DOES MOTOR COORDINATION INFLUENCE PERCEPTUAL-COGNITIVE AND PHYSICAL FACTORS OF AGILITY IN YOUNG SOCCER PLAYERS IN A SPORT-SPECIFIC AGILITY TASK?

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ABSTRACT

This study aims to determine whether motor coordination influences the perception-decision time (perceptual-cognitive factor) and movement response time (physical factor) of young soccer players in a sport-specific agility task regardless of maturation. Eighty-seven young male soccer players were analyzed. Anthropometric measurements were used to determine the maturity offset, while physical qualities including agility, change of direction speed (CODS) and motor coordination were also assessed. The following variables were obtained from these tests: Motor coordination score, perception-decision time, movement response time, agility time and CODS time. Motor coordination revealed a non-significant correlation with perception-decision time (r = 0.10, p = 0.34). However, motor coordination showed negative and significant correlations with CODS time (r = -0.47, $p < 0.01$), agility time (r = -0.52, $p < 0.01$) and movement response time (r = -0.62, $p < 0.01$). In addition, regression analysis showed that each increase in motor coordination score was associated with significant decreases in agility time (b = -0.023), movement response time (b = -0.021) and CODS time (b = -0.021) independent of maturity offset. The results of this study indicated that motor coordination was significantly related to the physical factors of agility in young soccer players.

Keywords: Physical activity, motor performance, movement response time, adolescents, change of direction speed.

Introduction

Agility is a reactive ability that requires changes in speed and direction using rapid and accurate movements in response to a stimulus (Hojka et al., 2016; Young et al., 2015). Agility depends on perceptual-cognitive and physical factors (Paul et al., 2016), involving stages of visual search, knowledge situation, decision-making, and change of direction (Young et al., 2015). The degree of participation of both perceptual-cognitive and physical factors occurs at different times (Young et al., 2015). For example, perceptual-cognitive factors are more required during perception-decision time, period in which an athlete perceives key elements of the stimulus from the external environment and processes this information to make appropriate movement choices (Young et al., 2015). While physical factors are more required during movement response time, time interval from decision-making until the beginning of the movement (Young et al., 2015; Zouhal et al., 2019). Therefore, the understanding that agility does not depend only on physical factors becomes fundamental, since agility has been routinely assessed through tests that measure only the change of direction speed (CODS), which have been described as a pre-planned change of direction movement without including the response to external stimulus (Krolo et al., 2020). Such testing approaches limit our understanding of agility and applicability to match-related situations in which decision-making is an important aspect (Coh et al., 2018).

Importantly, agility is a clear determinant of performance in many team sports, such as soccer, where changes in movement patterns are constantly required (Morral-Yepes et al., 2020; Pojskic et al., 2018). Consequently, the ability to respond quickly to a stimulus is paramount for success in soccer (Pojskic et al., 2018; Young et al., 2015). One of the skills that can contribute to the agility performance is motor coordination, since previous investigations has shown that motor coordination plays an important role during CODS performance and thus is an essential component for team-sport performance (Pion et al., 2015; Rommers et al., 2019). Motor coordination is understood as a complex and multidimensional skill, in which the sensory-neuro-muscular systems interact harmoniously to ensure efficient and accurate motor responses in a constantly changing environment (Sommer, 2014). Studies suggest that motor coordination development can lead to improvements in anticipation of opponents'actions, assessment of situation, decision-making, CODS and spatio-temporal coordination (Fernandes et al., 2016; Vänttinen et al., 2010). Given the need to make appropriate postural adjustments after the perception of the stimulus for an efficient application of reactive forces (Sheppard et al., 2014), it can be assumed that motor coordination could contribute to a better agility performance, directly influencing the perceptual-cognitive and physical factors of agility. While a relationship between motor coordination and agility can be reasoned, this relationship needs to be tested experimentally, especially in young athletes who are establishing strong foundations of athleticism during the developmental years (Lloyd & Oliver, 2012).

