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THE STUDY OF THE RELATIONSHIP BETWEEN PHYSICAL DEVELOPMENT AND CARDIORESPIRATORY FITNESS IN MALE CHILDREN AND ADOLESCENTS AGED 9-17 YEARS

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The study of the relationship between physical development and cardiorespiratory fitness in male children and adolescents aged 9-17 years

Abstract. The aim of the study is to identify the orientation and degree of interrelationships between the indicators of physical development and cardiorespiratory endurance of male children aged 9-17 years. The anthropometric profile of the study participants was assessed by the following indicators characterizing the physical development of children and adolescents: height, weight, waist circumference, body fat percentage at two points on the body (in the triceps and subcapular region), body mass index and waist-to-height ratio. Cardiorespiratory endurance was assessed by us based on the results of the "20 m progressive shuttle run" test. As a result of the study, we did not receive unambiguous confirmation of the relationship between indicators of physical development and cardiorespiratory endurance. We found this dependence only in the age periods from 9 to 12 years, as well as from 16 to 17 years. In these age groups, physical development indicators such as weight, BMI, waist circumference, waist-to-height ratio, and body fat negatively correlated with the results of the progressive 20 m shuttle run, such as the number of stages, number of shuttles, distance traveled, total running time, and VO_2 max.

Key words: children, adolescents, physical development, physical fitness, cardiorespiratory endurance.

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9-17 жас аралығындағы ер балалар мен жасөспірімдердің дене дамуы мен кардиореспираторлық даярлығы арасындағы байланысты зерттеу

Аңдатпа. Зерттеудің мақсаты – 9-17 жас аралығындағы ер балалардың дене дамуы мен кардиореспираторлық төзімділігінің көрсеткіштері арасындағы өзара байланыстың бағыты мен дәрежесін анықтау. Зерттеуге қатысушылардың антропометриялық профилі балалар мен жасөспірімдердің физикалық дамуын сипаттайтын келесі көрсеткіштер көмегімен бағаланды: бойы, салмағы, бел шеңбері, дененің екі нүктесіндегі дене майының пайызы (трицепс және субкапулярлы аймақ), бой-салмақ индексі және бел мен бойдың арақатынасы. Кардиореспираторлық төзімділікті біз «20 м прогрессивті шаттлмен жүгіру» сынағының нәтижелері бойынша бағаладық. Зерттеу нәтижесінде біз физикалық даму көрсеткіштері мен кардиореспираторлық төзімділік арасындағы байланыс туралы біржақты растау алған жоқпыз. Бұл байланысты тек 9 жастан 12 жасқа дейінгі, сондай-ақ 16 жастан 17 жасқа дейінгі жас кезеңдерінде байқадық. Аталған жас топтарында салмақ, БСИ, бел шеңбері, бел мен бой арасындағы қатынасы және дене майы сияқты дене дамуы көрсеткіштері, сатылар саны, шаттлдар саны, жалпы қашықтық, жалпы жұмыс уақыты және ОТШ сияқты 20 м прогрессивті шаттл жүгірісінің нәтижелерімен теріс байланыста екендігін байқадық.

Түйін сөздер: балалар, жасөспірімдер, дене дамуы, дене дайындығы, кардиореспираторлық төзімділік.

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Изучение взаимосвязи между физическим развитием и кардиореспираторной подготовленностью у детей и подростков мужского пола в возрасте 9-17 лет

Аннотация. Целью исследования является выявление направленности и степени взаимосвязей между показателями физического развития и кардиореспираторной выносливости детей мужского пола в возрасте 9-17 лет. Антропометрический профиль участников исследования оценивался по следующим показателям, характеризующим физическое развитие детей и подростков: рост, вес, окружность талии, процентное содержание жира в двух точках тела (в области трицепса и лопатки), индекс массы тела и отношение талии к росту. Кардиореспираторная выносливость оценивалась по результатам теста «прогрессивный челночный бег на 20 м». В результате проведенных исследований не получено однозначного подтверждения взаимосвязи между показателями физического развития и кардиореспираторной выносливостью. Такая зависимость обнаружена только в возрастных периодах от 9 до 12 лет, а также от 16 до 17 лет. В этих возрастных группах показатели физического развития, такие как вес, ИМТ, окружность талии, соотношение талии к росту и жировые отложения, отрицательно коррелировали с результатами прогрессивного 20-метрового челночного бега, такими как количество этапов, количество шаттлов, преодоленная дистанция, общее время бега и МПК.

Ключевые слова: дети, подростки, физическое развитие, физическая подготовка, кардиореспираторная выносливость.

Introduction. Physical development is an important indicator of the health of children and adolescents, which is used in screening [1]. When conducting mass studies, the most predictive indicators for obtaining an understanding of the health of the study population are physical development indicators such as height, weight, BMI, body fat percentage, waist circumference, and indices calculated on the basis of these indicators. The assessment of the obesity index, the Tri-ponderal Mass Index, the waist-to-body mass index ratio [2-4], the body mass index, which is recommended by the World Health Organization [5] as an indicator of the prevalence of excess weight and obesity in the child and adolescent population, as well as the waist-to-height ratio [6], which allows differentiating between fat and lean mass, has great potential in the diagnosis of overweight and obesity. Most of these indicators are highly correlated with the risk of developing metabolic syndrome, obesity, and cardiorespiratory system pathologies in children and adolescents [7-9]. Given that the prevalence of overweight and obesity and the associated risks in the child and adolescent population is increasing every year, studying these indicators is a pressing issue.

