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Differential Influence of General Anthropometric and Motor Predictors on Pre-planned Agility in Pubescent Boys and Girls: A Multiple Regression Study

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Abstract

In this study, we investigated the influence of balance, jumping power, and speed as well as morphological variables for three different agility tests in early pubescent boys (n=73) and girls (n=63). The predictors included body height and mass, body fat, high jumps, the overall stability index, ankle mobility, and a 10 and a 15 m sprint. The statistical analysis included calculations of correlations, regression models for the correlated variables, and the validation of the regression models. The calculated regression models for the male group explained 38% of the variance in a Zig-Zag test, 12% in a 20-yard test (20Y), and 81% in a T-test. The significant regression model for the Zig-Zag test included body mass, high jumps, and a 10 m sprint. The 20Y test had no predictors in the male group. For the T-test, the only predictor was the 10 m sprint. The calculated regression models for the female group explained 57% of the variance in the Zig-Zag test, 32% in the 20Y test, and 42% in the T-test. The significant regression model in the female group included only the 10 m sprint for all three agility criteria. The regression models were cross-validated using the second half of the sample (boys: n=36; girls: n=31). The correlation between the predicted and the achieved scores provided a statistically significant validation for all agility tests.

Keywords: *morphology, change of direction, motor abilities, children, mobility*

Introduction

Agility is defined as the ability to undertake a fast and effective change of movement direction and speed (Sekulic et al., 2013). It consists of an explosive movement start, acceleration, deceleration, a change of direction, and the restoration of fast movement whilst maintaining a dynamic balance (Sheppard & Young, 2006). Current research shows that agility has two different forms: pre-planned and non-planned (Young et al., 2015). Pre-planned agility does not include a response to external unpredictable stimuli whereas non-planned does (Farrow et al., 2005). Both agility types occur in the majority of sporting activities. In more complex activities such as team sport games, non-planned agility is of greater importance for a successful performance (Young & Willey, 2010).

As in the adult athlete population, agility is significantly present in the physical activities of children. The majority of unstructured games and structured sports games of children abound with fast and reactive short runs, various jumps, and hops. The development of agility is influenced by biological maturation; certain phases of child development are more sensitive than others. According to Balyi & Hamilton (2004), the best age for developing agility is between the 9th and 12th year. In the study of Demirhan et al. (2017), the authors reported that agility develops rapidly until puberty and that three years after this period, agility performance decreases.

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After a period of rapid development, agility increases once more until maturity (Demirhan et al., 2017).

Due to its complexity, agility depends on motor abilities such as speed, power, coordination, or balance, but also on several anthropometric characteristics. However, a literature review shows inconsistent findings. In study of Little and Williams (2005), the authors concluded that acceleration, maximum speed, and agility were specific qualities that were relatively unrelated to one another. Similar findings were reported by Marković (2007), where the author found a poor relationship between strength and power qualities and agility performance. Conversely, Negra et al. (2017) concluded that agility performance, speed time, and jumping ability could represent the same motor abilities in competitive-level young male team sport athletes. Similarly, in the study of Barnes et al. (2007), the authors found that individuals with a greater countermovement performance also had quicker agility times, indicating that training predominantly in the vertical domain may also yield improvements in agility performance.

Following on from the above-mentioned studies, it is also important to identify the factors that influence agility performance in children. Such information could help strength and conditioning experts as well as physical education teachers to design training plans with greater efficiency for the agility development of children. Hence, the main goal of this research was to assess if speed, power, mobility, and balance as well as several anthropometric measures could be predictors of agility performance in early pubescent boys and girls. It was expected that the selected predictors would independently explain the variance in the agility criteria.

Methods

Participants

Boys (n=73) and girls (n=63) aged 12 to 13 years were recruited for this study from several schools in the same city. The average height was 170.93±8.47 for boys and 166.36±5.78 for girls (mean±SD). The average body mass was 62.49±15.21 kg for boys and 56.23±9.90 kg for girls. The testing was performed as part of the initial screening at the beginning of their sportive seasons. All participants were in good health based on an initial medical screening. Two had suffered recent musculoskeletal disorders (i.e., injury and pain prevalence) and were not included in the investigation. The participants were required to answer a questionnaire that was designed to assess the type of sports in which they had previously engaged. If participants played in agility-saturated sports, they were not included in the study (n=17). Only the participants who were not previously involved in sports or those who were involved in sports where agility was not systematically trained (e.g., swimming, track and field, and rowing) were included in this investigation (n=71). The total sample of participants was randomly divided into validation (boys: n=36; girls: n=31) and cross-validation (boys: n=37; girls: n=32) subsamples. The Ethical Board of the University of Split, Faculty of Kinesiology, Split, Croatia, provided written approval to proceed with the investigation. The participants were informed of the purpose of the study and their parents provided written consent.

