Normative Values for Measures of Physical Fitness Among Tunisian School Children

Running title: Reference values for measures of physical fitness in youth

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Abstract

BACKGROUND: This study aimed to i) provide normative data for measures of physical fitness (PF) (i.e., muscle strength, muscle power, linear sprint speed) in 8- to 14-year-old Tunisian children and ii) to examine sex and age group differences in these measures. **METHODS:** A total of 597 subjects participated in this study. **RESULTS:** The two-way ANOVA showed credible age by sex interactions for all measures of PF (Effect Size (ES) ranged from 0.28 to 0.68; $p<0.05$). The findings indicated a main effect of age in handgrip strength, countermovement jump (CMJ) height, and linear sprint speed (all $p<0.05$), regardless of sex. Post-hoc analyses showed early increases in handgrip strength for boys from 8 to 14 years. For CMJ height, an increase in performance was observed from 10 to 11 years (ES= 0.23) and 12 to 13 years (ES= 0.14) (all $p<0.05$). For linear sprint speed, performance enhancement was observed from 10 to 11 years (ES= 1.00). In girls, an increase in handgrip strength was noted from 9 to 12 years (ES= 1.00). However, the changes across age were less convincing for CMJ height and linear sprint speed tests, suggesting that differences for girls were not supported by the collected data. Boys outperformed girls in all measures of PF ($p<0.05$). A summary of the estimated centiles of 10 and 30-m sprint speed, grip strength, and CMJ height for boys and girls allow a particular child's test values to be compared to the norms for the group. **CONCLUSIONS:** In summary, this study provides normative data that can be used as a tool to classify sprint speed, strength, and jump height performance in children of both sexes aged 8 to 14 years.

Key words: athletic performance, youth, normative data, sex.

Introduction

The benefits of physical activity (PA) on health in youth are undisputed, irrespective of age, maturity status, and sex (Pedersen and Saltin, 2015;Bull et al., 2020). It is well-known that PA is the only way to promote physical fitness (PF) (Moran et al.) (Bull et al., 2020). There is compelling evidence indicating that different components of PF, such as muscle strength, muscle power, and cardiorespiratory endurance are associated with improved markers of health (e.g., bone mineral density, improved blood lipid profile) (Faigenbaum and Myer, 2010; Bull et al., 2020). Relatedly, it has been shown that low levels of PA are associated with an elevated risk of developing adverse health events (e.g., overweight and obesity, systolic blood pressure, insulin resistance) in school-aged individuals (Ortega et al., 2008; Lopes et al., 2012; Rodrigues et al., 2013; Smith et al., 2014).

Given the time youth (i.e., children and adolescents) spend in the school environment, schools should play a crucial role in the provision and promotion of PA and, therefore, PF (Pate et al., 2006). It is well known that a relationship exists between fundamental movement skills (e.g., throwing, jumping, sprinting) and PF (Chaabene et al., 2020). However, performing and further developing these fundamental movement skills requires sufficient levels of muscle strength and power (Faigenbaum et al., 2011;Faigenbaum and Myer, 2012). Therefore, assessment of PF has become increasingly important in youth with growing awareness of its association with better health status and well-being. For instance, grip strength is a frequently used assessment tool in youth (Ruiz et al., 2011). It has been shown that handgrip strength represents an indicator for overall muscle strength (Wind et al., 2010) and health status in youth. Additionally, the level of mastery of fundamental movement skills such as jumping and sprinting are particularly important as these provide an indication of the risk of sedentary behavior at later stages of life (Faigenbaum et al., 2013). To evaluate these variables within a particular population, either criterion levels or normative reference data are needed. Centile growth charts for height and body mass are now common in auxology and seen as an essential component of the pediatric toolkit (Bull et al., 2020). More recently the use of centile charts has expanded to include PF parameters (Santos et al., 2014). Studies reporting centiles for PF in youth have shown that, on average, older perform better than younger and boys perform better than girls on most but not all PF components (Eisenmann et al., 2011;Catley and Tomkinson, 2013). Findings from the aforementioned studies are helpful for the identification of individuals with particular PF characteristics (e.g., talent identification) and the quantification of performance differences between ages and sex.