Another important indicator of the health of children and adolescents is physical fitness, defined as a person's ability to perform physical exercises in harmony with their biological, psychological, and social nature [10] and identified by fitness testing. Monitoring and correction of physical fitness parameters in children and adolescents is particularly important, as it is a way of primary prevention and health promotion. In later stages of life, physical fitness will directly and indirectly determine a person's health and social well-being [11].

The main component of physical fitness is endurance or cardiorespiratory performance, which is evaluated in the laboratory by ergometric tests, such as the PWC_{170} bicycle ergometric test. The results of the PWC_{170} test, as well as the integral indicator reflecting aerobic performance (VO_2max indicator), are in direct correlation. The prognostic value of these indicators is due to the fact that an individual's physical performance is limited by the activity of the cardiovascular and respiratory systems [12]. Studies have also shown a negative relationship between indicators that characterize aerobic performance and the risk of spreading metabolic pathologies, obesity, and related diseases [13]. The study of aerobic performance can also contribute to obtaining information about the epidemiological and socio-cultural aspects of children and adolescents' health, since this indicator depends on a wide range of factors, such as family income, availability of adequate nutrition and its quality, weight, physical activity, screen time, etc. [14]. This makes it necessary to include endurance and aerobic performance assessments in child and adolescent health monitoring protocols.

In the absence of expensive equipment, aerobic performance can be determined by running tests, such as the progressive shuttle run for 20 m, the reliability and informative value of which is proved in the works of a number of authors [15, 16].

The study of the relationship between the results of progressive shuttle running and indicators that characterize physical development is of great interest to researchers and specialists in the field of physical education.

The aim of the study is to identify the direction and degree of correlation between indicators of physical development and cardiorespiratory endurance in male children aged 9-17 years.

Research objectives:

1. To identify whether there is a relationship between physical development and cardiorespiratory endurance.
2. To determine whether it is possible to use individual indicators of physical development to form conclusions about the presence or absence of overweight and obesity in children and adolescents.

Materials and Methods.

Procedure

The study protocols were approved by the Academic Commission of the Kazakh Academy of Sports and Tourism (Protocol № 1 dated November 25, 2022). Informed consent to participate in the study was obtained from the school principal, school teachers, children and their parents. The study protocol was developed in accordance with the Helsinki Declaration of 1975, as amended in 2024 [17].

A preliminary research program has been developed with a detailed description of the measurement procedure and frequently encountered errors during measurement. 6 researchers were instructed, who, in cooperation with physical education teachers, conducted research during physical education lessons. Each researcher monitored the measurement of one indicator. All researchers had knowledge of the age characteristics of the studied group (physiological features and physical training of children and adolescents).

After a preliminary analysis of literature sources and studying the practice of foreign countries that successfully implement systems for monitoring the physical health of children and adolescents, we identified tools that show high validity and are reliable tools for assessing physical development and the level of endurance development. During the study, we measured the following indicators that characterize the physical development of children and adolescents: height (cm), weight (kg), waist circumference (cm), body fat percentage at two points on the body (in the area of the triceps and subcapular area) [18]. During the study, we calculated the body mass index (kg /m2) and the waist-to-height ratio [19].

Cardiorespiratory fitness was assessed based on the results of a progressive 20 m shuttle run, the reliability and effectiveness of which has been proven by numerous studies. Testing was conducted in a closed gym of the school.

Participants

The study involved male children and adolescents (n=593) studying in secondary education institutions in Kazakhstan.

According to age, participants of the the study were divided into 4 age categories: 9 years (n=38), 10 years (n=73), 11 years (n=60), 12 years (n=67), 13 years (n=80), 14 years (n=76), 15 years (n=63), 16 years (n=62), 17 years (n=74). The inclusion criteria were: age from 9 to 17 years, absence of any chronic diseases, absence of infectious diseases at the time of the study, absence of contraindications to physical exercises, attendance of physical education classes at school.

The exclusion criteria were: the presence of musculoskeletal injuries and infectious diseases at the time of the study, contraindications to physical exercise. Participants were able to make their own decision to stop participating in the study without giving reasons and at any stage.

Measurements

Measurement of anthropometric parameters was carried out in the school's medical office. To measure height and weight, we used the BSM370 Automatic BMI Measuring Stadiometer with the function of measuring length, body weight and calculating body mass index. Height and weight were recorded in the protocol with an accuracy of 0.5 cm and 100 g.

To measure the waist circumference (WC), the subject stood up straight. The measurement was performed three times, and the average result of three measurements was recorded.

When measuring the thickness of skin folds (%BF), we were guided by the standardized ISAK protocol [20]. The following measurements were made:

vertical crease in the area of the triceps;.

subcapular fold on the lower corner of the scapula.