Measures and Procedures

The anthropometric variables that were analysed in this study were body height, body mass, and body fat. Additional tests included an explosive power test (high jump), a balance test measurement of the overall stability index, and a 10 and a 15 m sprint test to measure running speed and ankle mobility. As different sports require different types of agility, three different agility tests were conducted: a T-shaped course test, a Zig-Zag test, and a 20Y shuttle test (Spasic et al., 2015; Sisic et al., 2015).

Body height and mass were assessed using a Seca Instruments stadiometer and a weighing scale (Hamburg, Germany). Body fat was measured using a Tanita BC-418 segmental body composition analyser (Tanita Corp., Tokyo, Japan), which provides a print-out of the calculated body fat (Pietrobelli et al., 2004). The subjects stood with bare feet on the metal sole plates of the machine. Agility and running speed were measured using a Brower timing system (Salt Lake City, UT, USA). The high jump was measured using an Optojump system, a dual-beam optical device that measures ground contact and flight time during a jump or series of jumps (Microgate, Bolzano, Italy; Schiltz et al., 2009). Balance was measured using a Biodex Balance System (Shirley, NY, USA).

For the T-shaped course test, 4 cones of 30 cm were arranged at the points of the required directional changes. When the test began, the participants were required to sprint forward along Course A (9.14 m) until they could touch the tip of the first cone with their right hand. They then side-shuffled leftward along Course B (4.75 m) until touching the tip of the second cone with their left hand. Next, they side-shuffled rightward along Course C (9.5 m) until touching the tip of the third cone with their right hand. They then side-shuffled leftward along Course D (4.75 m) until touching the tip of the fourth cone with their left hand. Finally, they back-pedalled over Course E (9.14 m) until reaching the finishing point (which was the original starting point). The trials were deemed unsuccessful if the participant failed to touch a designated cone, crossed their legs whilst shuffling, or failed to face forward at all times.

The Zig-Zag agility test consisted of maximal running throughout a 4×5 m zig-zag course. The timing began on a sound signal and stopped when the participant passed through a timing gate.

For the 20Y shuttle test, the examinee started with a three-point stance and ran along Course A (5 yd, 4.57 m), Course B (10 yd, 9.14 m), and finally along Course C (5 yd, 4.57 m). The countermovement jump test began with the participant standing in an upright position. A fast downward movement to approximately a 90° knee flexion was immediately followed by a quick upward vertical movement as high as possible, all in one sequence. The test was performed without an arm swing as the hands remained on the hips.

The overall stability index presents the average tilt in degrees from the centre of a platform. The higher the numerical value of the index, the greater the variability from the horizontal positioning; i.e., the greater the instability whilst balancing on the platform. The stability testing was performed without footwear. The participants established a foot position with a comfortable stance width that allowed them to maintain the most stable (horizontally levelled) position possible on the platform. The positioning of the feet was recorded and marked with tape using coordinates on the grid of the platform to ensure that the stance was consistent during the trials. The participants were required to maintain an upright posture whilst keeping the arms to the sides and looking straight ahead at the Biodex LCD monitor, which was approximately 0.3 m away. One practice trial was allowed before the three test trials. Each testing trial lasted 20 s. The resistance level was set at number 9 on a scale with anchors of 1 (least stable) and 12 (most stable).

For the 10 m sprint, the start-line position was placed 1 m before the first timing gate. The timing was only triggered when the infrared beams were disrupted. A second electronic timing gate was positioned 11 m from the start line. The participants were instructed to begin with their preferred foot forward placed on a line marked on the floor and to run as quickly as possible along the 11 m distance. The times were recorded in hundredths of seconds. The same procedure was conducted for the 15 m sprint, with timing gates positioned 1 and 16 m from the start line (Duthie et al., 2006).

