC-418 device (Amsterdam, Netherlands) was used to measure body mass.

The SSRAG and SSCODS tests were developed to mimic soccer-specific movement templates (Figure 1). Test reliability and validity were recently reported in detail (Krolo et al., 2020). Briefly, a player runs from the starting line. At 1 m, the player passes the gate where the infrared signal is placed. After passing this point, the time begins, and one of the two cones lights up. The subject needs to run as fast as possible to the lighted cone and kick the ball placed near the cone through a small goal. Thereafter, the player runs as quickly as possible back past the infrared signal again, and time is stopped. After a few seconds of rest, the subject starts a new attempt. In the SSCODS, the test subject knows in advance which cone will light up and repeats the test twice (once to the left and once to the right cone). In the SSRAG, the pattern of movement is unknown, and the player needs to react on a light stimuli and move in the correct direction to complete the task as quickly as possible. The SSRAG test is repeated 5 times. The main component of the measurement system is a hardware device based on an ATMEL microcontroller (model AT89C51RE2; ATMEL Corp, San Jose, CA, United States). A photoelectric infrared sensor (E18-D80NK) with a response time of less than 2 ms (500 Hz) was used as an external time and LED (placed in the 30-cm-high cones) trigger. Finally, the device was connected to a PC laptop using the Windows 7 operating system.

Figure 1. Testing of the soccer specific reactive agility and change of direction speed



In the generic CODS 20-yard test (20-yard), three marker cones are placed on a line five yards apart. The player's starting position is a lateral stance 50 cm on the right from the middle line (cone). With 90° body rotation and by running to the left, the player activates the timing gate (Powertimer, Newtest, Finland) and starts the test. After coming to the first cone 5 yards from the middle line, the player turns directions and runs 10 yards to the opposite cone. Finally, the player turns again and finishes the test by running pass the timing gate. Subjects performed the test thrice with a 3-minute rest period between each attempt, and the best attempt was taken as the final result.

The Powertimer system was used for SPRINT-10m. In this test, the subject is placed 1 meter behind the start line in the high start position. After the subject moves forward and starts running, the first timing gate is activated. A second time gate is placed on the finish line (10 m), and the time stops after the subject passes it. Subjects made three attempts with a 2-minute rest period between each attempt. The best score was used for the analyses. The Powertimer system was previously validated and used in studies (Enoksen, Tønnessen,, & Shalfawi, 2009.; Krolo et al., 2020).

The Optojump system with two photoelectric beams (Microgate, Bolzano, Italy) connected to a PC laptop was used to conduct CMJ and to evaluate the RSI (Glatthorn et al., 2011.). The subject starts from an upright position with hands placed on the hips. A fast downward movement to 90° of knee flexion followed by a maximum-force upward vertical motion is performed, and the height of the jump is measured . Starting position and movement in 15-seconds-jumop-test is same with subject making continuous jumps for 15 seconds. The reactive strength index (RSI) was calculated from the average achieved height and the average time spent on the ground developing the force required for particular jump (Pehar et al., 2017). CMJ and 15-seconds-jumop-test were performed three times with a two-minute rest period between attempts, and the best score was taken as the final result.

Maturity offset was calculated using the Moore 2 formula (Kozieł & Malina, 2018):

Maturity offset = -7.999994 + (0.0036124 x (age (yrs.) x height (cm))

Statistical Analyses

In the first phase, the intratesting reliability of all tests assessing conditioning capacities was assessed by calculating the intraclass coefficient (ICC) and coefficient of variation (CV).

After assessing the normality of the distributions using the Kolmogorov-Smirnov test, descriptive statistics included the means and standard deviations presented as the true results for each variable. To identify the univariate associations between variables, Pearson's product moment correlation was calculated.

Multiple regressions were calculated to identify the multivariate relationships between predictors (anthropometrics, conditioning capacities, age, and MO) and criteria (20 yards, SSCODS, and SSRAG). Prior to calculation of multiple regressions, the predictors were assessed for multicollinearity. The high multicollinearity was evidenced for body height, maturity offset, and chronological age. Consequently, and due to better correlation with conditioning capacities (please see later Results for details), the maturity offset was retained as the predictor in multiple regression calculations.

A 95% p-level was applied, and Statistica v.13.0 (Dell Inc., Palo Alto, CA, USA) was used for all statistical analyses.