The measurement was performed on the right side of the torso.

When calculating the percentage of fat, the two-component model Slaughter MH et al. (1988) is used as a basis [21].

Calculation of the percentage of subcutaneous fat was carried out according to the formula:

$\%F\ (\%BF) = 1{,}21 \times (TR+SS) - 0.008 \times (TR+SS)^2 - 1.7$

If the sum of skin-fat folds is more than 35 cm, the calculation was carried out according to the formula:

$\%BF = 0.783 \times (TR+SS) + 1.6$

where TR (triceps skinfold) and SS are the thickness of the skin-fat fold in the area of the triceps and subscapular zone (subscapular skinfold) in mm.

When interpreting the results, we were guided by the limits proposed by WHO for boys aged 9-17 years [22].

Test "Progressive shuttle run for 20 m". It was held during physical education lessons. The Beep Shuttle Advanced Rev:3.2 software was used to conduct the test.

Before the test, a light warm-up for the main muscle groups and a preliminary instruction were conducted. At the same time, 2-3 participants took part in the race. The number of stages, shuttles, total running time, distance, and MOC values were counted automatically after participants completed the test. BMD indicators were compared using evaluation tables developed by Kolimechkov S., Petrov L. & Alexandrova A. (2019) [23] to assess cardiorespiratory endurance in European children and adolescents.

Statistical analysis

Statistical analysis was performed in the IBM SPSS STATISTICS software package (version 27), suitable for research in the humanities.

Statistical processing was preceded by an initial check of the quality and structure of the data. To identify the central trend of the sample, the spread of data, and the most frequently occurring values of the indicator, we calculated the arithmetic mean and standard deviation (SD).

The reliability of differences in the studied indicators with age was assessed using the Kruskal-Wallis test (H-test), as a nonparametric analogue of one-factor analysis of variance. The use of this method is justified by the fact that the distribution of the study data did not correspond to the normal distribution ($p < 0.05$ according to the Shapiro-Wilk test).

The relationship between the two variables was estimated using Spearman's paired rank correlation coefficient.

Results. The main anthropometric indicators of male children aged 9-17 years are in Table 1.

It was revealed that all anthropometric indicators of Kazakhstani children aged 9-17 years are within the age norm. A large variability of the studied indicators was also revealed, as evidenced by large SD values.

Table 1 – Indicators of anthropometric measurements of Kazakhstani male children aged 9-17 years

Age, years	Height, cm	Weight, kg	BMI, kg/m^2	WC, cm	% BF	W/H, cm/cm
Mean ±SD						
9.66±0.24 (n=38)	140.03±6.25	36.26±9.62	18.33±3.88	63.00±10.83	16.20±9.84	0.45±0.07
10.48±0.26 (n=73)	142.15±5.93	35.85±7.89	17.65±3.04	62.36±8.13	14.83±7.70	0.44±0.05
11.5±0.29 (n=60)	146.77±6.12	38.37±7.97	17.69±2.76	62.10±7.08	15.69±7.07	0.42±0.04
12.40±0.31 (n=67)	154.88±7.81	44.58±9.73	18.44±2.87	65.17±8.46	16.06±7.27	0.40±0.10
13.38±0.27 (n=80)	161.60±8.19	49.15±10.42	18.71±3.18	66.43±6.71	14.90±6.05	0.41±0.04
14.49±0.29 (n=76)	166.55±7.93	54.17±10.22	19.43±2.91	70.08±7.23	14.94±6.81	0.40±0.09
15.44±0.27 (n=63)	172.24±6.10	61.75±13.62	20.72±3.97	73.15±9.51	15.59±7.18	0.42±0.07
16.48±0.27 (n=62)	176.39±6.66	65.42±9.41	21.07±2.91	71.98±6.43	15.65±4.81	0.41±0.04
17.46±0.34 (n=74)	177.10±6.95	65.20±10.84	20.77±3.22	72.21±8.68	14.64±6.39	0.40±0.08