Several studies related to sex and age-specific normative data on measures of PF in youth have been published in the literature (Tomkinson et al., 2003;Ruiz et al., 2011). However, the majority of the published studies recruited school children from high-income countries in North America (Tremblay et al., 2010;Carrel et al., 2012), Asia/Oceania (Tomkinson et al., 2003;Tomkinson and Olds, 2007), and Europe (Gulías-González et al., 2014;Haugen et al., 2014). In particular, no population-based studies have been conducted to assess youth living in lower-income countries such as North Africa, for which PF normative values need to be produced or at least existing values adjusted. Moreover, there has been no handgrip strength, jump height, and linear sprint speed normative data for healthy Tunisian youth. Therefore, it is important to have reference values relevant to the Tunisian population. To the best of our knowledge, this is the first study to produce centile curves for fitness parameters for Tunisian children. Accordingly, our study aimed to generate normative data for handgrip strength, jump height, and linear sprint speed for 8- to 14-year-old and to investigate between sex and age group differences in these measures.

Methods

The experimental approach to the problem

This study aimed at generating normative data for handgrip strength, jump height, and linear sprint speed for 8- to 14-year-old subjects and to examine sex and age group differences in these measures. Parents were asked to advise the researchers of any known illness or condition that could result in adverse responses. Data collection was carried out over a 3-month period by the same researchers (YN and SS). Written informed parental consent and participant assent were obtained before the start of the study. All youth athletes and their parents/legal representatives were informed about the experimental protocol and its potential risks and benefits before the start of the research project. The study was conducted per the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the ***.

Participants

The sample consisted of a total of 597 participants (396 boys and 201 girls) aged 8 to 14 years. All participants were recruited from primary and secondary schools in the north of Tunisia. The participants were grouped based on chronological age into 1-year age categories: Each age group was categorized by the midpoint of an age range. For example, the group of children with 10 years old included all the children between 9.50 and 10.49 years, and so forth. Participants were assured that they could withdraw from the study without penalty at any time without providing a reason.

Procedures

All participants were required to complete a handgrip strength, vertical jump height, and linear sprint speed tests. All testing sessions occurred during scheduled physical education classes.

Anthropometric measurements

All the anthropometrical measurements were taken by one trained anthropometrist assisted by a recorder in accordance with standardized procedures of the international society for the advancement of kinanthropometry (ISAK) (Slaughter et al.,1988).

Testing was carried out in a standardized order after a proper calibration of the measuring instruments. Each participant's height (against the wall) (m) and body-mass (kg) were assessed to the nearest 0.1 cm and 0.1 kg, using a SECA stadiometer and a SECA weighing scale (SECA Instruments Ltd, Hamburg, Germany), respectively. Body mass index (BMI) was calculated using body-mass divided by height squared (kg/m2). Skinfolds measurements (in millimeters) were taken on the right-hand side of the body at two sites (the triceps and the subscapular) using Harpenden skinfold calipers (Harpenden Instruments, Cambridge, UK). Skinfold data, alongside the skinfold equation of Slaughter et al. (1988), were used to estimate the fat mass (kg) and fat-free mass (kg).The percentage of body fat (%BF) of children with triceps and subscapular skinfolds <35 mm was calculated as follow: Boys= 1.21 (sum of 2 skinfolds)-0.008 (sum of 2 skinfolds^2)-1.7, and for girls= 1.33 (sum of 2 skinfolds)-0.013 (sum of 2 skinfolds^2)-2.5. The %BF for children with triceps and subscapular skinfolds ≥35 mm was calculated as follow: Boys= 0.783 (sum of 2 skinfolds) - 1.7, and for girls=0.546 (sum of 2 skinfolds) + 9.7 (Slaughter et al.,1988). Fat-mass was calculated as follow: fat-mass = (body mass * % BF)/100; fat-free mass (kg) = body mass - fat mass (Slaughter et al.,1988). All anthropometric measures were recorded twice and the mean scores were retained for the statistical analysis. The Intraclass correlation coefficients for test-retest reliability for all anthropometric and skinfolds measures ranged from 0.97 to 0.99 and all typical errors of measurement were <5%.

Handgrip strength

The handgrip strength test measures the maximal isometric force that can be generated by the forearm for the dominant hand. Participant stays in a standard bipedal position with the arms fully extended while holding the dynamometer (TKK 5101; Takei, Tokyo, Japan). Without touching the body, the participant performs two trials of a maximal grip effort for 3 seconds. The dynamometer was adjusted to each individual's hand size (Ruiz et al., 2011). The ICC for test-retest reliability was 0.89.

