Acta Kinesiologica 18 (2024) Issue.1
DOI. 10.51371/issn.1840-2976.2024.18.1.9

Original Investigation

Percentile norms for the 10x5-meters shuttle run test in a large sample of primary school-aged children: A cross-sectional study

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Purpose: In the preceding two decades, comprehensive documentation pertaining to reference standards of health-related physical fitness of school-aged children has emerged. However, prevailing research has mainly concentrated on the establishment of muscular and cardiorespiratory metrics, neglecting certain physical fitness components (notably, motor fitness) for which reference standards have yet to be formulated. Therefore, the main objective of this study was to construct reference standards for the 10×5-meters shuttle run test for Croatian primary school-aged children.
Methods: In this cross-sectional study, the participants were 1.512 healthy children and adolescents residing in the urban area of the city of Zagreb, Croatia (mean age: 9.7 years, range 7-14 years; mean height: 151.0 cm, range 138-173 cm; mean weight: 45.1 kg, range 32-60 kg; 52.5% girls). Sex- and age-specific variations, as well as effect sizes (ES), were investigated through the application of analysis of variance within the study framework for the 10×5-meters shuttle run test.
***Results*:** he median scores for the 10×5-meters shuttle run test were 22.1 seconds for boys and 23.2 seconds for girls. Sex- and age-specific analyses revealed statistically significant differences, indicating that boys achieved better results compared to girls ($F_{1,15}$ = 36.06, P< .001; ES = .33). Additionally, older boys and girls outperforming their younger counterparts ($F_{1,15}$ = 30.32, P< .001; ES = .45). Finally, the interaction between sex and age remained significant ($F_{1,15}$ = 2.50, P= .015; ES = .24), underscoring that older boys were faster in completing the task when compared to individuals of other sex and age groups.
Conclusions: This study revealed discernible sex- and age-related disparities in the 10×5-meters shuttle run test among primary school children. These findings imply that chronologically younger children, particularly younger girls, achieved lower scores. Consequently, these findings underscore the necessity of targeted interventions to enhance speed and coordination/agility abilities in the aforementioned demographic subgroups.

Keywords: Standards; Children; Motor fitness; Differences; School

Introduction

Physical fitness has been widely recognized as a noncommunicable marker intricately linked to well-being and health[1]. In the literature, physical fitness is often defined as 'an integrated measure of most, if not all, body functions (skeletomuscular, cardiorespiratory, haematocirculatory, psychoneurological and endocrine–metabolic) involved in the performance of daily physical activity and/or physical exercise'.[1] Research has demonstrated that children with higher levels of physical fitness are at a lower risk of developing cardiovascular disease in adulthood.[2-4]
Physical fitness represents a multifactorial construct encompassing elements such as body composition, muscular and cardiorespiratory fitness, speed/agility and flexibility[1]. Most of these components have been used to create reference standards for school-age children and adolescents[2,5,6]. The importance of defining sex- and age-specific values of physical fitness is to allow for the identification of children and adolescents with problems in physical and/or motor development[7]. For example, children with poor physical fitness may exhibit a delayed motor development accompanied by difficulties in motor coordination and problems with the execution of everyday activities.[4] Additionally, comparing and interpreting physical status at the individual and population levels allows for the implementation of effective interventions and policies aiming to maintain or even increase physical fitness[8].
Although previous studies have created reference charts for physical fitness in children and adolescents[5,6,9], only a limited number of studies have specifically established data pertaining to speed/agility tests for the assessment of motor fitness[9-12]. Reference standards on this topic are crucial for establishing children with lower levels of motor performance, which may indirectly be associated to poor motor development in future years[4]. The most prevalent field-based test designed to assess motor fitness is the shuttle run test[9], which requires a combination of both speed and agility/coordination to complete a trial. Unfortunately, the most comprehensive earlier study involved participants aged 9 to 17 years, omitting those aged younger than nine years. Kolimechkov et al.[11] highlighted a notable gap in the existing European norms for the shuttle run test, specifically emphasizing the absence of percentile scores.
Therefore, the primary objective of this study was to establish reference standards for the 10×5-meters shuttle run test, aiming to assess speed and agility in Croatian primary school children aged between seven and 14 years. Based on previous literature

indicating an improvement in motor skills, including speed and agility, with age, we hypothesize that older boys and girls would exhibit faster times than their younger counterparts[9-12].