All of the tests were performed indoors on a wooden gymnasium floor. Before testing, the participants completed a 15 min warm-up, which included jogging, lateral displacement drills, dynamic stretching, and light jumping. The sequence of testing was the same for all the participants. The first day of data collection consisted of an anthropometric assessment and power and speed measurements. During the second day, the participants performed the balance test and the three agility tests. During the course of the testing, the participants were asked to maintain their normal diet. To account for a diurnal variation in fitness abilities, all of the tests were performed at the same time of the day (9 to 11 a.m.) from April to June. Before the data collection began, the participants were familiarized with the testing procedures and allowed one practice trial of each test at a slow tempo. The participants performed three trials of each test with 3–4 min rest between the trials except for the balance tests, where 1 min of rest was allowed between the trials. In the case of evident fatigue, a longer rest period was allowed. The participants performed the tests wearing their choice of running shoes (excluding the balance testing, which was completed with bare feet). For tests automatically measured by the Brower timing system, Optojump, and the Biodex balance system, the same examiner assessed all participants.

Statistical Analyses

The statistical analyses included the calculation of the descriptive statistical parameters (means and standard deviations) and the calculation of the Pearson correlation to assess the associations between the variables. The results of the correlation analysis determined the pick of the variables for the multiple regression analysis; only significantly correlated variables were included. All other variables were excluded from the regression analysis. The predictors that were included in the regression analysis were the body height, vertical jump, and 10 m sprint. The successful regression models were then applied to the cross-validation group. The regressions were cross-validated by Bland–Altman plots of the average between the calculated and the achieved scores (abscise) and the differences between the achieved and the calculated scores (ordinate). For all the analyses, Statistica 14.0 (TIBCO Software Inc, USA) was used, and a p-level of 95% was applied.

Results

Significant linear correlations were found between the vertical jump height (VJH) and the 10 m sprint (S10m) as motor predictors and agility criteria (Table 2).

Table 1. Descriptive statistic results

Variables	M	F
	Mean ± SD	**Mean ± SD**
BH	170.93 ± 8.47	166.36 ± 5.78
BM	62.49 ± 15.21	56.23 ± 9.90
BFat	20.63 ± 8.20	24.24 ± 7.32
VJH	26.16 ± 7.22	22.09 ± 4.17
S10m	1.42 ± 0.59	1.70 ± 0.34
S15m	2.42 ± 1.00	2.91 ± 0.57
LOS	34.57 ± 10.33	35.52 ± 11.36
TTest	12.15 ± 1.21	12.65 ± 0.99
ZigZag	6.37 ± 0.55	7.02 ± 0.56
20Y	5.87 ± 0.53	6.30 ± 0.47
ADD	33.84 ± 14.63	38.97 ± 7.79
ABD	36.52 ± 15.91	42.10 ± 8.36
DFlex	21.70 ± 10.16	27.41 ± 7.43
PFlex	36.38 ± 15.67	44.03 ± 8.52

Legend: BH - body height; BM - body mass; BFat - body fatt; VJH - vertical jump height; S10m - sprint 10m; S15m - sprint 15m; LOS - balance test; TTest - T course agility test; ZigZag - zig zag agility test; 20Y - 20 yards agility shuttle test; ADD - ankle adduction; ABD - ankle abduction; DFlex - dorsiflexion; PFlex - plantarflexion

Body mass (BM) and body fat (BFat) as morphological predictors also showed significant correlations with the agility tests. Body height showed no significant correlations with the agility criteria in both groups. The balance test (LOS) only correlated with the 20Y agility test in the male group. The ankle mobility tests showed no correlations with the agility criteria in the male group, but ankle adduction (ADD) and ankle abduction (ABD) showed significant correlations with the ZigZag agility test in the female group (Table 2).