RESULTS

Descriptive statistics and reliability coefficients are presented in Table 1. Generally, all applied tests of conditioning capacities had appropriate reliability, with ICC higher than 0.75, and CV lower than 11%.

Table 1. Descriptive statistics of the study variables and intra-testing reliability of the applied tests of analyzed conditioning capacities

	Mean	SD	ICC	CV
Body height (cm)	167.1	8.7		
Body mass (kg)	56.1	4.9		
Maturity offset	0.74	0.31		
20-yard (s)	5.16	0.32	0.81	0.07
SSCODS (s)	2.55	0.19	0.8	0.09
SSRAG (s)	2.84	0.19	0.77	0.09
CMJ (cm)	25.22	5.84	0.86	0.07
RSI (index)	2.76	0.40	0.76	0.10
SPRINT-10m (s)	1.88	0.14	0.80	0.08

ICC – intraclass coefficient, CV – coefficient of variation, 20-yard – generic test of change of direction speed, SSCODS – soccer specific test of change of direction speed, SSRAG – soccer specific test of reactive agility, CMJ – countermovement jump, RSI – reactive strength index, SPRINT-10m – sprinting over 10-meters distance

The age, maturity offset, and body height were consistently correlated with most of the study variables. However, biological maturity evaluated by MO was better correlated with anthropometrics and conditioning capacities than subjects' age (Pearson's r: 0.35-0.88, p<0.05 and 0.28-0.51, p<0.07 for MO and age, respectively). The MO was more strongly correlated with generic conditioning capacities (Pearson's r: 0.52-0.61, p<0.001), than sport-specific capacities (Pearson's r: 0.38-0.48, p<0.05). SPRINT-10m was significantly correlated to 20-yard, CMJ, and SSRAG (Pearson's r: 0.57,p=0.001; -0.67,p=0.001; and 0.42, p=0.006 respectively). Similarly, the CMJ was significantly correlated with agility components (Pearson's r: -070,p=0.001; - 0.64, p=0.001; -0.43, p=0.005 for 20-yard, SSCODS, and SSRAG, respectively). The 20-yard, SSCODS, and SSRAG were significantly inter-correlated, and shared 25% to 30% of the common variance (Table 2).

Table 2. Pearson's product moment correlation coefficients between studied variables

	Age	**Maturity offset**	**Body height**	**Body mass**	**SPRINT -10m (-)**	**20-yard (-)**	**CMJ**	**RSI**	**SSCODS (-)**
Age									
Maturity offset	0.74***								
Body height	0.32*	0.88***							
Body mass	0.28	0.68***	0.75***						
SPRINT-10m (-)	-0.28	-0.35*	-0.30	-0.13					
20-yard (-)	-0.51***	-0.63***	-0.52***	-0.31	0.57***				
CMJ	0.48**	0.61***	0.52***	0.27	-0.67***	-0.70***			
RSI	0.37*	0.52***	0.47**	-0.22	0.18	-0.56***	0.46**		
SSCODS (-)	-0.42***	-0.48**	-0.38*	-0.23	0.19	0.56***	-0.64***	-0.29	
SSRAG (-)	-0.35*	-0.36*	-0.26	-0.13	0.42**	0.55***	-0.43**	-0.15	0.55***

(-) indicates variables with opposite metrics - better achievement is evidenced by lower result, 20-yard – generic test of change of direction speed, SSCODS – soccer specific test of change of direction speed, SSRAG – soccer specific test of reactive agility, CMJ – countermovement jump, RSI – reactive strength index, SPRINT-10m – sprinting over 10-meters distance, *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Predictors explained 65% variance of the 20-yard performance ($p < 0.01$) with significant partial contribution of CMJ (Beta: -0.35, $p < 0.05$), and RSI (Beta: -0.33, $p < 0.05$). In general, better performance in 20-yards was associated with superior jumping performance (Table 3). When multiple regression was calculated for SSCODS criterion, predictors explained 38% of the variance ($p < 0.05$), with CMJ being the only significant predictor of SSCODS (Table 4). The multiple regression calculated for SSRAG did not reach statistical significance (24% of the explained variance, $p = 0.07$) (Table 5).