Materials and methods

Study participants and testing procedure

This study builds upon previously published work[13]. In brief, by using a random sampling approach, a representative sample of 1.514 healthy children and adolescents aged between 7 and 14 years were recruited from the city of Zagreb (the capital city of Croatia) between September 2022 and December 2023. All procedures performed in this study were anonymous, in accordance with the Declaration of Helsinki, and approved by the local University. Written informed consent for participation was obtained from all participants and from the parents or legal guardians of the participants under the age of 16.

Participants were required to have comprehensive data measurements, including height (using stadiometer with a precision of 0.1 cm, Seca Corp.), weight (using digital scale with a precision of 0.1 kg), waist circumference (measured 2 cm above the umbilicus at the widest part of the trunk) and completion of the 10×5-meters shuttle run test. The inclusion criterion for participants was an absence of any musculoskeletal or mental health issues, as verified by a medical professional. Individuals diagnosed with acute or chronic conditions that prevented them from attending physical education classes, as well as individuals lacking complete data, were excluded. The testing protocol and data evaluation have been described previously[13]. In brief, the 10×5-meters m shuttle run test was measured from September to October in each selected school and during physical education classes indoors. Before testing, all physical education teachers were instructed about the procedure for undertaking the 10×5-meters shuttle run test. During the testing, children were told to wear a light T-shirt, shorts and training shoes. All participants were well-rested and were instructed to give their best in completing the assignment.

The 10×5 meters shuttle run test

To assess motor fitness, the participants performed the 10×5-meters shuttle run test. In the field test, two parallel lines, each 1.20 m long, were drawn on the floor using tape. The lines were positioned five metres apart and marked with cones at their ends. Each participant was instructed to cross the line each time with both feet, executing turns as quickly as possible. To minimize slipping, the test was conducted on a slip-resistant floor. Scores were determined using a stopwatch. The time required to complete five cycles was recorded in tenths of a second[14].

Statistical analysis

The mean and standard deviation (SD) were used as basic descriptive statistics. Specific analyses and differences stratified by sex and age were calculated by using analysis of variance with Bonferroni-corrected *post hoc* comparisons. For the 10×5-meters shuttle run, percentile values (5th, 10th, 25th, 50th, 75th, 90th and 95th) were performed. The assumptions of Levene's test of homogeneity, a normal population distribution and data independence were all met. To assess the magnitude of difference between sex and age, the Cohen *d* effect size (ES) was calculated with the following cut-offs: 1) < .3, small; 2) .3–.5, medium; 3) .5–.8, large; and 4) > .8, very large[15]. The significance level was fixed at $P< .05$. All analyses were conducted using Statistical Packages for Social Sciences version 23 (SPSS, Inc., Chicago, Illinois, USA).

Results

For the purpose of this study, 1,512 children and adolescents aged seven to 14 years were included (mean age: 9.7±2.4 years; stature: 151.0±17.6 centimetres; body mass 45.1±9.1 kg; 52.5% girls). Basic descriptive statistics are presented in Table 1. Notably, compared with girls, boys exhibited greater height, weight, waist circumference and waist-to-height ratios.