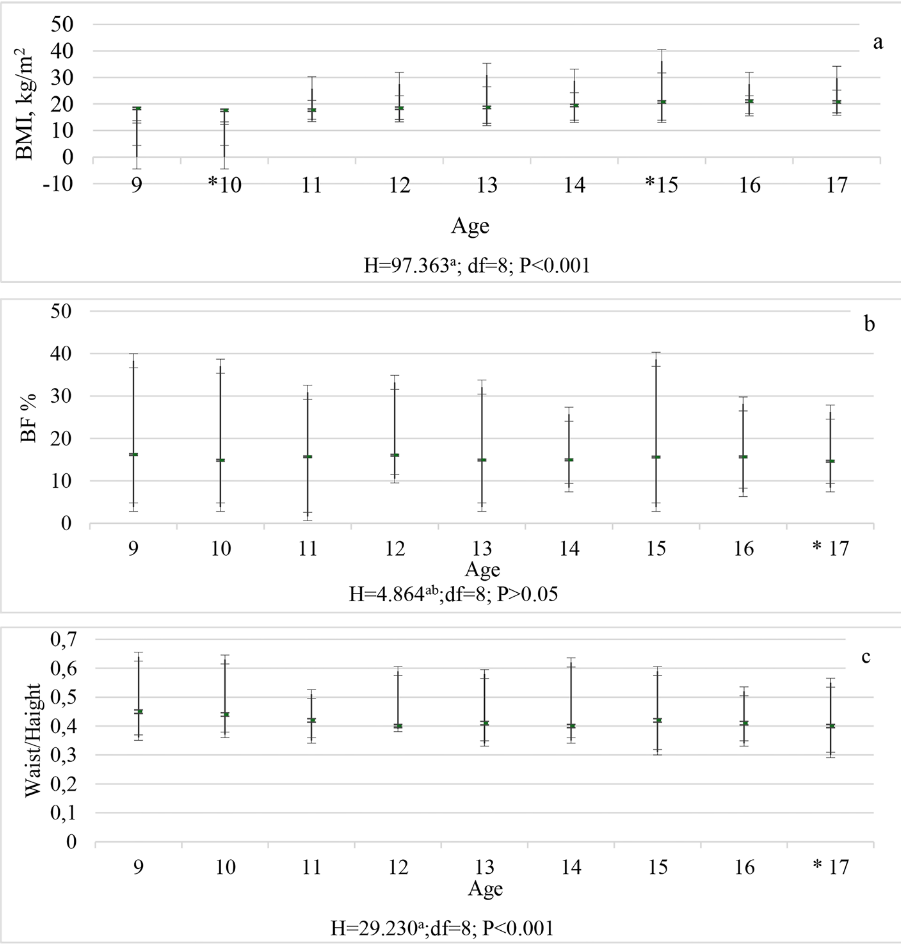
A regular increase in the indicators of height and weight, waist circumference of Kazakhstani children and male adolescents aged 9-17 years was revealed. Table 1 shows a tendency for BMI to increase with age, while no clear trend in body fat percentage was observed. The highest values of this indicator were found in children aged 9 and 12 years.

Analysis of the reliability of the dynamics of anthropometric indicators in boys aged 9-17 years using the Kruskal-Wallis method (Figure1a) showed that statistically significant dynamics of this indicator was revealed only when comparing this indicator in 9-year-olds, compared with 14-year-olds ($p<0.05$), 9-year-olds and 15-year-olds, 16 and 17-year-olds ($p<0.001$). There was also a significant difference in BMI between children aged 10 and adolescents aged 13 ($p<0.05$), as well as adolescents aged 14, 15, 16 and 17 ($p<0.001$); in 11-year-olds with 14, 15, 16 and 17-year-olds ($p<0.001$); in 12-year-olds with 14-year-olds ($p<0.05$) and 15, 16, and 17-year-olds ($p<0.001$); in 13-year-olds with 15, 16, and 17-year-olds ($p<0.001$). A less noticeable but still significant difference was found in the BMI index in 14-year-olds compared to 16 and 17-year-olds ($p<0.05$). There was no significant difference in BMI in 16- and 17-year-old adolescents.

The analysis did not reveal statistically significant changes in the percentage of body fat in children aged 9-17 years with age ($H=4.864^{ab}$; df=8; $p>0.05$) (Figure 1b).

The values of the waist-to-height ratio generally did not exceed normal values and amounted to 0.417±0.068 cm/cm in the study group. Analysis of multiple paired comparisons revealed insignificant but statistically considerable dynamics of this indicator only in the group of 9-year-olds compared to 16-year-olds ($p<0.05$) and in the group of 10-year-olds compared to 13, 16 and 17-year-olds ($p<0.05$) (Figure 1c).

Analysis of the results of progressive shuttle running for 20 m showed a tendency to increase the quantitative indicators of work performed with age (Table 2). However, despite the increase in the number of stages, shuttles, the total distance covered and the total time spent working with age, the opposite trend was revealed in terms of VO_2 max indicators.



Note: In each row, the null hypothesis that Sample 1 and Sample 2 have the same distributions is tested. Asymptotic values (2-sided criteria) are given. The significance level is .050. a – The Bonferroni correction was made to the significance values for several trials; ab – Multiple comparisons were not performed because the general criterion did not show significant differences in all samples.

Figure 1 – Dynamics of anthropometric indicators in Kazakhstani male children aged 9-17 years

Table 2 – Results of the test "Progressive shuttle running for 20 m" of Kazakhstani male children aged 9-17 years

Age, years	**Number of stages**	**Number of shuttles**	**Distance**	**Total operating time of**	**VO_2 max ml / min/kg**
	Mean ±SD				
9.66±0.24	3.89±1.42	26.66±12.77	533.16±255.46	191.99±90.03	47.42±3.45
10.48±0.26	4.03±1.37	28.36±11.95	567.12±239.08	204.28±86.19	46.02±5.97
11.5±0.29	4.68±1.39	34.22±12.61	684.33±252.13	244.62±87.74	46.44±3.54
12.40±0.31	4.60±1.49	33.98±13.29	679.55±265.82	241.98±94.52	44.79±3.94
13.38±0.27	7.90±1.69	36.25±15.50	725.00±310.11	257.89±106.08	43.92±4.44
14.49±0.29	5.30±1.69	40.09±15.58	801.84±311.69	284.08±105.09	43.26±4.52
15.44±0.27	5.98±1.90	47.38±18.66	947.62±373.29	334.0.4±122.66	40.91±8.49
16.48±0.27	6.02±1.99	47.84±18.77	956.77±357.32	362.50±210.19	42.37±5.65
17.46±0.34	5.88±1.69	46.02±16.24	920.41±324.82	323.77±107.29	40.30±5.14