Another factor that can influence agility performance in youth is maturation, which influences a wide range of cognitive, physical, and neuromuscular developments (Dotan et al., 2012; Dugdale et al., 2020; Lloyd & Oliver, 2014), directly affecting decision-making and motor response processes. Maturation can also cause a decrease in agility performance, as some adolescents may experience a temporary disruption of motor coordination, a phenomenon known as motor awkwardness (Quatman-Yates et al., 2012). However, considering the high level of cognitive and physical demands required during agility performance, it seems to be relevant account for a maturation when examining agility in adolescents, especially because this relationship has not yet been investigated.

Despite the importance of motor coordination for agility, especially during puberty, no study has attempted to investigate the relationship of these two qualities with tests that possess high external validity (Vandorpe et al., 2011; Young et al., 2011). In addition, while some studies have tested the relationship between motor coordination and CODS in young players (Rommers et al., 2019; Vandendriessche et al., 2012), less is known about the relationship between motor coordination and perceptual-cognitive (perception-decision time) and physical (movement response time) factors of agility. Therefore, the present study aimed to determine whether motor coordination could influence on perceptual-cognitive (perception-decision time) and physical factors (movement response time and CODS time) in agility in young soccer players regardless of maturation. We hypothesized that motor coordination would be significantly correlated with perceptual-cognitive (perception-decision time) and physical (movement response time) factors of agility.

Methods

Participants

A *priori* power analysis (GPower V3.0.1, Dusseldorf, Germany) showed that a sample size of 80 would result in statistical power of 0.80 at an alpha level of 0.05 for a correlation of $r = 0.5$. After inviting 102 young male soccer players from five local soccer teams, a final sample of 87 youth (aged 14.2 ± 1.1 years) volunteered to participate in the study. All participants took part in three sessions per week of football training. Written informed consent was obtained from all the players and their guardian/parents after receiving verbal and written information about the procedures, requirements, risks and benefits involved in this study. The Research Ethics Committee of the XXXXXXX approved the study (nº: XXXXXX). The study procedures were conducted in accordance with the latest version of the ethical standards of the Helsinki Declaration.

Design and procedure

The youth soccer players participating in this cross-sectional study performed different assessments, including tests of agility, speed of change of direction (CODS) and motor coordination (KTK). In addition, maturity offset was obtained from anthropometry in order to control for the confounding effects of somatic maturation. All tests were supervised by certified strength and conditioning specialists throughout the study. All participants were previously familiarized with all testing procedures before starting the experimental trials. Each assessment was conducted by a single experienced researcher throughout the study to ensure reliability of the measurements.

Protocols

Anthropometry

Anthropometry was undertaken following ISAK (International Society for the Advancement of Kinanthropometry) guidelines (Norton, 2019). Body mass (kg) was measured barefoot with a digital scale (± 0.1 kg; Welmy, São Paulo, SP, Brazil) and height (cm) was measured using a fixed stadiometer (± 0.1 cm; Sanny brand, São Paulo, Brazil). Sitting height (cm) was measured with a stadiometer (± 0.1 cm; Sanny brand, São Paulo, Brazil) while the participant was seated in an upright position on a wooden bench (a flat box with a height of 50 cm), with leg length calculated as stature minus sitting stature.

Maturation offset

To estimate participant maturity status, anthropometric measurements (height, sitting height, body mass) were entered into an equation to predict maturity offset: $-9.236 + (0.0002708$ x (leg length x sitting height)) – (0.001663 x (age x leg length)) + (0.007216 x (age x sitting height)) + (0.02292 x ((body mass/height) x 100)) (Mirwald et al., 2002). Maturity offset was obtained in years from peak height velocity with a standard error of measurement of 0.59 yrs (Mirwald et al., 2002).