The calculated regression models for the male group ex-

Table 2. Pearson correlation between studied variables

Predictors	M			F		
	Zig-Zag	**20Y**	**T-test**	**Zig-Zag**	**20Y**	**T-test**
BH	0.17	-0.07	-0.01	0.10	-0.02	0.00
BM	0.37*	0.21	0.28*	0.38*	0.27*	0.40*
BFat	0.28*	0.27*	0.33*	0.31*	0.51*	0.51*
VJH	-0.37*	-0.51*	-0.47*	-0.33*	-0.47*	-0.47*
S10m	0.55*	0.79*	0.81*	0.40*	0.54*	0.37*
LOS	-0.21	-0.26*	-0.25	0.01	-0.15	-0.10
ADD	0.02	-0.10	-0.08	0.27*	0.04	0.08
ABD	0.08	-0.01	-0.06	0.27*	-0.07	-0.06
DFlex	0.02	-0.16	-0.15	0.26	0.05	0.04
PFlex	0.05	0.03	-0.00	-0.01	-0.13	-0.15

Legend: BH - body height; BM - body mass; BFat - body fatt; VJH - vertical jump height; S10m - sprint 10m; S15m - sprint 15m; LOS - balance test; TTest - T course agility test; ZigZag - zig zag agility test; 20Y - 20 yards agility shuttle test; ADD - ankle adduction; ABD - ankle abduction; DFlex - dorsiflexion; PFlex - plantarflexion

plained 38% of the variance in the Zig-Zag test, 12% in the 20Y test, and 81% in the T-test (Table 3). The significant regression model for the Zig-Zag test included the body mass (BM), high jump (VJH), and 10 m sprint (S10m). The 20Y test had no predictors in the male group. For the T-test, the only predictor was the 10 m sprint (S10m).

Table 3. Regression summary for dependent variables for male participants

Predictor Zig-Zag	Beta	SE (beta)	b	SE (b)	t	p
Intercept			1.58	0.88	1.79	0.08
BH	0.32	0.12	0.02	0.01	2.64	0.01
VJH	0.38	0.10	0.08	0.02	3.74	0.00
S10m	0.32	0.11	0.84	0.29	2.89	0.01
R= .64; R2= .38; F=4.68; p=.00; SE=1.22						
Predictor 20Y	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			5.88	0.67	8.83	0.00
R= .34; R2= .12; F=2.35; p=.06; SE=.83						
Predictor T-test	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			5.88	0.67	8.83	0.00
S10m	0.92	0.06	7.30	0.47	15.42	0.00
R= .91; R2= .81; F=82.96; p=.00; SE=1.97						

Legend: BH - body height; VJH - vertical jump height; S10m - sprint 10m

The calculated regression models for the female group explained 57% of the variance in the Zig-Zag test, 32% in the 20Y test, and 42% in the T-test (Table 4). The only significant regression model in the female group was the 10 m sprint (S10m) for all three agility criteria.

The correlations between the obtained regression models

Table 4. Regression Summary for dependent variables for female participants

Predictor Zig-Zag	Beta	SE (beta)	b	SE (b)	t	p
Intercept			0.16	1.21	0.1	0.90
S10m	0.76	0.10	3.54	0.46	7.8	0.00
R= .78; R2= .57; F=15.02; p=.00; SE=1.04						
Predictor 20Y	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			2.23	1.11	2.00	0.05
S10m	0.43	0.11	1.52	0.40	3.79	0.00
R= .61; R2= .32; F=8.62; p=.00; SE=.98						
Predictor T-test	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			0.49	2.35	0.21	0.83
S10m	0.71	0.10	6.00	0.85	7.05	0.00
R= .71; R2= .47; F=15.20; p=.00; SE=2.08						

Legend: S10m - sprint 10m

and the achieved test results are shown in Tables 5 and 6. The regression models were confirmed because all the correlations were significant in both groups. In the male group, the highest correlation between the achieved and the predicted test results was noticed for the T-test (0.85) and the lowest was for the 20Y test (0.44). Similar to the male group, in the female group, the highest correlation between the achieved and the predicted test results was noticed for the T-test (0.71) and the lowest was for the 20Y test (0.61).

Bland–Altman plots were presented for all three agility tests. The plots showed that almost all cross-validation scores were positioned within the 95% CIs in the agility score differences (the observed minus the predicted scores). The biggest diversity was noticed in the Zig-Zag test for the female group.