An analysis of the dynamics of this indicator, conducted using the Krussskol-Wallis method, showed that there was no significant difference in VO_2 max indicators in the age range between 9 and 12 years (Figure 2). There was a difference in VO_2 max indicators between the following age groups: 9-year-olds compared to 13-year-olds ($p<0.005$); 14-year-olds ($p<0.001$); 15-year-olds ($p<0.05$); 16-year-olds and 17-year-olds ($p<0.001$). There was also a difference in VO_2 between 10-year-olds compared to 13-year-olds ($p<0.05$), 14-year-olds ($p<0.001$), and 16 and 17-year-olds ($p<0.001$). The difference in this indicator is also present in the group of 11-year-olds compared to 13-year-olds ($p<0.05$); 14-year-olds ($p<0.05$); 16 and 17-year-olds ($p<0.001$). In the group of 12-year-olds, VO_2 max indicators significantly differ from those of 17-year-olds ($p<0.001$), and in the group of 13-year-olds, a significant difference was found only in comparison with the group of 17-year-olds ($p<0.05$).

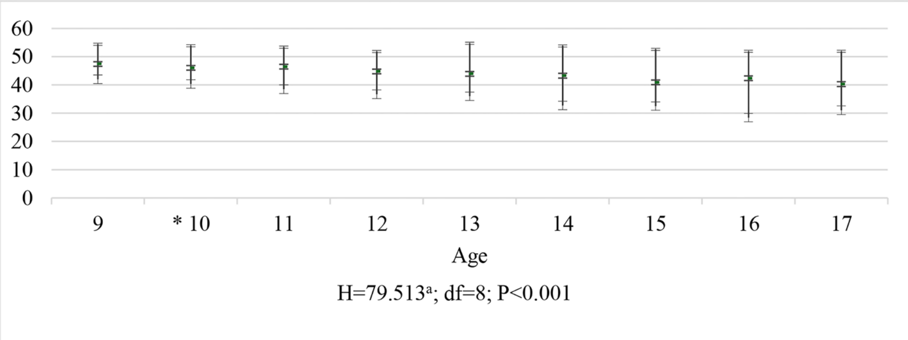


Figure 2 - Dynamics of VO_2 max in male children of Kazakhstan aged 9-17 years

Analysis of individual performance values of Kazakhstani children and adolescents aged 9-17 years on the test "20 m progressive shuttle run" showed that the results of most of the surveyed people are estimated as "average" (Figure 3).

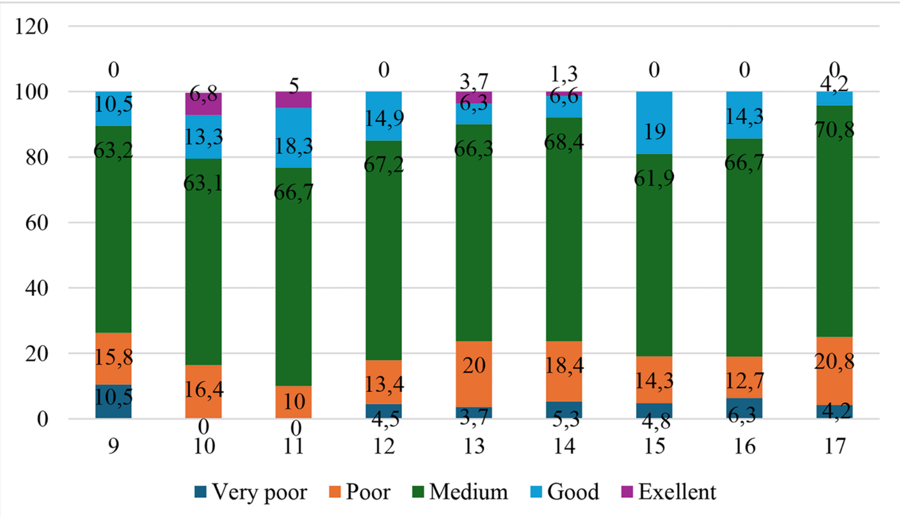


Figure 3 – Distribution of cardiorespiratory endurance indicators in male children of Kazakhstan aged 9-17 years (%)

Figure 3 shows that the percentage of children and adolescents with cardiorespiratory endurance rated as "good" and "very good" increases until the age of 11. In subsequent age periods (from 12-

15 years), there is a tendency to reduce the number of children and adolescents who have successfully mastered the regulatory requirements of the "progressive 20 m shuttle run" test. In the group of 17-year-old boys, the percentage of those who passed this test with a "good" grade decreased, while the proportion of adolescents who passed with a "poor" and "very poor" grade increased to 20.8% and 4.2%, respectively.