Agility test

Agility performance was measured using an agility test validated by Young et al. (2011) which requires participants to react to the pass performed by a player displayed on a 3 x 3 m projection screen (Figure 1). In the displayed video, a young soccer player dribbles the ball and performs a pass, while changing direction to right or left. Participants were instructed to run forward and react to the player's pass as if they were in a true game situation, moving as fast as possible to the same direction as the ball. The instruction was that the player should attempt to intercept the pass displayed in the video. After the start of the test, participants performed approximately 4 m sprint forward and then changed direction by ~ 45º followed by a 4-m sprint to complete the test. The test started with a sound that automatically trigged the video through a photocell system (Speed Test 6.0 Standard, Cefise, Nova Odessa, SP, Brazil) interfaced with a laptop (Dell Inspiron 14 2620, Dell, Inc., Round Rock, Texas, USA) and a video projector (Epson Powerlite X39, Seiko Epson Corporation, Nagano, Japan). The test finished the instant the participant passed through the left or right photocell located at the finish gate. After test familiarization, each participant performed three trials presented in a random order, with 30 seconds of recovery between trials. The mean of the three trials (in seconds) was used as the test score in accordance with Young et al. (2011). In addition, a high-speed camera (Canon EOS REBEL T5i, Canon Inc., Tokyo, Japan) was placed 5 m behind the testing zone to obtain the video data for each test trial. The video data was in two-dimensional (2D) format and aligned with the trigger of the photocell system. For each trial the following variables were obtained:

Perception-decision time: a perceptual-cognitive factor represented by the time interval between the instant the ball was released by the player in the video to the instant the tested player planted his supporting foot to change direction. The supporting foot refers to the ground contact of the weight-supporting leg when braking to change direction.”

Movement response time: a physical factor represented by the time interval between the instant the tested player planted his supporting foot to change direction to the instant the tested player crossed the finish gate.

Agility time: It encompasses perceptual-cognitive and physical factors represented by the interval the time interval between the instant the ball was released by the player in the video to the instant the tested player crossed the finish gate. The sprint that precedes the stimulus was not included in the agility time because it is a planned action and including the time of this phase will contaminate the true measure of agility (Henry et al., 2011).

Figure 1. Near here

Construction of the video clips used in the agility test

All videos used for the agility test were recorded from a defensive player perspective on a soccer field and had the participation of a soccer player with similar characteristics of the present sample. The athlete was asked to run approximately 6 m towards the camera while dribbling a ball and then simultaneously perform a change of direction and a side pass. This process resulted in six videoclips (three turns to the left and three turns to the right) with minor changes among them. Then, from these 6 videoclips, we calculated the number of possible combinations to form with 3 videos without repetition in each one by using the following equation:

$$^{\mathrm{n}}C_r = \frac{n!}{r!\,(n-r)!}$$

n **-** represents the total number of elements (6 videoclips)

r **-** represents the number of items being chosen at a time (3 videoclips)

! – factorial (all positive integers less or equal to the number preceding the factorial sign)

Through the equation above, it was possible to form 20 combinations of which 2 were discarded, because all videos of these combinations were in the same direction. Thus, 18 combinations remained and one of them was randomly selected at the time of assessment for each subject using an online randomization tool.

To ensure that the evaluated players changed direction before 4 meters from the starting line, a predetermined time between the start of the test and the change of direction stimulus was used. This predetermined time was obtained from a pilot study with a sample similar to the present investigation. It is worth mentioning that an exact point for changing direction was not used to reflect the open skill nature of agility (Young et al., 2011; Young & Rogers, 2014). The videoclips were edited using a video-editing software (Sony Vegas Pro 13.0; Sony Creative Software Inc., Middleton, WI, USA).

Change of direction speed test

To evaluate the change of direction speed (CODS), a test with the same layout as the VRA test was used, and also started with a sound command (Hachana et al., 2013) triggered by a photocell system. Before each trial, participants were told which direction they should turn. Two marker cones were positioned parallel 4 m in front of the start line, separated by 1.50 m to signal that participants could only initiate the change of direction when they had passed through the cones (Figure 2). After familiarization, each participant performed a total of two trials (one to the right, the other to the left, respectively) with a rest period of 30 seconds between each trial. The mean of the two trials (in seconds) was used as CODS time.