Table 3. Multiple regression calculation for generic test of change of direction speed (20-yard)

20-yard	**β**	**Std.Err. β**	**B**	**Std.Err. B**	**t(33)**	**p**
Intercept			5.65	0.87	6.50	0.00
Maturity offset	-0.19	0.19	-0.10	0.10	-0.99	0.33
Body mass	-0.02	0.15	0.00	0.01	-0.13	0.90
SPRINT-10m	0.11	0.14	0.26	0.32	0.81	0.42
CMJ	-0.35	0.16	-0.02	0.01	-2.17	0.04
RSI	-0.33	0.13	0.00	0.00	-2.57	0.01
R	0.80					
Rsq	0.65					
p	0.01					

SPRINT-10m – sprint over 10-meters distance, CMJ – countermovement jump, RSI – reactive strength index, Intercept – interception coefficient, β – standardized regression coefficient, B – nonstandardized regression coefficient, R – coefficient of the multiple correlation, Rsq – coefficient of determination

Table 4. Multiple regression calculation for soccer specific change of direction speed test (SSCODS)

SSCODS	β	Std.Err. β	B	Std.Err. B	t(33)	p
Intercept			3.91	0.70	5.60	0.00
Maturity offset	-0.23	0.26	-0.07	0.08	-0.90	0.37
Body mass	0.06	0.19	0.00	0.00	0.29	0.77
SPRINT-10m	-0.32	0.19	-0.44	0.26	-1.69	0.10
CMJ	-0.59	0.22	-0.02	0.01	-2.72	0.01
RSI	-0.07	0.17	0.00	0.00	-0.43	0.67
R	0.62					
Rsq	0.38					
p	0.01					

SPRINT-10m – sprint over 10-meters distance, CMJ – countermovement jump, RSI – reactive strength index, Intercept – interception coefficient, β – standardized regression coefficient, B – nonstandardized regression coefficient, R – coefficient of the multiple correlation, Rsq – coefficient of determination

Table 5. Multiple regression calculation for soccer specific reactive agility test (SSRAG)

SSRAG	β	Std.Err. β	B	Std.Err. B	t(33)	p
Intercept			2.15	0.76	2.84	0.01
Maturity offset	-0.31	0.28	-0.10	0.09	-1.09	0.28
Body mass	0.14	0.21	0.00	0.00	0.67	0.51
SPRINT-10m	0.26	0.21	0.36	0.28	1.28	0.21
CMJ	-0.11	0.24	0.00	0.01	-0.44	0.66
RSI	0.01	0.19	0.00	0.00	0.06	0.95
R	0.49					
Rsq	0.24					
p	0.07					

SPRINT-10m – sprint over 10-meters distance, CMJ – countermovement jump, RSI – reactive strength index, Intercept – interception coefficient, β – standardized regression coefficient, B – nonstandardized regression coefficient, R – coefficient of the multiple correlation, Rsq – coefficient of determination

DISCUSSION

The results indicated several most important findings. First, the biological maturity of youth soccer players was significantly correlated with their studied conditioning capacities (i.e., sprinting, jumping, CODS and RAG) with a stronger influence on generic than on sport-specific capacities. Next, biological maturity and jumping capacity were correlated with generic CODS and SSCODS. Finally, of all studied agility components, RAG was the least explained by studied predictors.

Biological maturity and conditioning capacities of youth soccer players

Both chronological (AGE) and biological (MO) age are significantly related to achievement in all tests. However, higher Pearson's correlation coefficients indicate that biological age explains the greater percentage of variance of all studied conditioning capacities (e.g., sprinting, jumping and different agility performances). More specifically, chronological age explains from 7% to 26% of the variance, while biological maturity explains from 13% to 40% of the variance for the observed performance tests.

More mature athletes possess superior physical capacity because entry into puberty and time at puberty are characterized by numerous physiological changes in the body that are primarily hormonal and affect the increase in muscle mass and longitudinal growth of bones (Malina et al., 2004). With the growth of the extremities (arms and legs), the young player's stride is longer. Thus, growth of the extremities combined with the increase in muscle tissue explains why accelerants (e.g., early maturers) perform better in variables measuring agility, speed and power. With the growth of muscles, the young player becomes generally more powerful and has the necessary hormonal support, primarily due to testosterone, for further development of that motor component (Malina et al., 2004).

