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SPEED AGILITY TRENDS IN CHILDREN ACCORDING TO GROWTH

Matteo Giuriato, Roberto Codella, Nicola Lovecchio, Vittoria Carnevale Pellino, Matteo Vandoni & Alan M. Nevill

ABSTRACT

Background: Speed-agility is considered as the whole assessment of speed of movement, agility and coordination. The 10x4m test has been broadly used to evaluate physical fitness and overall health in children of developmental ages. A myriad of studies have investigated the ecology of speed-agility (SA). However, body dimensions are rarely appraised, and this is a weakness because body shapes are affected by growth.

Aim: This study aimed at modeling SA-specific allometric equations, developing an approach objectively predictive for performance while controlling for maturity through age at peak height velocity (agePHV).

Subjects and methods: A total of 7317 (3627 girls) children aged 8–11 years were SA-tested. Multiplicative models with allometric body-size components, agePHV, and categorical differences, were implemented to evaluate SA performance.

Results: Model 1 accounted for body-size and shape only, whereas Model 2 included agePHV and Model 3 considered standing broad jump (SBJ) as a surrogate marker for explosive strength. An ectomorphic dominance was revealed across all the models.

Conclusion: The explosive strength resulted in influencing SA per height-to-weight ratio. Further, positive exponent of agePHV suggested that the late maturers were likely to show better SA performances. Predictive equations modeled on developmental factors are fundamental to scrutinise performances as valuable health and fitness outcomes in childhood.

Keywords: allometry, 4 × 10-m shuttle run test, children coordination, growth, speed-agility

Introduction

Physical fitness is a major health factor in children (Ortega et al. 2015a; Ruiz et al. 2011), and it is positively associated with present and future health-related outcomes such as risk for obesity, cardiovascular disease, skeletal health and mental health (Castro-Piñero et al. 2010; Ortega et al., 2008). Cardiorespiratory endurance and muscular strength are often referred to as health-related fitness and are usually associated with disease prevention and health promotion (Howley 2001). Conversely, balance, coordination, speed-agility (SA) are described as markers of physical fitness associated with enhanced performance in sports and motor skills (Howley, 2001). In particular, speed relates to the ability to perform a movement within a short period; agility relates to the ability to rapidly and accurately change the position/direction of the entire body in response to a stimulus. Balance regards the maintenance of equilibrium while stationary or moving (Haga 2008; Lubans et al. 2010).

In this framework, the physical fitness field test has become a useful and ecological tool to enforce health surveillance and monitor one's fitness status and behaviour. (Ortega et al. 2015b; Giuriato et al. 2019)

In particular, the assessment of SA performance is strongly coupled to health (especially bone health) in young people (Ortega et al. 2008) and contributes to improve individual motor skills competence (Schmidt & Lee, 2005; Palou et al., 2019). Several studies claimed the reliability and validity of the 4x10 m shuttle-run test to measure SA in childhood using sponges to improve coordination (Ortega, et al. 2008; Ortega et al. 2015b; Sheppard & Young, 2006). The nervous system develops considerably in children from eight to ten (Malina & Bouchard, 1994), especially via an exercise-elicited cascade of neurological changes in the hippocampus, enhancing memory consolidation and skilled actions. In particular, short-term physical activity bouts selectively improve children's cognitive performance such as speed and accuracy (Donnelly et al. 2016).