Vertical jump height

To assess vertical jump height, the countermovement jump (CMJ) test was used. Participants started from an upright erect standing position and performed a fast downward movement by flexing the knees and hips before rapidly extending the legs and performing a maximal vertical jump. Participants were instructed to jump and land in the same position and to keep the legs fully extended during the flight phase. Throughout the execution, participants maintained their arms akimbo. The performance was recorded using an Optojump photoelectric system (Microgate, SRL, Bolzano, Italy). Each participant performed two trials with a 3-min rest between each. The best trial was used for further analysis. The ICC for test-retest reliability was 0.93.

Linear sprint speed

A thirty-meter linear sprint speed test was conducted using an electronic timing system (Microgate SARL, Bolzano, Italy). Participants started from a standing position, 0.3-m before the first infrared photoelectric gate, which was placed 0.75-m above the ground to ensure it captured trunk movement and avoided false signals via limb motion. In total, three single-beam photoelectric gates (0-m, 10-m, and 30-m) were used. Each participant performed two trials with a 3-min rest between each. The best trial was used for further analysis.The intraclass correlation coefficients (ICCs) for test-retest reliability for 10-m and 30-m sprint speed intervals were 0.97 and 0.92 respectively.

Statistical analysis

Data are presented as means and standard deviations (SD). Two-way analysis of variance (ANOVA) was used to identify the presence of the main effect of age, sex, an age × sex interaction for all tests. Finally, an independent samples t-test was applied to examine differences for all tests, between the sexes within each age group, with the size of effect size determined by converting partial eta-squared to Cohen's d. According to Cohen (Cohen, 1988), ES can be classified as small ($0.00 \le d \le 0.49$), medium ($0.50 \le d < 0.79$), and large ($d \ge 0.80$).

Centile curves for boys' and girls' PF measures were fitted as a function of age (continuous) using generalized additive models for location scale and shape (GAMLSS) introduced by Rigby and Stasinopoulos (Rigby and Stasinopoulos, 2005). These models were fitted with the gamlss package (5.1-6) in R (4.0.0; R Core Team, 2020). GAMLSS uses a distributional regression approach where not only the location of the distribution but also the scale and shape of the distribution can be modeled by explanatory variables (Stasinopoulos et al., 2018). Each model was fitted Box-Cox Cole and Green, Box–Cox power exponential, and the Box-Cox-t distributions and estimated nine reference centiles at 1^{st}, 3^{rd}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, 97^{th}, and 99^{th}. The goodness of fit was assessed using both the Akaike information criterion (AIC) (Lieberman et al.), and Bayesian Information Criterion (BIC). The models with the lowest AIC and BIC were selected. Post-estimation diagnostics were performed using quantile plots (QQ plots) and worm plots to determine how well the statistical model fit the data. Test-retest reliability was assessed using $ICC_{3,1}$. The alpha level of significance was set at $p<0.05$. Data analyses were conducted using SPSS 24.0 program for Windows (SPSS, Inc, Chicago, IL, USA).

Results

The anthropometric characteristics of participants are displayed in Table 1. Participants' characteristics including age, sex, and PF performance are presented in Table 2. The two-way ANOVA showed age by sex interactions for all measures of PF (all p<0.01, ES ranged from 0.28 to 0.68). For boys, our statistical calculation indicated a main effect of age for the handgrip strength ($F_{(6, 389)}$ =116.9, p<0.01), vertical jump height ($F_{(6, 389)}$ = 40.7, p<0.01) and linear sprint speed (10-m: $F_{(6, 389)}$ =16.59 and 30-m: $F_{(6, 389)}$ = 28. 28; both p<0.01). As to girls, a main effect of age for the handgrip strength (F= $_{(6, 193)}$ = 29.68, p<0.01), CMJ height (F= $_{(6, 193)}$ = 3.79, p<0.01) and linear sprint speed (10-m: F= $_{(6, 193)}$ = 3.12, p<0.01, and 30-m: F= 5.91, p<0.001) were observed. Post-hoc analyses showed early increases in handgrip strength for boys from 8 to 14 years (Table 2). For CMJ height, increased performance was observed from 10 to 11 years and 12 to 13 years (p<0.05). Linear sprint speed increased from 10 to 11 years, and from 12 to 13 years (both p<0.05). Regarding girls, increases in handgrip strength were noted from 9 to 12 years (ES=1.00; p<0.05). However, for CMJ height and linear sprint speed tests, the null hypothesis could not be rejected (p>0.05), suggesting that differences for girls were not supported by the collected data.