Studies regularly confirmed the positive influence of maturity status on performance in youth. A study on 14-year-old basketball players revealed significantly worse results in 9 tests of speed, agility and explosive power for late maturers compared to average and early maturers (Jakovljevic et al., 2016). Brazilian researchers found that maturity positively influences agility and speed in youth basketball players (Pittoli, Barbieri, Pauli, Gobbi, & Kokubun, 2010). A study on Belgian soccer players aged 15–16 years showed that more mature players were more advanced in morphology and in most of the studied variables (Vandendriessche et al., 2012). The influence of biological maturity on physical performance was also studied on male youth handball players from three age groups (U14, U15 and U16) were players on the back position were significantly more mature than wings and pivots which was influenced by the fact that youth players with the most advanced maturation status are consistently positioned in the back position (Matthys, Fransen, Vaeyens, Lenoir, & Philippaerts, 2013).

However, our results expand findings from previous studies since certain differences were evidenced among tests with regard to their generic vs. sport-specific features. For the purpose of our investigation, the most intriguing are differences between generic- and sport-specific tests of agility components.

Correlates of change-of-direction performances

Biological maturity was more related to 20Y than SSCODS, although both CODS tests measure pre-planned agility. The main explanation this finding is the fact that 20Y does not include soccer-specific skills and therefore does not challenge specific motor coordination to a great extent. In other words, because performance in 20Y does not include soccer techniques, execution is influenced by basic motor abilities (i.e., strength, power, speed) and consequently was more influenced by maturity status. Regarding SSCODS, the results are less related to biological age given that soccer-specific motor proficiency is an important component of performance.

Although we could not find a study where previous consideration was directly confirmed by correlation/regression results, the findings of studies where authors simultaneously studied generic and sport-specific tests at least partially confirm our conclusions. In a handball study, youth players were grouped according to maturity status and were assess using various conditioning capacities, including different CODS tests, and maturity status was a stronger determinant of generic compared with handball-specific CODS (Hammami et al., 2018). This finding is explained by the increased importance of physical capacities in generic compared with handball-specific tests (with the latter being more influenced by handball-specific skills) (Hammami et al., 2018).

The importance of sport-specific skills and motor proficiency on agility was highlighted in another handball study (Spasic, Krolo, Zenic, Delextrat, & Sekulic, 2015). The sample was divided in two groups according to their playing position (offensive and defensive players) and assessed for sprinting, jumping, and handball-specific RAG and CODS capacities (both designed to mimic defensive movement templates). In brief, although offensive players achieved better results in sprint and jump components, defensive players outperformed offensive players in handball-specific agility components. This finding confirmed authors' initial hypothesis that defensive players will outperform offensive players in sport-specific capacities given the higher skill level irrespective of their lower level of generic conditioning status (Spasic et al., 2015).

Analysis of multivariate associations with agility performance reveals that jumping capacity significantly influences both CODS tests. This finding is consistent with previous studies that stated that the change of direction depends on the explosiveness of the lower extremities (Sheppard & Young, 2006). Interestingly, a nonsignificant but negative coefficient was noted for the 10-meter sprint and SSCODS test in multiple regression, suggesting that faster players have lower stop-and-go capacities probably due to weaker motor control while running at higher speeds. Supportively, such conclusions were highlighted in previous studies where predictors of various CODS performances were analyzed in early pubescent boys, and similar tendencies of the potentially negative influence of running speed on stop-and-go CODS performances was also noted (Sekulic et al., 2014) .

Correlates of soccer-specific change of direction and reactive agility

As discussed previously, predictors used in this study explained a larger proportion of variance for generic tests than sport-specific tests. However, when exclusively considering sports-specific tests (SSCODS and SSRAG), a larger proportion of variance is explained for the SSCODS. Hence, it is obvious that measures of speed and explosive power have a greater impact on CODS performance than RAG among young soccer players. This finding could be explained by the fact that CODS and RAG are independent qualities (Spasic et al., 2015).

Indeed, in a study where authors investigated differences between preplanned and unplanned responses when reacting to a stimulus in an identical spatial scenario, the results indicated that CODS (e.g., preplanned scenario) and RAG (nonplanned scenario) are two different and independent skill domains that define agility and should be tested and trained using different methods (Coh et al., 2018). Most importantly, in SSCODS, subjects knew the pattern of movement in advance. However, in SSRAG, the subject changed the direction of movement after perceiving and processing the visual stimulus. Therefore, although these tests may seem similar with regard to movement template, SSCODS and SSRAG are influenced by different predictors. Thus, it is likely that some other components not tested in this study significantly impact SSRAG.