For this reason, several youth fitness batteries (Castro-Piñero et al. 2010; Ortega, Artero, et al. 2008; Ruiz et al. 2011) included SA evaluation since early childhood. From these studies, normative values for children and adolescents were created, suggesting that 50th percentiles could represent a valuable reference to properly establish the level of performance. Nevertheless, these batteries seemed to have some limitations. For example, as to the 4x10 m shuttle run test, Kolimechkov et al. (2019) showed a mean reduction of 0.4 s between 8 and 9 years, and 0.3 s between 10 and 11 years in girls, and a mean reduction of 0.5 s between 9 to 11 years in boys. This stratification would help primary surveillance (Lovecchio et al., 2019; Lovecchio et al., 2020; Tomkinson et al., 2007; Valarani et al., 2020). However, it would not be as much accurate as needed for training evaluation or developmental analysis. Childhood is a crucial age in which 4x10 m shuttle run performance increases slowly, approximately by 1,5-2% per year (Kolimechkov et al., 2019). Moreover, since age of 8-11, children performance in agility test depends on body mass and height (Id et al. 2020) but not on the index summarising these two variables (i.e. body mass index; BMI); therefore, BMI cannot be considered as an accurate indicator of the actual performance (Lovecchio et al., 2019a; Giuriato et al., 2020). Indeed, growth has a misaligned pattern (Gonzalez et al., 2017): height increases by 3-4% per year and mass by 8-10% (Cole and Lobstein, 2012). Furthermore, the traditional ratio of speed/body mass, commonly accepted to scale for body mass, frequently produces artefacts being a body dimensionless index (Welsman & Armstrong, 2008; Welsman, 2019). As said, the stratification of performance according to social condition (Lovecchio et al., 2015) or BMI categories (Lovecchio & Zago, 2019) could be an alternative. However, this would result in a non-robust analysis due to performance variations during growth phases (Armstrong & Welsman, 2019; Van Praagh & Doré; 2002). Some studies have attempted to model the development of various athletic characteristics, including maturation and anthropometry (non-linear relationship; Carnevale Pellino et al., 2020; Towlson et al., 2018) applying classic

polynomial regression models. However, these analytical approaches do not necessarily consider transition points in the maturity-physicality relationship, and the regression parameters are not directly interpretable (Towlson et al., 2017). To overcome these pitfalls it is necessary to scale for actual maturity differences and determine the role of body size (allometric model) on performance (Doré et al. 2005). Indeed, scaling aims at producing a "size free" variable (Meylan et al., 2014).

This framework is crucial to outline an additive polynomial model appraising developmental growth and maturation's contribution, especially considering the exponential trend of human growth (Nevill et al., 2009). In light of this, allometric analysis becomes the golden approach since it is the best method of scaling when physical outcomes are assessed during growth (Bustamante et al., 2015; Cunha et al., 2011; Meylan et al., 2014; Nevill et al., 2009; dos Santos et al., 2016; Valente-dos-Santos et al., 2014). Further, some authors applied scaling methods in SA (Negra et al., 2014; Silva et al., 2016; Bustamante Valdivia et al., 2015).

Additionally, the evaluation process should also account for the "age-distance" (at the peak of maturity). Predicted maturity offset defined as the time before or after peak height velocity (PHV). PHV ~~can capture the peculiar significance of~~ influences speed and power results throughout growth (Giuriato et al., 2020). While the strength outcome depends on the physiological determinants' developmental stage, the peak of strength corresponds to PHV. Particularly, absolute values of specific "strength actions", such as jumping, are differently positioned into the peak-performance-velocity curves of PHV (Beunen & Malina, 1988; Sherar et al., 2005). For all these reasons, it is crucial to control maturity (Mirwald et al., 2002). Thus, this study aims at determining the ideal body shape and allometric equations to assess SA performance assessment in children of different height, mass, sex, and age. Predictive equations will enact an accurate and robust surveillance, adjusted per pediatric developmental stages, in children aged 8-11.

Materials and Methods

Participants and study design

This cross-sectional study involved a total of 7317 (3627 girls) children aged 8–11 years recruited from 37 schools (368 classes) of North East Italian primary schools (third, fourth, and fifth grade). Descriptive statistics in table 1. Children with known chronic cardiac, respiratory, neurological, or musculoskeletal disease were not recruited. All the described measures were taken during the regular Physical Education lessons at school (8.00-12.00 AM). The study protocol, including each feature of the experimental design, was approved by the schools' ethical board in accordance with the "World Medical Association Declaration of Helsinki" as revised in 1983.