Figure 2. Near here

Motor coordination test

Motor coordination was measured using the Körperkoordinationstest für Kinder (KTK) test (Kiphard & Schilling, 2007). This test is a reliable and valid instrument and has previously been used to test motor coordination in youth soccer players (Rommers et al., 2019; Vandendriessche et al., 2012). The KTK test consists of four motor tasks: (a) backward balance: walking backwards on balance beams of decreasing width (6, 4.5, and 3 cm, respectively); (b) one-legged hopping: hopping over a foam obstacle with increasing height in consecutive steps of 5 cm; (c) jumping sideways: 2-legged jumping sideway over a wooden slat for 15 seconds; (d) moving sideways: moving sideways on wooden platforms for 20 seconds. All four motor tasks were performed under standardized conditions according to the procedures described by Vandorpe et al. (2011). The raw scores for each of the four KTK tasks were converted to Z-scores and summed to give the total motor coordination score.

Data analyses

Data are presented as mean ± *sd* and 95% confidence intervals (CIs). Normality and homogeneity of variance were examined using the Kolmogorov–Smirnov and Levene's test, respectively. Test-retest reliability was calculated from 20 randomly selected players that performed two tests one week apart after initial testing. Tests were perfomed at the same time and on the same day of the week. In addition, the number of trials for all evaluations in the retest was the same as the first data collection. The data obtained from the first and second testing sessions were assessed for reliability using intraclass correlation coefficients (ICC, 2-way mixed model) to determine absolute agreement and the typical error of measurement (TE) calculated by dividing the SD of the difference between scores by $\sqrt{2}$.

Pearson correlation coefficients were used initially to evaluate relationships of motor coordination and maturity offset with agility time, perception-decision time, movement response time, and CODS time. Linear regression was used to verify the influence of motor coordination on agility time, perception-decision time, movement response time, and CODS time controlling for maturity offset. For this, we inserted motor coordination as the independent variable and maturity offset as the covariable. Perception-decision time, movement response time, agility time and CODS time were inserted as dependent variables. Multicollinearity between independent variables was tested for using variance inflation factor and tolerance as well as the Durbin-Watson test. Lack of collinearity indicated a weak association between motor coordination and maturity offset. Statistical significance for all tests was set at $p < 0.05$. All statistical analyses were processed using SPSS, v25 (IBM SPSS Statistics Inc., Chicago, IL, USA).

Results

Descriptive statistics for anthropometric characteristics, maturity offset, and performance tests are shown in Table 1. Test-retest reliability analysis revealed that all measures possessed moderate to high ICCs (0.80–0.99) and TE (<5%).

Table 1. Near here

Pearson correlation analysis showed that no significant correlation existed between motor coordination and perception-decision time (r = -0.10, p = 0.34). However, motor coordination had a negative and significant correlation with both movement response time (r = -0.62, p = 0.001) and agility time (r = -0.52, p = 0.001). In addition, motor coordination had a negative and significant correlation with CODS time (r = -0.47, p = 0.001).

Regarding the correlations between maturity offset with motor coordination and the variables of VRA and CODS tests, our results revealed that maturity offset was not significantly correlated with perception-decision time (r = -0.05, p = 0.64) or motor coordination (r = -0.146, p = 0.17). It was also observed that maturity offset had a negative and significant correlation with agility time (r = -0.25, p = 0.01) and movement response time (r = -0.30, p = 0.005). Maturity offset also had a negative and significant correlation with CODS time (r = -0.35, p = 0.001).

Regression analyses are presented in Table 2. Considering the effect of maturation, each increase in motor coordination score resulted in a significant improvement in agility time (β = -0.023 s; p < 0.001), movement response time (β = -0.021s; p < 0.001), and CODS time (β = -0.021s; p < 0.001). In addition, it was also observed that maturity offset was negatively associated with movement response time (β = -0.021 s; p = 0.012) time and CODS (β = -0.038 s; p = 0.002).

Table 2. Near here

Discussion and implications

To our knowledge, this is the first study to investigate the relationship between motor coordination and perceptual-cognitive (perception-decision time), physical (movement response time) factors of agility performance in young soccer players while controling for maturation offset. The results of our study partially confirm our hypothesis, demonstrating a significant correlation between motor coordination and the physical factor of agility measured as movement response time. Because no significant correlation was found between motor coordination and cognitive factor of agility measured as perception-decision time. The results of this study also demonstrated a significant correlation between motor coordination with agility time and CODS time. Furthermore, it is important to highlight that these findings were not significantly altered by maturity offset.