According to authors who studied sport-specific CODS, performance in these test, with the exception of the technique of the sport itself, depends primarily on conditioning capacities (Sheppard & Young, 2006). On the other hand, perceptual and decision-making components (visual scanning, situational knowledge, pattern recognition and anticipation) are crucial for RAG performance (Sheppard & Young, 2006). Supportively, in a study on a sample of university athletes, the authors investigated associations among jumping capacity, reactive strength and balance with stop-and-go CODS and RAG (Sattler et al., 2015). Unlike CODS, the observed predictors did not appear to be significantly associated with RAG for men. Therefore, it has been concluded that RAG performance was influenced by factors in addition to those observed conditioning capacities (jumping, reactive strength, balance), such as cognitive and perceptual features (Sattler et al., 2015). A similar study was performed on professional basketball players, and the results showed that cognitive measures (response and decision-making time) had the greatest influence on RAG performance (Scanlan et al., 2014).

The results of this study showed that biological maturity did not significantly affect the SSRAG results. As mentioned previously, biological age has a significant impact on conditioning capacities, while motor knowledge and skills are less maturity dependent. Given that motor skill level is crucial in RAG, the obtained results can be explained accordingly. Supportively, a study with youth soccer players reported that proper movement technique may be a more important determinant of sport-specific CODS and RAG than conditioning capacities in sport-specific settings, leading to the conclusion that development of CODS and RAG in this age group is mostly dependent on training for the specific motor proficiency (Pojskic et al., 2018).

Direct support for all previously discussed topics can be found in one of the most comprehensive studies of the influence of biological maturity on various capacities in youth soccer. In short, authors examined 15- to 16-year-old Belgian players, and morphology, fitness (strength, speed, agility, flexibility), and soccer-specific (dribbling) and nonspecific motor coordination skills were assessed (Vandendriessche et al., 2012). Results showed that more mature players exhibited increased morphological measures and better results on almost all fitness tests compared with late maturers. On the other hand, no significant differences were noted in soccer-specific and nonspecific motor coordination tests. These results indicated that morphology and fitness are more influenced by biological maturation than motor coordination skills. Considering these facts, authors suggest that during the talent identification and selection process, measures of biological maturity status should be included in order to detect real biological age of players which will have big influence on their motor abilities. Also, it is crucial to include specific sport performances, not influence by maturity, to prevent the dropout of promising late maturing players (Vandendriessche et al., 2012).

Limitations and strengths

This study was cross-sectional, which represents its most important limitation. Specifically, although some causalities may be intuitively interpreted (i.e., MO is likely a predictor of anthropometrics and conditioning capacities), some cause-effect relationships should be further evaluated in intervention studies (controlled trials). Additionally, biological maturity was not assessed in laboratory-based settings. Finally, the assessments that directly measure some important determinants and components of studied RAG performances (i.e., cognitive and perceptual-reactive capacities)were not included.

This is one of the rare studies where youth soccer players were assessed using generic and sport-specific tests of agility components, which allowed insight into the differential influence of studied predictors on agility in youth soccer players. To the best of our knowledge, this is the first study using validated tests of soccer-specific CODS and RAG to assess factors that influenced the studied performances while contextualizing the importance of biological maturity.

CONCLUSION

Maturity status significantly influences the level of certain conditioning capacities, such as sprinting, jumping and CODS, in youth soccer players. Coaches working with young soccer players should be informed that this is a logical consequence of advanced growth and development of organs and tissues in boys who are more advanced in biological age. More mature players exhibit the following features: (i) better performance in various tests of conditioning capacities (due to advanced growth), and (ii) more effectively recover from strenuous exercise (because of the higher level of circulating anabolic hormones).

Results of this study showed that differences in biological age do not generally influence performances of higher complexity. Specifically, biological maturity has lower importance in sport-specific performances and performances where coordination, cognitive and perceptual capacities are important determinants of achievement. Therefore, coaches should be aware that sport-specific movement skills and techniques could be effectively developed regardless of a player's maturity status.

Young players of the same chronological age may exhibit significantly different biological maturity, and this notion should be taken into consideration when creating training plans and programs and especially during team selection. Calculating biological age is a tool for assessing athlete potential. By taking a player's biological age into account, coaches can have a better understanding of the player's current abilities and can more precisely evaluate the potential of each individual.

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