Procedure

Data collection included demographic/anthropometric information (gender, age, mass, height) measured before the test sessions using standardised techniques are shown in Table 1. Height was measured using a portable stadiometer with a precision of ± 1 mm (Stadiometer Seca 213, Intermed S.r.l. Milan, Italy), with children in an upright position, bare feet placed slightly apart, arms extended, and head positioned in Frankfort plane. Body mass was assessed using a beam scale with a precision of ± 100 g (Seca 813, Intermed S.r.l. Milan, Italy), with children in light clothing, without shoes, and stood upright the centre of the platform of the mass scale. We calculated the age of the children from the birth date and subsequently rounded down values. The SA was evaluated by the 4×10 m shuttle run test (Oja & Jurimae; 1997; Niederer et al., 2011). This test consisted of running and turning as fast as possible between two parallel lines (10 m apart) where children had to exchange sponges when crossing the lines (4 times $\times 10$ m) (Ortega et al., 2008). The result was measured with a stopwatch (Kalenjy, Onstart 710, Lille, France) to the nearest 0.1 s by a trained rater (Vicente-Rodríguez et al., 2011). The best of two attempts was recorded in seconds. A higher score indicated a worse performance. Before

starting the test, evaluators performed an example to ensure that the children understood the test correctly.

The explosive leg strength of the children was measured by a standing broad jump (SBJ) test: a practical, time-efficient and low cost field-test widely adopted in school or gym context (Lovecchio et al., 2019b; Lovecchio & Zago, 2019; Ruiz et al., 2011; Tomkinson et al., 2007). Every child jumped for distance from a standstill. During the jumps performance, the children were asked to bend their knees with their arms in front of them, parallel to the ground, then swing both arms, push off vigorously and jump as far as possible. The test was performed three times, scored in centimetres, and the best value was recorded. The score was obtained by measuring the distance between the last heel-mark and the take-off (Ortega et al., 2015). Fitness assessment was performed twice so systematic error was nearly null for both tests (Ortega et al., 2008).

In particular, all tests were conducted by a team of ten tutors of the Sport Science Faculty during the scheduled Physical Education classes. The presence and collaboration of the curricular Physical Education teachers were guaranteed at any time to meet the confidence of the students (Ceccarelli et al., 2020).

Data analysis

The biological maturation (MO) was estimated through the somatic maturation method proposed by Moore et al. (2015). This formula was chosen for the low number of measurements (age, height), minimising bias.

This method estimates MO from stature and chronological age using an algorithm, providing the result offset in years to peak height velocity (PHV). In brief, the MO was determined using a specific formula for girls and boys:

$$\text{Maturity offset for girls (years)} = - 7.709133 + (0.0042232 \times (\text{age} \times \text{height}))$$

$$\text{Maturity offset for boys (years)} = - 7.999994 + (0.0036124 \times (\text{age} \times \text{height}))$$

Then, the age of PHV (agePHV) was determined by subtracting the maturity offset from the chronological age. Participants were classified as late, early, or on-time through the one SD method derived from the current sample.

Statistical Methods

The multiplicative model with allometric body-size components of body mass (M), height (H), was used to identify the most appropriate body size and shape characteristics (Eq.1) associated with the physical performance variable SA (4x10m). The model is similar to that used to predict Greek children's physical performance variables (Nevill et al., 2009).

$$Y = a \cdot M^{k1} \cdot H^{k2} \cdot \varepsilon \quad (1)$$

The model (Model 1) has the advantage of having proportional body size components and a multiplicative error that assumes, ε , will increase proportionally with the physical performance variable Y (see Figure 1a, b). The model (Eq.1) can be expanded to incorporate maturity (using AgePHV) (reported as Model 2) plus leg strength (SBJ test) (reported as Model 3) , and categorical differences (e.g., sex, age), incorporated as fixed factors, in the physical performance variable SA.