Table 1. Basic descriptive statistics of the study participants

Variables	Boys	Girls	ES	*P*
Stature (cm)	152.0 (19.4)	150.2 (15.7)	.10	.046
Weight (kg)	46.5 (13.3)	43.9 (14.0)	.19	.007
Body mass index (kg·m^{-2})	19.2 (3.7)	18.9 (3.3)	.09	.158
Normal weight (%)	85.3 (78.4 – 90.3)	85.5 (79.0 – 89.2)		
Overweight/obesity (%)	14.7 (12.7 – 16.8)	14.5 (13.0 – 16.4)		.943
Waist circumference (cm)	67.1 (10.0)	64.0 (8.8)	.33	<.001
Waist-to-height ratio	.44 (.05)	.43 (.05)	.20	<.001
10x5-metre shuttle run test (s)	22.6 (3.2)	23.6 (2.8)	.33	<.001

Note: all variables are showed as mean/SD, ES= effect size (* - $P< .05$).

The distributions of 'normal' weight and 'overweight/obesity' classifications were similar among boys and girls. Furthermore, boys demonstrated faster completion times in the 10×5-meters shuttle run test than girls did (22.62 ± 3.15 s *vs.* 23.61 ± 2.81 s, $P < .001$).

Table 2 shows the reference standards for the 10×5-meters shuttle run stratified by sex and age. Analyses based on sex and age revealed that boys outperformed girls ($F_{1,15} = 36.06$, $P< .001$; ES = 0.33), and older boys and girls achieved better results compared to their younger counterparts ($F_{1,15} = 30.32$, $P< .001$; ES = .45). Notably, a Bonferroni-corrected *post hoc* analysis indicated that 13- and 14-year-old boys and girls exhibited significantly better scores in the 10×5-meters shuttle run than did their counterparts aged seven to 12 years. Finally, a significant main effect was observed for the interaction between sex and age ($F_{1,15} = 2.50$, $P= .015$; ES = .24). Notably, the fastest results were achieved by older boys, followed by older girls and subsequently younger boys and girls. Visual representations of the 10×5-meters shuttle run test are provided in Figure 1 for boys (A) and girls (B).

Table 2. Reference standards (percentiles, P) for the 10x5-meters shuttle run in boys and girls

Gender	Age (y)	N	P5	P10	P25	P50	P75	P90	P95
Boys	7	190	29.00	27.84	24.98	22.20	21.10	20.40	20.17
	8	85	28.59	26.77	23.99	22.07	20.90	20.56	19.86
	9	102	27.21	25.60	23.54	21.92	20.59	20.07	18.61
	10	72	27.81	26.63	23.80	22.11	20.90	20.56	19.22
	11	70	27.83	26.54	24.34	22.09	20.96	20.16	19.32
	12	65	27.12	25.55	23.75	22.48	20.76	20.07	19.22
	13	69	25.12	23.87	22.77	21.00	19.49	18.90	18.02
	14	66	24.16	22.67	21.31	20.16	18.74	18.50	18.07
Girls	7	228	30.12	28.80	25.15	23.38	22.02	20.91	19.89
	8	72	29.72	27.62	25.88	23.90	22.25	21.68	20.16
	9	153	29.27	27.11	25.40	23.70	22.09	21.48	20.53
	10	67	29.24	27.14	25.26	23.60	22.32	21.60	20.35
	11	75	27.38	26.27	24.54	22.76	21.40	20.74	20.20
	12	65	26.93	24.99	23.68	22.40	21.24	20.47	19.59
	13	70	25.92	25.13	23.33	22.07	20.67	20.22	19.11
	14	65	26.18	25.34	23.68	21.74	20.41	20.16	19.15

Discussion

The main purpose of this study was to establish reference standards for the 10×5-meters shuttle run test in children aged seven to 14 years. The key findings of the study are as follows: (i) boys outperformed girls; (ii) older boys and girls achieved faster times than their younger counterparts; and (iii) older boys, especially those aged 12 to 14 years, achieved faster times than younger boys and both older and younger girls in the 10×5-meters shuttle run test.