Comparison of the average VO_2 max values with the normative standards proposed by Kolimechkov S., Petrov L., Alexandrova (2019) [23] for assessing cardiorespiratory endurance in European children showed that the average values of this indicator generally correspond to normal (Table 2). In children aged 9 and 11, the median VO_2 max values correspond to the 50th percentile, in children aged 10, 12, 13, 14 and 16 – the 40th percentile, and in 15 and 17-year-olds-the 30th percentile.

Analysis of Spearman's paired rank correlation values showed that the correlation between anthropometric indicators and indicators characterizing cardiorespiratory performance is present only in the group of boys aged 9, 10, 11 and 12 years (Table 3, 4, 5, 6, 7) and teenagers aged 16 and 17. In the age range of 13-15 years, there was no significant relationship between these indicators.

The analysis showed that the direction and strength of the correlations between individual physical development indicators and the results of the 20 m shuttle run are not uniform (Table 3).

Table 3 – Spearman's paired rank correlation values between growth indicators and the results of progressive shuttle running in boys aged 9-17 years

Ages	Body height Body weight	Body height BMI	Body height WC	Body height W/H	Body height % BF	Body height Number of levels	Body height Number of shuttles	Body height Covered distance	Body height Total time B	Body height $VO_{2\,max}$
9	.599**	.299	.319	.053	.221	.025	.025	.002	.001	.001
10	.587**	.140	.352**	-.069	.099	-.085	-.110	-.110	-.121	-.128
11	.965**	.306*	.329**	.246	-.098	.080	.141	.141	.145	.114
12	-.034	.087	.100	-.017	.104	-.139	-.143	-.143	-.140	-.258*
13	.661**	.281*	.438**	-.242	-.082	.117	.081	.081	.081	.050
14	.716**	.371**	.423**	-.033	.136	.144	.116	.116	.114	.097
15	.632**	.287*	.288*	-.011	-.012	.103	.105	.105	.100	.093
16	.299*	-.202	.182	-.225	.095	.061	.054	.054	.042	.054
17	.438**	-.020	.165	-.220	-.067	.024	.035	.035	.023	-.002

*Note: ** The correlation is significant at 0.01 (two-way); * The correlation is significant at 0.05 (two-way)*

Table 3 shows that growth does not correlate with any of the results of the progressive 20 m shuttle run. The exception is the age period of 12 years, in which there is a weak negative correlation (-0.258; $P<0.05$) between height and VO_2 max.

It was also found that in most cases, growth indicators significantly correlate only with indicators of weight, BMI and waist circumference. The only exception is the age of 12 years, when no correlation was found between these indicators. There was no correlation between height and waist-to-height ratio, or between height and body fat percentage.

Weight indicators do not affect any of the results of the progressive 20 m shuttle run (Table 4).

The exception is a reliable negative correlation of weak intensity, identified in the group of 10-year-old boys between weight and number of levels (-0.250; $P<0.05$), shuttles (-0.241; $P<0.05$), distance covered (-0.241; $P<0.05$), and total working time (-0.249; $P<0.05$). At the same time, the correlation between weight and VO_2 max was statistically unreliable. In the group of 9-year-old boys, although there was a correlation between these indicators, it was statistically unreliable.

Table 4 – Spearman's paired rank correlation values between weight indicators and the results of progressive shuttle running in boys 9-17 years

Ages	Body weight Body height	Body weight BMI	Body weight WC	Body weight W/H	Body weight %BF	Body weight Number of levels	Body weight Number of shuttles	Body weight Covered distance.	Body weight Total time B	Body weight $VO_{2\,max}$
9	.599**	.920**	.690**	.473**	.644**	-.270	-.271	-.271	-.286	-.286
10	.587**	.860**	.744**	.517**	.489**	-.250*	-.241*	-.241*	-.249*	-.227
11	.965**	.298*	.336**	.241	-.079	.093	.148	.148	.152	.147
12	-.034	.298*	.336**	-.079	.241	.093	.148	.148	.152	.147
13	.661**	.885**	.792**	.318*	.360**	-.003	-.027	-.027	-.027	
14	.716**	.880**	.737**	.380**	.461**	.125	.106	.106	.101	.087
15	.632**	.924**	.739**	.512**	.571**	.053	.046	.046	.047	.040
16	.299*	.828**	.740**	.607**	.594**	-.193	-.203	-.203	-.139	-.219
17	.438**	.855**	.787**	.567**	.463**	-.206	-.157	-.157	-.161	-.184
*Note: ** The correlation is significant at 0.01 (two-way); * The correlation is significant at 0.05 (two-way)*										

In all declared age groups, weight indicators significantly correlate with all other indicators of physical development. This pattern was not found in the age periods of 11 and 12 years, in which the relationship between weight and waist-to-height ratio, as well as weight and body fat percentage were not statistically significant. The analysis also showed a significant correlation between BMI and some results of progressive 20 m shuttle running (Table 5) in the age groups of 9 -, 11 -, 21-year - olds and 16-year-olds.