$$Y = a \cdot M^{k1} \cdot H^{k2} \cdot \text{SBJ}^{k3} \cdot \exp(b \cdot \text{agePHV}) \cdot \varepsilon \quad (2)$$

The model (Eq. 2) can be linearized with a log transformation (Eq.3). A linear regression analysis or analysis of covariance (ANCOVA) on Ln(Y) (note that Ln=log_e) can then be used to estimate the unknown parameters of the log-transformed model:

$$\text{Ln}(Y) = \text{Ln}(a) + k_1 \cdot \text{Ln}(M) + k_2 \cdot \text{Ln}(H) + k_3 \cdot \text{Ln}(\text{SBJ}) + b \cdot \text{agePHV} + \text{Ln}(\varepsilon) \quad (\text{Eq. 3})$$

Other categorical differences within the population, e.g. sex, age, can be explored by allowing the constant intercept parameter 'Ln(a)' to vary for each group by introducing them as fixed factors (plus possible interactions) within an ANCOVA (note that the terms Ln(M), Ln(H), Ln(SBJ) and agePHV in Eq. 3 are the covariates used in the ANCOVA). The significance level was set at P<0.05.

Figure 1a. The association between speed-agility (m.s⁻¹) and height for girls

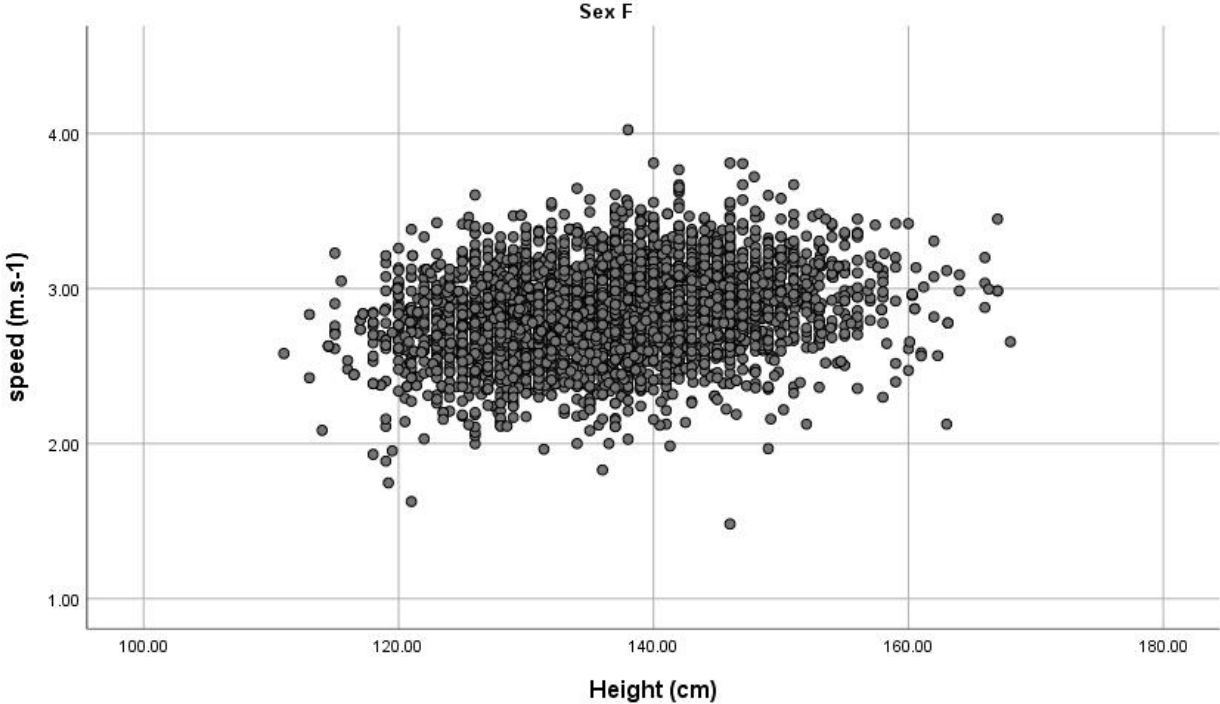
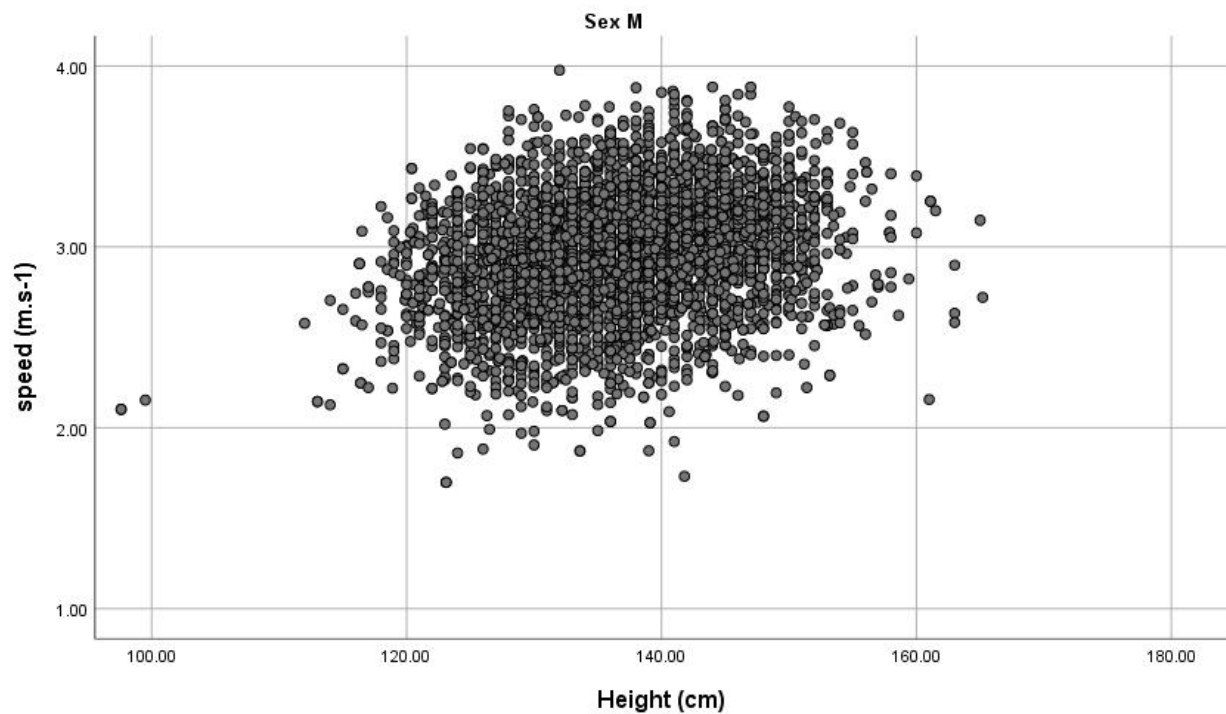


Figure 1b. The association between speed-agility ($\text{m}\cdot\text{s}^{-1}$) and height for boys.



Results

Descriptive statistics of all subjects are reported in Table 1.

Speed agility 4x10m test (Model 1)

Agility performance expressed through the 4x10m test revealed a mean value (SD) of 13.69 sec (1.62) and 14.18 sec (1.49) for boys and girls, respectively.

The estimated parameters from the multiplicative model relating log-transformed 4x10m SA to the body-size components in Eq.1 (Model 1), are given in Table 2a.

****Table 2a near here****

The model 1 (Eq.1) relating the 4x10m Speed Agility to the body-size components was:

$$\text{Speed Agility (m.sec}^{-1}\text{)} = a \cdot M^{-0.178} \cdot H^{0.583}$$

These exponents suggest the optimal body-shape associated with 4x10m SA is to be taller (H exponent=0.583) but with lighter body mass (M exponent=-0.178), that is a subject with a ectomorphic body shape.