*****Table 1 near here*****

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

Centiles

A summary of the estimated centiles of grip strength, CMJ height, and 10 and 30-m sprint speed for boy and girl Tunisian children aged 9 to 14 years are presented in Tables 3, 4, 5, and 6. These tables and the corresponding centile charts (see figure 1-2) allow a particular child's test values to be compared to the norms for the group. The interpretation of centiles is straightforward, for example in the case of a girl 30m sprint speed time for a particular age, if that child's time is on the 25th centile, it means that for every 100 children of that same age, 25 would have a lower sprint speed and 75 a higher sprint speed performance.

*****Table 3 near here*****

*****Table 4 near here*****

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*****Figure 1 near here*****

Figure 2 near here

Discussion

This study represents the first population-based normative data for handgrip strength, vertical jump height, and sprint speed performance for 8- to 14- year-old Tunisian school children. The established normative data is useful for the sake of talent identification and serves as a classification tool for strength, jump height, and sprint speed in schoolchildren aged 8 to 14 years. Additionally, the centile age curves presented for each PF component are unique for this particular population and provide reference values by age and sex. These continuous growth curves provide the reader the opportunity to accurately determine the level of a particular child's performance on a particular test compared to other Tunisian school children of a similar age and sex. Handgrip strength using hand-held dynamometer is a widely to evaluate muscle strength in youth (Ruiz et al., 2011). This is because of its simple use and inexpensive cost (Ruiz et al., 2011). Additionally, It has been revealed that handgrip strength represents an indicator for overall muscle strength (Wind et al., 2010). Bohannon et al. (2007) mentioned that reference values in Asians are not appropriate for Japanese people. In fact, different cut-off values are used for handgrip strength between different countries (Europe vs. Asia). The Handgrip strength outcomes measured in our study are different from those performed in Canadian children where performance values ranged between 24 and 27 kg in boys and 21 and 24 in girls aged 8 to 10 years (Tremblay et al., 2010). These discrepancies may be due to various factors (i.e., biological maturation, the model of dynamometer, testing protocol). Beunen et al. (1988) suggested that differences found in handgrip strength performance can be mainly attributed to biological maturation. However, our results are in line with those found in the Italian children aged 9 to 10 years. This finding reinforces the importance of having reference values for different populations.

Many studies have indicated that muscle strength increases during childhood (Malina et al., 2004;Ruiz et al., 2011). This was also the case in the present study across centiles. The present findings showed that, on average, boys performed better than girls at the age of 9,10, 13, and 14 years, however differences between children 8-, 11- and 12-years-old could not be established from the data and were compatible with a null hypothesis of no difference. Nevertheless, girls in the highest centiles are predicted to outperform boys in lower centiles.

These findings confirm the sex differences on measures of muscle strength often reported for youth (Olds et al., 2006;Eisenmann et al., 2011;Catley and Tomkinson, 2013) that can be attributed to normal development and growth (Malina and Katzmarzyk, 2006). In addition, the current findings revealed that handgrip strength performance continued to improve year on year for boys. However, in girls, clear increases in handgrip strength were noted only from 9 to 12 years (ES=1.00). Many studies have reported normative values for vertical jump height performance in young adults (Patterson and Peterson, 2004). The CMJ data for boys in the present study are also comparable to those reported by Focke et al. (2013), however, for girls aged 8 to 14 years, the same authors reported a jump height performance between 17 and 22 cm which is approximately 4 cm greater than the performance recorded in our study. Conversely, the normative CMJ data in the present study are lower (approximately 5 cm) compared with those reported by Taylor et al. (2010) for a sample of English school children. These comparative observations imply that the transfer of reference values for PF between populations and geographic regions are not straightforward, implying that specific norms need to be developed for each population. This highlights the importance of the centile tables and centile growth curves we present.