Table 5. Comparisons between calculated and achieved scores for female and male students

Predictor	Female		r	Male		r
	Achieved	Predicted		Achieved	Predicted	
T-test	12.65±0.99	12.37±2.09	0.71*	12.15±1.21	10.55±4.28	0.85*
Zig-Zag	7.02±0.56	5.56±0.40	0.70*	6.37±0.55	5.82±0.95	0.82*
20Y	6.30±0.47	6.16±0.72	0.61*	5.87±0.53	5.54±0.28	0.44*

Legend: TTest - T course agility test; ZigZag - zig zag agility test; 20Y - 20 yards agility shuttle test

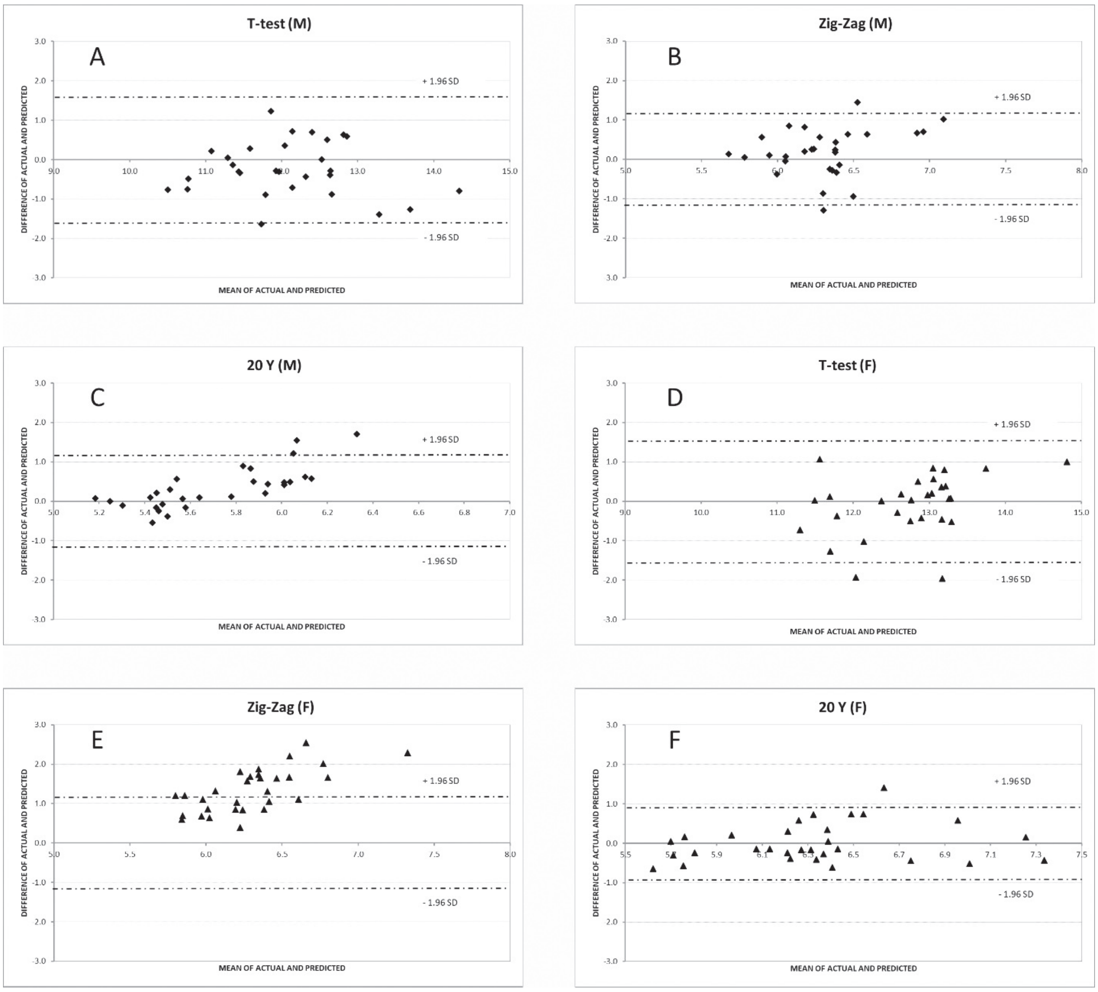

FIGURE 1. Bland-Altman plot for the calculated and achieved scores on the T-test. Zig-Zag and 20Y test for the cross-validation sample.

Discussion

This study had two major findings: (1) the 10 m sprint was found to be the most important predictor of agility performance; and (2) the body height and vertical jump were found to be predictors of the Zig-Zag agility test in the male group.