Fitting Model 1 (Eq.1) revealed significant differences in the constant 'a' parameter (table 2a) due to sex (P<0.001), and age (P<0.001) but with a non-significant age x sex (P= .320) interaction (Figure 2a).

****Figure 2a here****

Speed agility 4x10m test incorporating Age at PHV (Model 2)

The estimated parameters from the multiplicative model relating log-transformed 4x10m SA to the body-size components in Eq.2, incorporating AgePHV, are given in Table 2b.

****Table 2b near here****

The model 2 (Eq.2) relating the 4x10m SA to the body-size components was:

$$\text{Speed agility (m.sec}^{-1}\text{)} = a \cdot M^{0.174} \cdot H^{1.03} \cdot \exp(0.104 \cdot \text{agePHV})$$

The model suggests the optimal body-shape associated with 4x10m is to be taller (1.03) but with lighter body mass (-0.174), indicating a subject that tends to have a ectomorphic body shape. The model also identified that having an older agePHV (0.104) or being a late mature is also associated with faster SA.

Fitting Model (Eq.2) revealed significant differences in the constant 'a' parameter (table 2b) due to sex (P<0.001), age (P<0.001) together with a significant interactions age x sex (P=0.002). No interaction between sex x agePHV was find (P= 0.310) (Figure 2b).

****Figure 2b here****

Speed agility 4x10m test incorporating SBJ (surrogate for Leg Strength) (Model 3)

The estimated parameters from the multiplicative model relating log-transformed 4x10m speed-agility to the body-size components in Eq.1, incorporating agePHV and lower limb strength through the SBJ test, are given in Table 2c.

****Table 2c near here****

The model 3 (Eq.2) relating the 4x10m SA to the body-size components was:

$$\text{Speed agility (m.sec}^{-1}\text{)} = a \cdot M^{-0.047} \cdot H^{0.317} \text{ SBJ}^{0.342} \cdot \exp(0.048 \cdot \text{agePHV})$$

The model suggests the optimal body-shape associated with 4x10m SA is to be tall (0.317) and with a low body mass (-0.047), indicating a subject that tends to have a ectomorphic body

shape. The model also identified that having an older agePHV (0.048) i.e., being a late mature and having a greater lower limb strength SBJ (0.342) is also associated with faster SA.

Fitting Model 3 (Eq.2) revealed significant differences in the constant 'a' parameter (table 2c) due to sex ($P < 0.001$), age ($P < 0.001$) together with a non-significant interactions age x sex ($P = .757$), AgePHV ($p < .001$). No interaction between sex x agePHV was found ($P = 0.718$) (Figure 2c).

****Figure 2c here****

Discussion

An allometric modelling approach was used to identify and analyse optimal body size and shape characteristics associated with the SA test (4x10m). Generally, boys outperformed girls at all ages, not only in absolute terms but also when adjusting for body size/shape and agePHV. The results of the current study are aligned with Nevill et al, (2021), in which performance was not significantly associated with PHV, and was negative in girls. Consistently, in our study, a negative parameter b in female x agePHV (see Table 2 b,c), indicated that girls' performances in speed agility were worse than males when adjusted per maturity state. Furthermore, no agePHV x sex interaction (see model 2 b,c) was registered, revealing a large variability of the performance. Moreover, the trend is contrary in other types of performance (i.e. explosive strength; Lovecchio et al, 2019a), in which girls outperformed boys.