Because motor coordination is responsible for the interaction between sensory-neuro-muscular systems (Sommer, 2014), it was reasoned that motor coordination would be associated with agility in youth (Fernandes et al., 2016; Sheppard & Young, 2006; Vänttinen et al., 2010). The current findings corroborate this theoretical reasoning, since this is the first study to demonstrate experimentally that motor coordination is associated with agility in youth. In addition, we further added to the literature by providing insight into how motor coordination is related to the different factors of agility, rather than just agility per se. However, direct comparisons of our results with other studies were not possible due to the lack of experimental studies regarding the relationship between motor coordination and agility.

Perception-decision time was the agility factor that did not correlate with motor coordination ($r = -0.10$, $p = 0.34$). This may be due to the fact that Perception-decision time are predominantly influenced by the sensory and neural systems, with little involvement of the motor system (Arnold et al., 2012). However, considering that perception-decision time was measured indirectly by quantifying the time between the presentation of the stimulus and the ground contact of the weight-supporting leg when braking to change direction, it can be argued that even during this time interval there may be an involvement of the motor system through a preparatory muscle pre-activation, whose level of motor pre-activation appears to depend on the ability to rapidly identify advanced kinematic cues (Spiteri et al., 2015). This is supported by Spiteri et al. (2015) who observed using a multidirectional reactive agility test together with electromyography, that adult elite basketball players who reacted and made decisions more quickly to a stimulus had a greater degree of muscle pre-activation, which requires high levels of motor coordination. Therefore, it could be inferred that participants of this study were not able to take advantage of the muscle pre-activation capacity and consequently motor coordination during the perception-decision phase because they were young adolescents, however, this notion requires further investigation.

The movement response time showed a negative and significant correlation ($r = -0.62$, $p = 0.001$) with motor coordination. A possible explanation is that immediately after decision making a series of postural adjustments take place, which requires a high degree of motor coordination to synchronize the sensory-neuro-muscular systems (Spiteri et al., 2015; Trecroci et al., 2015). These postural adjustments allow an effective application of reactive force that depends on appropriate inter and intramuscular coordination, which enables efficient transition from eccentric to concentric muscle actions in order to perform efficient propulsion and lateral acceleration (Young & Farrow, 2006). The present investigation is the first to experimentally demonstrate that in fact motor coordination explains a significant amount of the variance in movement response time.

Although the CODS test is pre-planned and of low complexity, which could lead to a reduced demand on motor coordination (Trecroci et al., 2015), a a negative and significant association (r = -0.47, p = 0.001) between motor coordination and CODS time was found. This result was similar to that found in the correlation between motor coordination and agility time (r = -0.52, p = 0.001). These results highlight the importance of motor coordination for both CODS and agility performance.

An important decision in this study was to control for the effect of maturation, since maturation is considered a confounding factor that can directly influence physical performance (Vandendriessche et al., 2012), and thus could generate inappropriate interpretations of the data. Regression analyses showed that motor coordination significantly influenced movement response time, agility time and CODS regardless of maturity offset. Although maturation has a high relationship with conditioning capacities, the motor learning and performance of these capacities also depends on the joint action of coordination skills with sensory, perceptual and conditioning capacities (Šimonek, 2014). This notion was corroborated by our experimental results, since maturation along with motor coordination significantly explained movement response time and CODS. These two variables seem to depend significantly on physical aspects (e.g. strength and power) when compared to the other variables tested (Sheppard & Young, 2006). In other words, although maturity-related adaptations promote improvements in physical performance, especially in tasks that require bursts of strength, power and speed (Eisenmann et al., 2020), the transfer effect of such adaptations will depend significantly on motor coordination skill of the individual (Šimonek, 2014).

Since some adolescents may experience a temporary disruption of motor coordination due to rapid body growth, which can temporarily impair physical performance (Quatman-Yates et al., 2012), it is worth highlighting the importance of developing and refining motor coordination at all stages of development. Increases in motor coordination would lead to improvements in athletic qualities, where small gains are worth noting, especially in the sporting environment. This notion is supported by our results as well as previous studies (Freitas et al., 2016; Vandendriessche et al., 2012). For example, motor coordination is independent of maturity status, thus motor coordination is not solely driven by natural development in youth, but also requires developmentally appropriate training.