Table 5 – Spearman's paired rank correlation values between BMI indicators and the results of progressive shuttle running in boys aged 9-17 years

Ages	BMI Body height	BMI Body weight	BMI WC	BMI W/H	BMI %BF	BMI Number of levels	BMI Number of shuttles	BMI Covered distance.	BMI Total time	BMI VO2 max
9	.299	.920**	.692**	.604**	.684**	-.299	-.312	-.312	-.335*	-.322*
10	.140	.860**	.723**	.709**	.594**	-.253*	-.223	-.223	-.227	-.200
11	.965**	298*	.563**	.524**	.363**	-.233	-.246*	-.246*	-.245*	-.266*
12	.087	.298*	.563**	.363**	.524**	-.233	-.246*	-.246*	-.245*	-.266*
13	.281*	.885**	.771**	.613**	.523**	-.049	-.056	-.056	-.054	-.044
14	.371**	.880**	.737**	.380**	.461**	.125	.106	.106	.101	.087
15	.287*	.924**	.767**	.644**	.685**	-.021	-.030	-.030	-.027	-.033
16	-.202	.828**	.714**	.774**	.611**	-.241	-.261*	-.261*	-.197	-.269*
17	-.020	.855**	.768**	.746**	.541**	-.163	-.124	-.124	-.124	-.136

Thus, in the group of 9-year-old boys, BMI moderately correlates with total working time (-0.335; P<0.05) and MPC indicators (-0.332; P<0.05). Although there was a connection between BMI and other test characteristics, it was not statistically significant. BMI in the group of 11- and 12-year-old boys significantly correlated with the number of shuttles, distance covered (-0.246; P<0.05), total work time (-0.245; P<0.05), and MOC (-0.266; P<0.05).

In subsequent age periods, no statistically significant relationship was found between the studied indicators. The exception is the age of 16 years, in which a significant negative relationship was found between BMI and the number of shuttles covered by distance (-0.261; P<0.05) and MOC (-0.269; P<0.05).

With a high degree of confidence, BMI also correlates with waist circumference (in the range of -0.563 to .771 P<0.001), waist-to-height ratio (within -0.363 to .774 P<0.001) and the percentage of body fat (within -0.363 to .685 P<0.001).

Waist circumference is moderately correlated with all the results of progressive shuttle running (Table 6). However, this relationship was found only in the group of 9-year-old boys, in which WC correlated with the number of levels (-0.538; P<0.001), the number of shuttles and distance covered (-0.555; P<0.001), total work time (-0.567; P<0.001) and VO_2 max (-0.573; P<0.001).

Table 6 – Spearman's paired rank correlation values between WC indicators and the results of progressive shuttle running in boys aged 9-17 years

Ages	**WC Body height**	**WC Body weight**	**WC BMI**	**WC W/H**	**WC %BF**	**WC Number of levels**	**WC Number of shuttles**	**WC Covered distance.**	**WC Total time B**	**WC VO2 max**
9	.319	.690**	.692**	.888**	.678**	-.538**	-.555**	-.555**	-.567**	-.573**
10	.352**	.744**	.723**	.892**	.644**	-.357**	-.353**	-.353**	-.359**	-.340**
11	.329**	.336**	.563**	.726**	.888**	-.093	-.103	-.103	-.100	-.095
12	.100	.336**	.563**	.888**	.726**	-.093	-.103	-.103	-.100	-.095
13	.438**	.792**	.771**	.708**	.573**	.092	.073	.073	.077	.071
14	.423**	.737**	.755**	.828**	.604**	-.029	-.011	-.011	-.016	.004
15	.288*	.739**	.767**	.918**	.648**	.153	.134	.134	.141	.125
16	.182	.740**	.714**	.894**	.546**	-.116	-.123	-.123	-.085	-.117
17	.165	.787**	.768**	.923**	.695**	-.296*	-.232	-.232	-.234	-.262

In the group of 10-year-old boys, this relationship between these indicators was less noticeable, but also had a high degree of confidence (in the range of-.340 to - .359; P<0.001). In the group of 17-year-olds, a moderate association between WC and test results was also found, but it was not statistically significant.

We also found a significant correlation between WC, on the one hand, and waist-to-height ratio indicators (in the range of -.708 to -.923; P<0.00,1), as well as body fat percentage (in the range of -.546 to -.888; P<0.00,1)

In this group, the relationship between waist-to-height ratio indicators, on the one hand, and the results of progressive shuttle running for 20 m (Table 7) is subject to the same regularity as in the previous age group.

The most pronounced relationship between W/H and the results of progressive shuttle running was expressed in the group of 9-year-old boys (in the range -.605 to .616; P<0.001). In the group of 10-year-old boys, W/H correlated with the number of levels (.330; P<0.001), the number of shuttles and distance covered (.316; P<0.001), and total running time (.317; P<0.001). We found a less pronounced relationship between W/H and VO_2 max (.292; P<0.05).

In all age groups, waist-to-height ratios correlate with almost all indicators of physical development, with the exception of height. There is no statistically significant relationship between the waist-to-height ratio and the weight of 11-year-olds and 12-year-olds.