In Model 1, through parameter b of Height and Mass, it was found that the height-to-body mass ratio fitted the optimal relationship between SA performance and body shape. Considering that the exponent of height was positive (.58), while that one of mass was negative (-.17), a tendency to an ectomorphic body shape could be inferred. In line with this piece of evidence, Valente-dos-Santos (2014) reported that agility performance based on multilevel models indicated that as much as a 1-kg increase in fat-free mass was associated with improved agility performance by 5%. These findings were obtained when body size, body composition and skeletal age were controlled in 10-to 18-year-old boys. Moreover, the positive exponents in height in Model 1, 2, 3, are in line with Nevill et al, (2021), who found similar results (i.e. positive height exponent) in sprint speed, jump, and change of direction performance, highlighting that the successful body size/shape in these tests was to be tall and lightweight. By including agePHV in the model, the tendency to ectomorphic body shape was confirmed. Furthermore, agePHV influenced the performance in the SA test (Figure 2b). In the third model, a measure of lower limb strength (SBJ) was incorporated in addition to agePH. As a result, this expression of strength changed the trend of SA (Figure 2c). The ratio of trunk length to leg length can also potentially influence motor performance, accounting for individual differences in sprinting speed (Dintiman and Ward, 2011). This could explain our findings concerning body shape associated with SA. On the other hand, the low variance (~21%) of the SA performance resulted unchanged despite maturity, suggesting to be an independent factor. In this view, Nevill et al, (2021), found no significant interaction between SA test (Illinois agility test) and PHV, confirming (as the present results) that late maturers perform better in drills with change of direction (SA test) (See table 2c). Furthermore, once lower limb strength was added to the model, the variance increased (up to ~48%). Agility performance is complex and is affected by several factors. Jeffreys et al. (2011) stated that the agility expression limits are mainly due to three factors: organismic, tasks, and environmental. Sheppard and Young (2006) reported that SA and change of direction

performances foresee physical demands (strength and conditioning), cognitive processes (motor learning) and technical skills (biomechanics). This multifactorial performance could be at the origin of the explanation of our study results, underlining that late maturers, with low centre of gravity, are favoured in such trials. Figueiredo et al. (2009), through a cross-sectional study based on multiple linear regressions models, indicated that chronological age and stature positively affected SA performance while adiposity was a neg-effector, accounting for 34% of the variance in the shuttle run test in subjects aged 11–12 years. This extent, after that, decreased to 24% for adolescents of 13–14 years. Also, resistance training had a small effect on linear sprint performance and SA. The lower outcomes might be justified by the complex nature of these qualities, with various determinants contributing to the performance level (Lesinski et al., 2016). Agility depends on perceptual factors and rapid changes of direction, which is again influenced by movement technique, leg muscle quality and straight sprinting speed (Young et al., 2002). Furthermore, muscle strength seemed to be the sole factor contributing to agility.

In Model 3, including agePHV and SBJ, maturity positively influenced speed-agility performance through chronological age. Thus, late mature youth appeared to better perform in SA. These results could be crucial in research of talent, suggesting that agility should be assessed during adolescence as surrogate markers of strength spurs. SBJ values were positively associated with SA performance, implying that increases in explosive strength and maturity are responsible for improved SA performance. Furthermore, the results confirmed that being tall and linear subjects (ectomorphic body shape), could be predictive of the performance in change of direction and SA.

Lastly, by including strength performance, the r squared variance increased at .485, proposing lower limb strength as a determinant factor for the agility performance.

Conclusion

In boys and girls aged 8-11, the optimal body shape for agility performance tended to be ectomorphic, pointing at the low fat mass as a positive effector. Scouting and coaching should focus on late maturers, especially when SA and change of direction are fundamental in a sports discipline. Furthermore, the expression of lower limb strength affected agility. In this perspective, the developed models including height, mass (first model) and agePHV (second model) described a trend fitting parallel to strength expression.

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Table 1. Descriptive statics (Mean \pm SD) per sex (girls, boys) and years (8-11).