Our results should be interpreted considering some limitations. For instance, we aimed to investigate the associations between motor coordination controlling for maturation off-set. As a result, our statistical models with two independent variables present a low explanatory power. Futures studies are needed to comprehensively address agility in adolescents using more robust statistical methods including several constructs as predictors as previously suggested (Hojka et al., 2016). Another limitation was the lack of control of the distance covered between the starting line and the moment of decision-making during the agility test. This lack of control may have led to faster athletes to present a lower movement response time. Such limitation was minimized in a pilot study in which we measured the time before stimuli presentation in a sample of similar adolescents.

Despite these limitations, this study presents important contributions to the literature. For example, one important novelty of our study was to include motor coordination in adolescents as a predictor of agility which has not been done in previous study (Hojka et al., 2016). As a result, coaches and sports scientists should seek to include activities that aim to develop motor coordination in addition to traditional soccer training, to promote improvements in agility performance. Given the age of the sample was around 14 years, revisiting and refining motor coordination around the time of the growth spurt seems a sensible approach, due to potential disruption caused by adolescent awkwardness.

Conclusion

In conclusion, our study indicated that motor coordination significantly influenced in the technical and physical factors of agility measured as movement response time, CODS time regardless of maturation, demonstrating that a better post-stimulus motor adjustment results in faster and more accurate agility performance in young soccer players.

Conflicts of interest

The authors report no conflicts of interest

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Figure 1.