Our results showed that boys, on average, jumped higher than girls from 8 years onwards. Although, as previously noted, higher performing girls outperform lower performing boys across age groups.. The current findings are similar to previous research in children (Temfemo et al., 2009) and adults (Patterson and Peterson, 2004). In addition, jump height performance continued to improve year on year for boys on average and across centiles. Our results are in line with previous research (Branta et al., 1984). However, on average and across centiles, jumping performance in girls group reached a plateau after 12 years of age, which is in line with previous studies who reported similar findings for 13 to 15 year-old girls (Klausen et al., 1989;Doré et al., 2008). Malina and Bouchard (1991) reported an increase in standing long jump performance for girls up to the age of 12 years, followed by a plateau or even a decline in performance. In addition, Loko et al. (2000) reported a reduction in vertical jump height between 13 and 14 years of age among Estonian girls. The findings of this study suggest a main effect of age in both sprint test intervals (i.e. 10- and 30-m). Data from earlier cross-sectional studies confirm our findings in as much as PF enhancements were reported in groups of increasing age (Woll et al., 2011;Catley and Tomkinson, 2013;Santos et al., 2014). For example, Catley and Tomkinson (2013) demonstrated increased sprint speed performance (i.e., 50-m sprint) across the years from 9 to 17 years. Our analysis showed that on average boys aged 11 outperformed their counterparts aged 10 years in both sprint speed intervals. In addition, our statistical calculation showed that 13 years boys outperformed their counterparts aged 12 years in 10-m, and 30-m sprint performance. According to Malina et al. (2004) age-related differences in PF are typically attributed to growth (i.e., increases in body size and body dimensions) and maturation (i.e., somatic, skeletal, and sexual maturity) that occur during childhood and adolescence. Likewise, our findings showed that 11 years old boys are taller and have more fat-free mass in comparison with their 10 years old peers (Table 1). In the same context, results revealed that 13 years old boys are taller than 12 years old peers (Table 1). These findings could be attributed to the fact that taller people have potential to build more absolute muscle mass because they have a bigger skeletal frame to attach it (Nevill et al., 2021). While this makes intuitive and physiological sense, the centile analysis predicts that those in the highest centiles for a particular age group can outperform older children, even those several years older (Tables 3 and 4). Our results suggest that boys outperformed girls in both sprint speed intervals except for those aged 8 years old. These sex differences may be explained by previous experience in exercises similar to these test items. It may be typically more common for boys to participate in activities that include these competences than it is for girls. The observed sex differences may also be explained by higher levels of physical activity in boys than in girls (Trost et al., 2002). Nonetheless, girls in the highest centiles are predicted to outperform boys in the low (C1) to mid (C50) centiles (Tables 3 and 4).

This study has some limitations which warrant discussion. Our findings are limited to healthy boys and girls aged 8 to 14 years. Further, we did not assess additional factors such as biological maturation (e.g., age at peak height velocity), daily activities (e.g., time spent watching TV or playing computer games) in our analyses that may have an impact on children's PF level and development. In addition, others physical qualities must be addressed in future studies (i.e., strength, flexibility, and change of direction speed).

Conclusions

This is the first normative data for handgrip strength, vertical jump, and sprint speed performances in 8 to 14 years old Tunisian children using centile curves. The results of the present study show the importance of producing normative values for particular populations. The reference values presented herein can be used for subsequent surveillance of the PF of Tunisian children and adolescents.

Data Availability:

The datasets generated during and/or analyzed during the current study are not publicly available because individual privacy, including self-information, could be compromised but are available from the corresponding author on reasonable request.

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Author A, B and author C have given substantial contributions to the conception or the design of the manuscript, author B and author E to acquisition, analysis and interpretation of the data. All authors have participated to drafting the manuscript, author D, and E revised it critically. All authors read and approved the final version of the manuscript. Authors A and B contributed equally to the manuscript and read and approved the final version of the manuscript.