The 10×5-meters shuttle run test has been widely employed to assess the level of combined speed and agility abilities in children and adolescents[9,14,16]. Our findings align with those of Tomkinson et al.[9]. Drawing upon results from children and adolescents representing 19 countries, median values ranged between 22.94 seconds (nine-year-olds) and 20.43 seconds (14-year-olds) for boys and from 23.88 seconds to 22.00 seconds for girls[9]. When contextualized, participants in our study achieved similar results compared to international norms (22.86±3.0 *vs.* our data = 23.11±3.03, $P = .355$). Unfortunately, physical fitness reference standards specific to Croatia were neither analysed nor added to the literature prior to this study[9]. Nevertheless, the same study indicated that boys outperformed girls, older boys and girls attained better results compared to their younger counterparts, and older boys exhibited faster results than older girls and younger boys and girls[9]. Notably, a

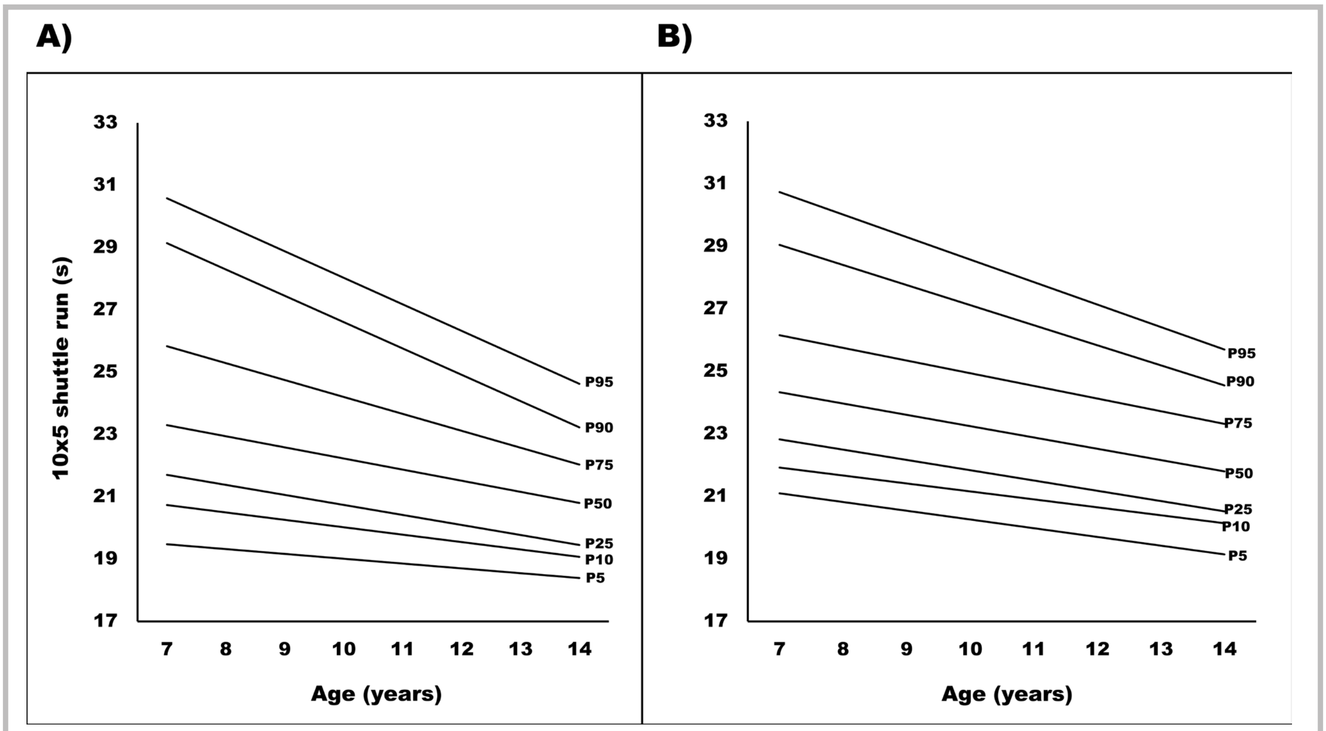

Figure 1. Graphical data of the 10×5-meters shuttle run percentiles for boys (A) and girls (B)