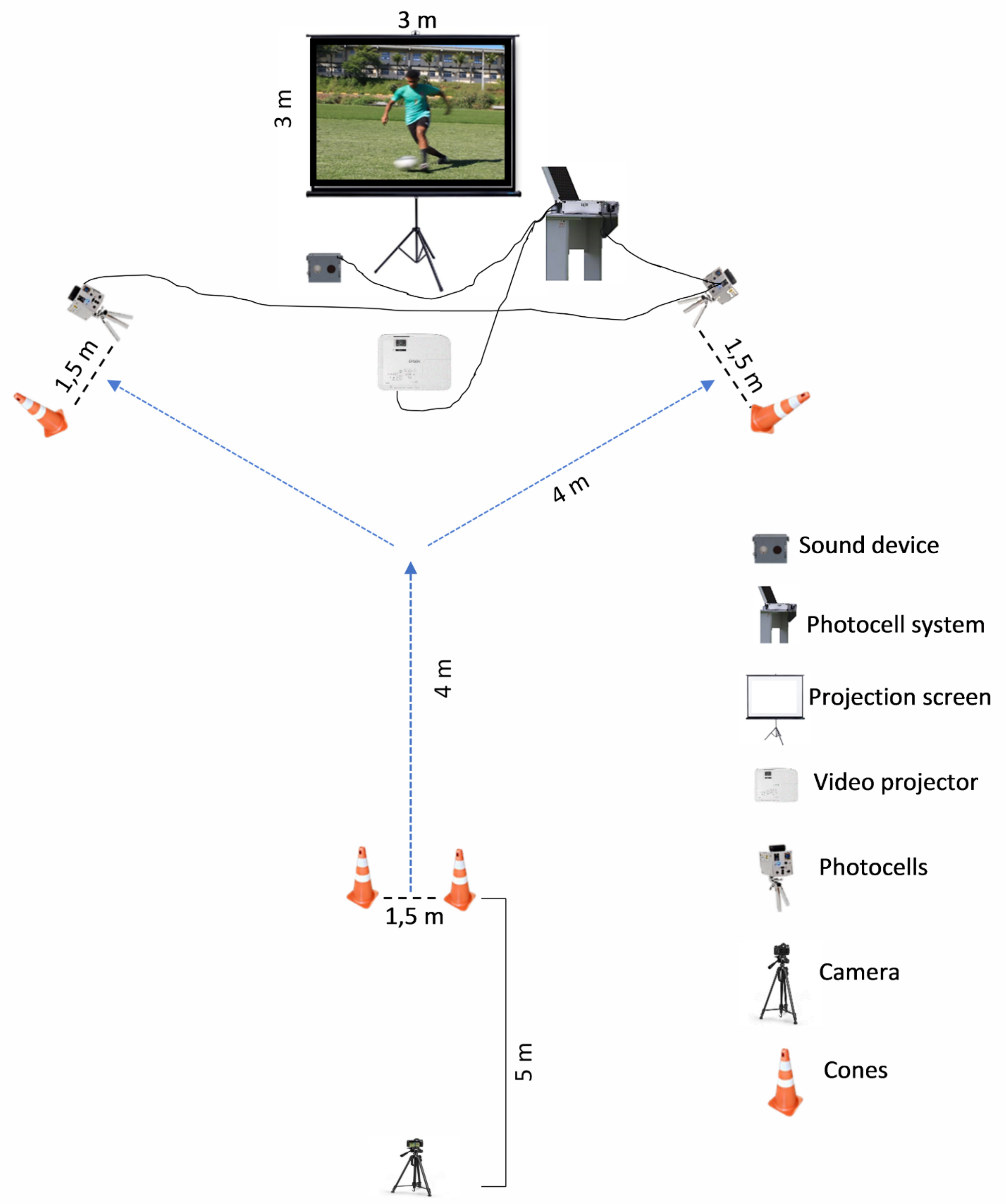

Figure 1. Schematic illustration of the agility test.

Figure 2.