		Age (years)						
	Gender	8	9	10	11	12	13	14
Number	Boys	63	53	88	76	44	42	28
	Girls	21	24	43	48	23	27	11
Height (m)	Boys	134.00±6.95	141.36±7.10[a]	146,05±6.23[a]	151.59±7.54[a]	157.53±10.46[a]	167.90±9.56[ad]	175.61±5.64[ad]
	Girls	133.54±5.30	139.91±8.02[b]	147.28±7.70[b]	151.82±5.70	156.98±7.60	159.04±3.80	160.55±8.10
BM (kg)	Boys	32.73±8.36	36.03±7.59	40.08±8.87	44.01±9.58	49.30±13.80	53.29±13.15	67.29±14.29 [a]
	Girls	31.49±7.75	37.21±11.51	43.95±13.51	47.46±10.72	55.90±15.04	49.67±10.80	61.15±17.53
BMI (kg/m^2)	Boys	18.04±3.15	17.98±3.28	18.69±3.38	19.01±3.10	19.66±4.27[c]	18.68±3.26	21.75±4.32[a]
	Girls	17.49±3.14	18.76±4.40	19.94±4.20	20.52±4.15	22.67±6.07	19.65±4.23	24.00±7.83
Body fat (%)	Boys	17.83±13.14	17.73±15.88	19.85±17.38	19.67±14.68	18.91±17.23	14.92±11.04[c]	18.92±14.91
	Girls	18.20±5.92	20.60±6.23	22.32±5.87	21.14±5.72	21.56±4.89	21.28±5.91	22.45±6.08
Fat mass (kg)	Boys	6.70±7.44	7.35±9.13	9.08±10.12	9.62±8.66	10.51±12.84	8.80±8.96[c]	14.40±14.53
	Girls	5.83±2.63	7.89±4.02	9.83±4.08	10.11±3.71	12.10±4.24	10.42±2.98	14.39±7.76
Fat free mass (kg)	Boys	26.03±3.83	28.62±4.72[a]	31.03±5.93	34.39±5.86[a]	38.79±10.92	44.49±9.17	52.89±8.35[a]
	Girls	25.66±6.32	29.32±8.48	34.12±10.66	37.34±8.55	43.80±12.15	39.25±9.70	46.76±10.47

a: denotes differences between age vs. previous age within boys' group, ($p<0.05$); b: denotes differences between age vs. previous age within girls' group, ($p<0.05$); c: denotes differences between boys and girls in the same age group, ($p<0.05$); d: denotes differences between boys and girls in the same age group, ($p<0.01$); BM: Body-mass; BMI: Body mass index

Table1: Means (± standard deviation) for anthropometric characteristics in healthy Tunisian schoolchildren by age and gender