	Age (years)	n	Height (cm)	Body mass (kg)	4x10m (sec)
Girls	8	799	127.76	27.70	14.91
			5.80	5.58	1.49
	9	1060	133.59	31.39	14.46
			6.40	7.14	1.43
	10	1199	144.51	39.00	13.48
			7.49	8.85	1.21
	11	757	140.19	36.21	13.85
			6.75	7.78	1.31
Boys	8	932	128.97	29.02	14.44
			6.02	6.27	1.56
	9	1131	134.39	32.15	13.91
			6.17	6.44	1.64
	10	1184	139.72	36.31	13.34
			6.28	8.05	1.38
	11	725	143.82	39.20	12.89
			6.45	8.74	1.38

Table 2a. The estimated parameters from the multiplicative model relating log transformed 4x10m agility speed (Ln(Speed Agility)) to the body-size components in Eq.1 (Model 1).

Parameters	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-1.109	0.144	-7.674	0.000	-1.392	-0.825
LnMass (k1)	-0.178	0.007	-24.018	0.000	-0.192	-0.163
LnHeight (k2)	0.583	0.033	17.900	0.000	0.519	0.646
Sex (Girls)	-0.049	0.005	-9.643	0.000	-0.059	-0.039
Years (8.0)	-0.103	0.005	-18.668	0.000	-0.113	-0.092
Years (9.0)	-0.070	0.005	-14.219	0.000	-0.080	-0.060
Years (10.0)	-0.031	0.005	-6.597	0.000	-0.040	-0.022

Boys (age 11) are taken as the reference/baseline group from which girls and other age groups are compared.

Table 2b. The estimated parameters from the multiplicative model relating log transformed 4x10m agility speed (Ln(Speed Agility)) to the body-size components and agePHV in Eq.2 (Model 2)

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-4,722	0.317	-14.875	0.000	-5.345	-4.100
LnMass (k1)	-0.174	0.007	-23.780	0.000	-0.189	-0.160
LnHeight (k2)	1.030	0.048	21.619	0.000	0.937	1.124
Sex (Girls)	0.082	0.011	7.165	0.000	0.060	0.104
Years (8.0)	0.041	0.013	3.309	0.001	0.017	0.066
Years (9.0)	0.021	0.009	2.425	0.015	0.004	0.038
Years (10.0)	0.008	0.006	1.495	0.135	-0.003	0.019
agePHV (years)	0.104	0.008	12.749	0.000	0.088	0.120
Girls*agePHV	-0.009	0.009	-1.101	0.310	-0.027	0.009

Boys (age 11) are taken as the reference/baseline group from which girls and other age groups are compared.

Table 2c. The estimated parameters from the multiplicative model relating log transformed 4x10m agility speed (Ln(Speed Agility)) to the body-size components, agePHV and SBJ in Eq.2 (Model 3).

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-2,577	0.261	-9.878	0.000	-3.089	-2.066
LnMass	-0.047	0.006	-7.489	0.000	-0.060	-0.035
LnHeight	0.317	0.040	7.832	0.000	0.238	0.396
Sex (Girls)	0.035	0.009	3.777	0.000	0.017	0.054
Years (8.0)	0.011	0.010	1.090	0.276	-0.009	0.031
Years (9.0)	0.003	0.007	0.384	0.701	-0.011	0.017
Years (10.0)	0.005	0.005	1.150	0.250	-0.004	0.014
agePHV (years)	0.048	0.007	7.060	0.000	0.034	0.061
LnSBJ	0.342	0.005	62.780	0.000	0.331	0.353
Girls*agePHV	-0.003	0.007	-0.362	0.718	-0.017	0.012

Boys (age 11) are taken as the reference/baseline group from which girls and other age groups are compared.

Figure 1a

Figure 1a. The association between speed-agility ($\text{m}\cdot\text{s}^{-1}$) and height for girls

Figure 1b

Figure 1a. The association between speed-agility ($\text{m}\cdot\text{s}^{-1}$) and height for boys

Figure 2a Estimated marginal means of 4x10m per sex (boys, girls)

Figure 2b Estimated marginal means of 4x10m per sex (boys, girls) and Maturity Offset

Figure 2c Estimated marginal means of 4x10m per sex (boys, girls), Maturity Offset, and explosive strength (SBJ)