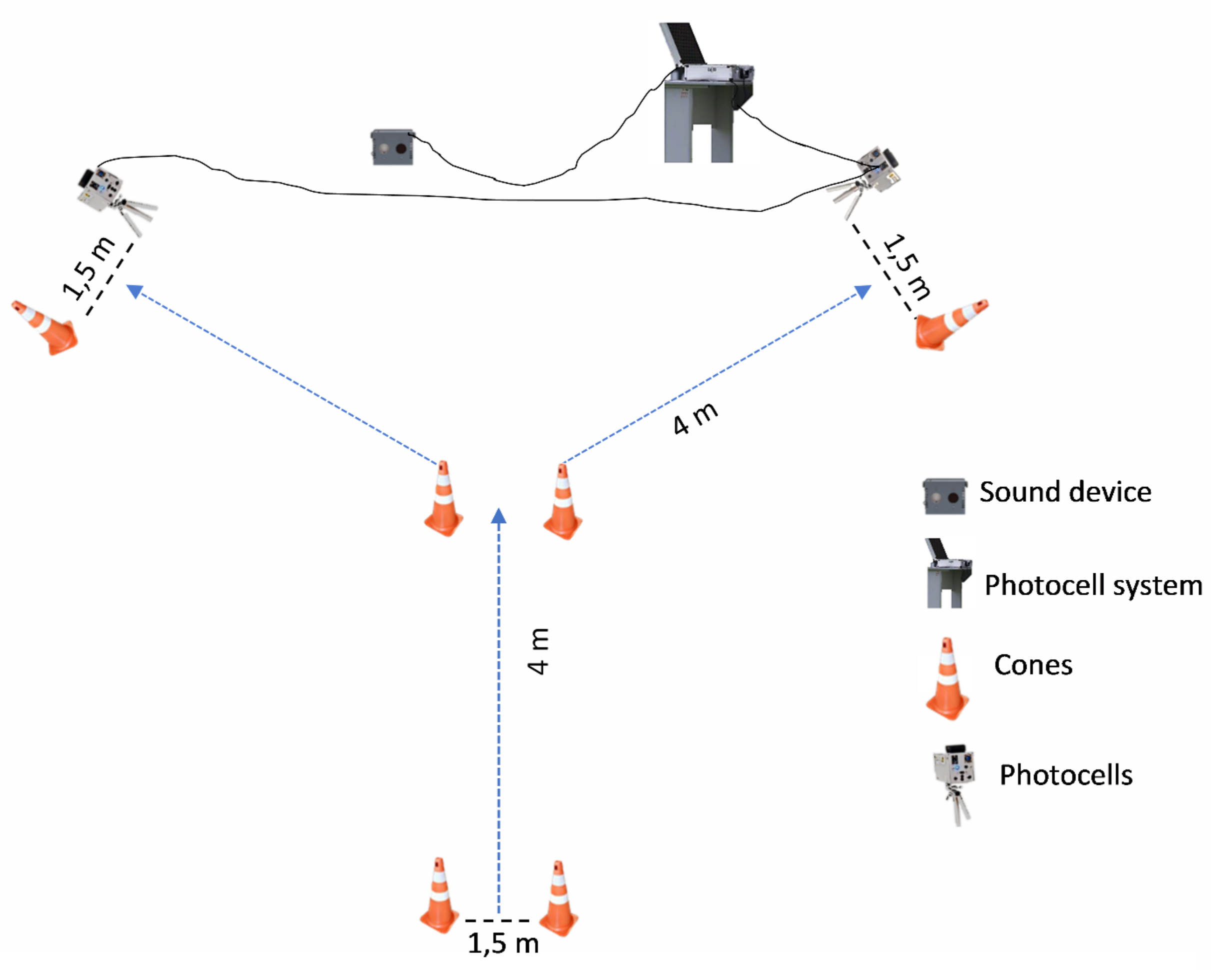

Figure 2. Schematic illustration of the change of direction speed test (CODS) test.

Table 1. Mean, standard deviation and confidence interval of anthropometric measurements, maturity offset, raw scores of the four KTK-tasks, and the variables of the change of direction speed (CODS) and agility tests.

Variables	*Mean (± SD)*	*CI 95%*
Characteristic of players		
Age (y)	14.17 (± 1.1)	(13.93 – 14.4)
Body mass (Kg)	55.8 (± 9.6)	(53.7 – 57.8)
Height (cm)	164.3 (± 9.2)	(162.3 – 166.3)
Sitting height (cm)	84.4 (± 5.7)	(83.2 – 85.6)
Maturity offset (years from PHV)		
Pre-PHV (n = 27)	-1,25 (± 0.58)	(-1.49 – -1.02)
PHV (n = 21)	-0,69 (± 0.28)	(-0.20 – 0.06)
Post-PHV (n = 39)	1,18 (± 0.42)	(1.04 – 1.32)
Performance tests		
KTK tasks (raw scores)		
Backward balance	55.47 (± 12.41)	(52.85 – 58.12)
One-legged hopping	66.24 (± 14.73)	(63.10 – 69.38)
Jumping sideways	65.91 (± 19.48)	(61.75 – 70.06)
Moving sideways	73.22 (± 15.30)	(69.96 – 76.48)
CODS test		
CODS time (s)	2.371 (± 0.149)	(2.339 – 2.403)
Agility test		
Perception-decision time (s)	0.177 (± 0.71)	(0.162 – 0.192)
Movement response time (s)	1.053 (± 0.105)	(1.030 – 1.075)
Agility time (s)	1.231 (± 0.139)	(1.201 – 1.260)

$CI_{95\%}$: 95% confidence interval. SD: standard deviation. PHV: Peak height velocity

Table 2. Coefficients of determination (R^2), percentage change of the R^2 (ΔR^2), unstandardized (b) and standardized coefficients (β) and p-value obtained from the linear regression model in relation to the variables of change of direction speed (CODS) and agility tests adjusted for motor coordination score and maturity offset.

Variable	**Predictor**	**R^2**	**ΔR^2**	***b***	**β**	***p***
Agility time (s)	Motor coordination Maturity Offset	0.306	0.031	-0.023 -0.022	-498 -180	*0.000* 0.057
Perception-decision time (s)	Motor coordination Maturity Offset	0.012	0.002	-0.002 -0.002	-0.097 -0.036	0.380 0.742
Movement response time (s)	Motor coordination Maturity Offset	0.430	0.045	-0.021 -0.020	-0.589 -0.214	*0.000* *0.012*
CODS time (s)	Motor coordination Maturity Offset	0.308	0.086	-0.021 -0.038	-0.428 -0.296	*0.000* *0.002*