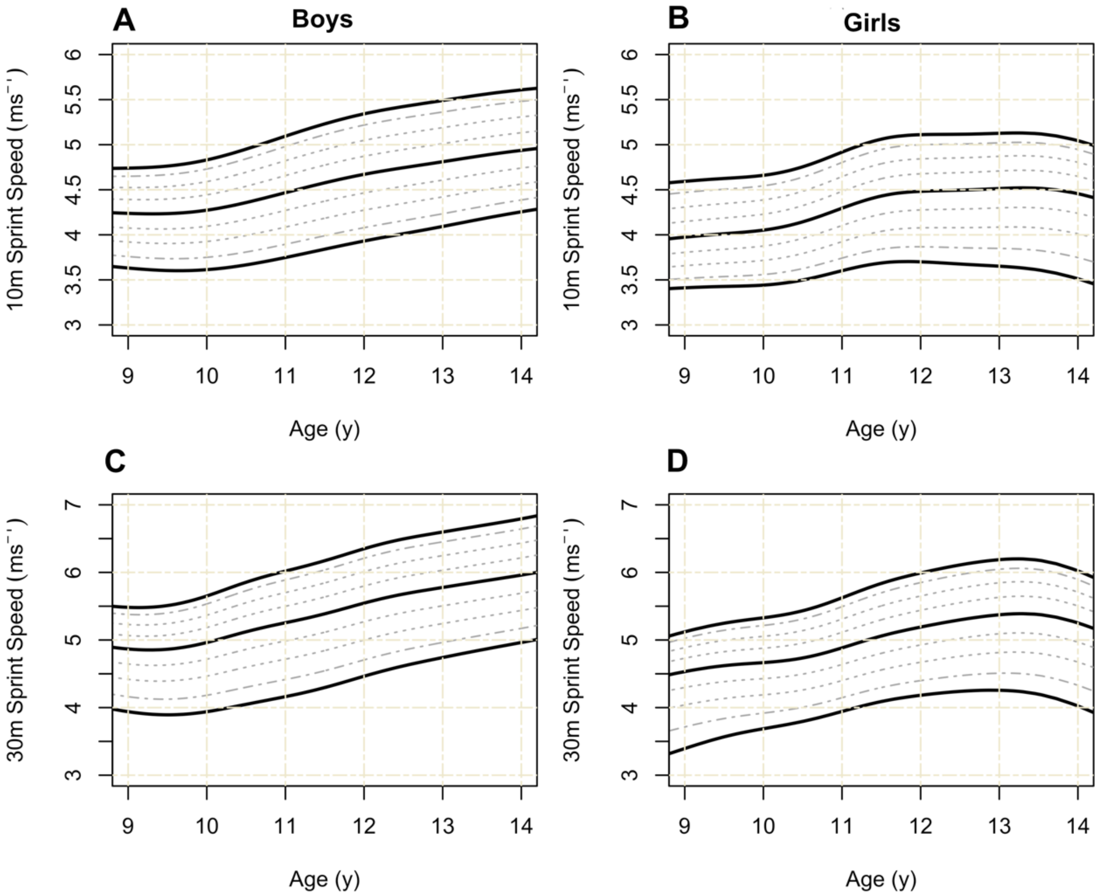

Figure 1. Centile charts for boys and girls 10m and 30m sprint speed (ms-1)

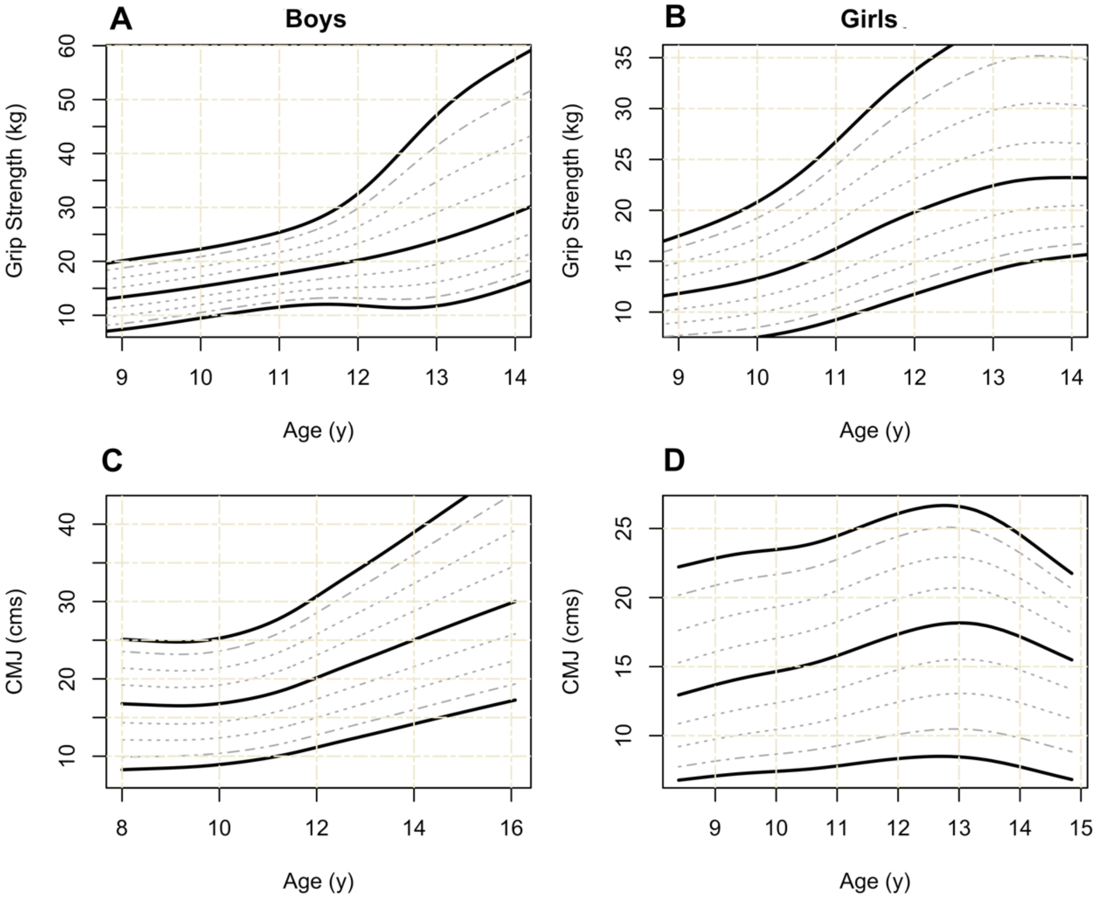

Figure 2. Centile chart for boys and girls grip strength (kg) and CMJ (cm)