study by Tomkinson et al.[9] revealed a moderate effect size (ES) in the 10×5-meters shuttle run test between boys and girls, a result consistent with our study (ES between sexes = .33). When age-specific analysis was applied, the findings in our study demonstrated a linear positive trend in both boys and girls. As anticipated, there was a progressive improvement in the 10×5-meters shuttle run test with increasing age. However, in the study by Tomkinson et al.[9], there was consistent improvement in results with age among boys, while girls reached a plateau at the age of 11, which is somewhat contradictory to the findings in our study. The disparity in findings could be attributed to variations in sample sizes within each sex- and age-specific category, differences in data collection methods (temporal[9] *vs.* cross-sectional at a single time point), and other factors that might have influenced the performance of fitness tests. The most recent study on this topic included nearly eight million test results, and Croatia was classified as an 'intermediate' European country in terms of cardiorespiratory and muscular fitness[9]. Although we did not assess other physical fitness components, the relatively better achievement in the 10×5-meters shuttle run test in this study could be attributed to previously reported higher values of cardiorespiratory and muscular fitness[9]. This suggests that physical fitness is a multicomponent construct and that higher values in one component may correspondingly result in higher values in another[9].

This study is not without limitations. First, due to the cross-sectional nature of the study design, the natural changes in the 10×5-meters shuttle run test could not be determined. Second, it is speculated that children with higher levels of physical activity may have been more motivated to participate in a study of this nature. Thus, the possibility of potential selection bias cannot be excluded. Additionally, the study exclusively involved participants from a single city, which means that careful consideration is needed when interpreting the generalizability of the findings. Furthermore, sex- and age-specific differences in reference standards are also limited by the potential for unmeasured confounding factors, such as biological maturation, which might have influenced the results.

Practical applications

Maintaining a higher level of physical fitness is a crucial component of overall health and a powerful protective factor against noncommunicable diseases later in life[1]. Notably, the assessment of physical fitness has become commonplace in several European countries, including Slovenia (SLOfit)[7], Portugal (FITescola)[17], Hungary (NETFIT)[18] and Finland (Move!)[19]. Such practices have produced significant benefits for children and adolescents. In a recent study, Slovenia was ranked among the European countries with the most physically fit citizens[5]. Despite the implementation of similar policies among Croatian youth[20], there is still a relatively high prevalence of overweight and obesity, estimated at approximately 35% to 40% for both boys and girls[21], which puts Croatia as one of the leading European countries that has a problem with overweight and obese children, compared to other countries.[22] Thus, health policy-makers should place special focus on enhancing the level of physical fitness from an early age.

Conclusions

This is the first study establishing sex- and age-specific reference standards for the 10×5-meters shuttle run test in a large sample of primary school-aged children. These newly established data are significant for several reasons. First, the data indicate that participants in the highest percentiles should be considered a target group for strategies aimed at enhancing motor speed and agility. Second, baseline percentiles can be easily remembered and tracked to assess longitudinal changes over time. Ultimately, these data can assist health-related and school-related professionals in incorporating the 10×5-meters shuttle run test as a screening tool at the beginning and end of a school year, which would enable the tracking of individual progress, evaluating intervention effectiveness and assessing outcomes.

Ethical Committee approval

Ethics Committee of the Faculty of Sports Studies, Masaryk University, Brno (ethical approval: 13-2022).

ORCID

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Topic

Sport Science.

Conflicts of interest

The authors have no conflicts of interest to declare.

Funding

No funding was received for this investigation.

Author-s contribution

Conceptualization, L.Š. and Z.K.; methodology, A.H.; software, L.Š. and Z.K.; validation, A.H. and Z.K.; formal analysis, L.Š. and Z.K.; investigation, L.Š. ;resources, L.Š. and Z.K; data curation, L.Š. and Z.K.; writing—original draft preparation, L.Š. and Z.K.; writing—review and editing, L.Š., Z.K. and A.H.; visualization, L.Š., Z.K. and A.H.; supervision, L.Š.; project administration, L.Š. All authors have read and agreed to the published version of the manuscript.

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Accepted: 16.03.2024.
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