A literature review showed that BH can be an advantage as well as a disadvantage whilst performing agility tasks. According to Mathisen and Pettersen (2015), agility is significantly correlated with body height at the age of 13–14 years, but not in pre- and post-peak height velocity groups. Our cohort was in the stage of development where BH has the fastest growth and can disturb coordinative skills; thus, a negative influence on agility performance was expected (Philippaerts et al., 2006). Nevertheless, we found no negative correlations with agility performance. The negative influence of body mass and body fat on agility is well-recorded in the literature, especially in agility-untrained cohorts such as ours (Dhapola & Verma, 2017).

Despite the importance of balance in agility movements, we found this only in one test in the male group (Sekulic et al., 2013; Acar & Eler, 2019; Cengizhan et al., 2019). The reasons for this could be found in the structure of the balance test used in our study. The LOS is a test that assesses dynamic balance in a stationary position. Conversely, in agility tests subjects have to maintain their balance through constant and fast movements. A lack of strong correlations between the specific measures of static and dynamic balance and agility was also reported by Sibenaller et al. (2010). Balance has a specific appearance during agility performance. This was proven in the study of Stirling, Eke & Cain (2018), where the authors reported that athletes with a higher agility score also had a higher balance score whilst undertaking an agility course and wearing inertial measurement units on their body. Hence, regression modelling should include more specific or surrogate agility balance tests. This was not the case in our study.

Girls had greater mobility in all ankle mobility tests. This could be connected to a lower muscle mass and muscle tone in girls compared with boys of an early puberty age (Round et al., 1999). We speculated that the weaker muscles in girls produced a less stable ankle. As the ankle is one of the most engaged joints in agility movements, its instability or over-mobility can negatively influence agility performance. This was our prediction for the female group. This type of correlation was noticed in the Zig-Zag test for the female group.

As reported in the Results section, the 10 m sprint was the variable that predicted agility performance in almost all agility tests. However, other criteria oscillated among the regression models of the tests for the different genders. Specifically, the regression model for the Zig-Zag test in the boys included BH, VJH, and S10m whereas in the girls, the Zig-Zag agility was predicted only with S10m. As presented in the Bland–Altman plots, the predicted scores for the girls in the Zig-Zag test were poorer than the achieved scores (Figure 1). As the Zig-Zag test was complex and had many "stop-and-go" manoeuvres, cuts, changes of movement direction, accelerations, and decelerations, it was reasonable to expect that its prediction would be associated with other anthropological criteria (Sisic et al., 2015; Begu et al., 2018). This was not the case for the female group. Although we could only speculate why the regression model for the Zig-Zag test for the girls did not include other variables, it was clear that Zig-Zag agility performance was influenced by characteristics and abilities other than those studied (e.g., stride length, reactive speed, and leg and foot dimensions). Similarly, the regression model for 20Y in the male group did not exclude any predictor of agility performance. This finding should be considered taking into account the movement demands during the 20Y performance and the predictors used in this study. This was the only test that had a 180° turn and in which the eccentric strength of the lower extremities was extremely important during the deceleration phase (Hewit et al., 2011; Graham-Smith et al., 2018;). As no eccentric strength variables were used in this study, a lack of predictors for 20Y agility performance was expected. The findings from the T-test regression modelling were the opposite. Although the T-test had significant lateral movement demands (in total, 20 m of lateral movement) and a change of direction during the lateral movements, the only predictor in both groups was S10m, which was more characteristic of forward movement patterns. The T-test performance also consisted of 10 m forward running; the regression modelling did not incorporate any variables connected to lateral movements (such as leg length, lateral jump power, full-body coordination, and adduction and abduction muscle strength). Hence, S10m was our logical predictor of T-test agility performance in early puberty-age children.

Conclusion

The calculated linear correlations agreed with the findings of our research conducted on early puberty-age children. All three agility tests had valid regression models for both genders. From all the anthropological variables used in the regression modelling, speed was found to be the most important predictor of agility performance. Body measures, balance, power, and mobility tests used in the study were not reliable predictors of agility performance in early puberty. A major limitation of this study was the lack of inclusion of other abilities that could significantly contribute to a prediction model of agility performance in early pubescent boys and girls; e.g., cognitive qualities, coordination, reactive speed, and flexibility. In future studies, regression modelling should include more specific and/or surrogate tests that are similar to agility test movement demands. The results of this study indicate that agility is a complex ability. Accordingly, agility research, assessment, and training should be extensive in early puberty-age children.

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Conflicts of interest
The authors declare that there are no conflicts of interest.

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