Table 7 – Spearman's paired rank correlation values between W/H indicators and the results of progressive shuttle running in boys aged 9-17 years

Ages	W/H Body height	W/H Body weight	W/H BMI	W/H WC	W/H %BF	W/H Number of levels	W/H Number of shuttles	W/H Covered distance.	W/H Total time B	W/H VO2 max
9	.053	.473**	.604**	.888**	.642**	-.591**	-.605**	-.605**	-.612**	-.616**
10	-.069	.517**	.709**	.892**	.636**	-.330**	-.316**	-.316**	-.317**	-.292*
11	.246	.241	.524**	.726**	.691**	-.132	-.162	-.162	-.159	-.147
12	-.017	-.079	.363**	.888**	.691**	-.132	-.162	-.162	-.159	-.147
13	-.242	.318*	.613**	.708**	.684**	-.031	-.003	-.003	.003	.019
14	-.033	.380**	.584**	.828**	.580**	.006	.044	.044	.043	.064
15	-.011	.512**	.644**	.918**	.680**	.093	.071	.071	.079	.056
16	-.225	.607**	.774**	.894**	.514**	-.170	-.172	-.172	-.124	-.166
17	-.220	.567**	.746**	.923**	.703**	-.258	-.203	-.203	-.200	-.215

The analysis showed that the percentage of body fat in the examined children and adolescents is more correlated with the results of progressive shuttle running (Table 8).

Table 8 – Spearman's paired rank correlation between %BF and cardiorespiratory endurance in boys aged 9-17 years

Ages	%BF Body height	%BF Body weight	%BF BMI	%BF WC	%BF W/H	%BF Number of levels	%BF Number of shuttles	%BF Covered distance.	%BF Total time B	%BF VO2 max
9	.221	.644**	.684**	.678**	.642**	-.497**	-.533**	-.533**	-.543**	-.528**
10	.099	.489**	.594**	.644**	.636**	-.379**	-.385**	-.385**	-.391**	-.361**
11	-.098	-.079	.363**	.888**	.691**	-.265*	-.311*	-.311*	-.305*	-.294*
12	.104	.241	.524**	.726**	.691**	-.265*	-.311*	-.311*	-.305*	-.294*
13	-.082	.360**	.523**	.573**	.684**	-.209	-.193	-.193	-.184	-.174
14	.136	.461**	.581**	.604**	.580**	-.118	-.119	-.119	-.116	-.087
15	-.012	.571**	.685**	.648**	.680**	-.080	-.089	-.089	-.085	-.099
16	.095	.594**	.611**	.546**	.514**	-.235	-.259*	-.259*	-.222	-.260*
17	-.067	.463**	.541**	.695**	.703**	-.397**	-.388**	-.388**	-.391**	-.378**

Table 8 shows that correlations of varying degrees of severity were found between the indicators studied in the age groups between 9-12 and 16-17 years. The most pronounced associations between %BF and the results of progressive shuttle running were found in the group of 9-year-old boys (ranging from -.497 to -.543; $P<0.001$). The associations were less pronounced, but with a high degree of confidence, in the groups of 10-year-old boys (ranging from -.361 to -.391; $P<0.001$) and 17-year-old adolescents (ranging from -.378 to -.391; $P<0.001$). In groups of 11 and 12-year-old boys, a moderate strength relationship was found between %BF on one side and the number of levels (.265; $P<0.05$), the number of shuttles and distance covered (.311; $P<0.05$), total running time and VO_2 max (.294; $P<0.001$). In the group of 16-year-olds, %BF is moderately correlated with the number of shuttles and distance covered (.259; $P<0.05$) and VO_2 max (.260; $P<0.05$). In the age range of 13-15 years, no relationships were found between the studied indicators.

Analysis of the results of the study also showed a link between %BF and other indicators of physical development, with the exception of height. In the group of 11 and 12-year-olds, the relationship between %BF and weight was also not significant.

Discussion. A review of the literature showed that anthropometric indicators such as BMI, fat percentage, and waist-to-height ratio can be used to predict the risk of developing chronic diseases and premature mortality from various causes [24, 25], which makes it important to study them in the child and adolescent population.

Some authors are skeptical about the predictive value of BMI, suggesting that it does not take into account gender, age, bone composition, and the ratio of fat to muscle mass and cannot be used as a predictor of overweight and obesity in the child population [26]. The authors suggest that drawing conclusions about the prevalence of overweight and obesity, relying only on this indicator, means reaching incorrect conclusions and missing out on opportunities for intervention [27].

Based on the results of our study, we suggest that the BMI indicator can be used to predict overweight and obesity in the child and adolescent population in conditions of limited time and lack of equipment for measuring body fat percentage. The basis for this assumption can be the relationship between the BMI indicator and other indicators that characterize the body composition of children and adolescents. So, we found a positive relationship between BMI indicators, on the one hand, and waist circumference, the ratio of waist circumference to height, as well as with the percentage of fat. We found this pattern in all the studied age groups. This fact indicates a high predictive value of BMI for assessing the prevalence of overweight and obesity among children aged 9-17 years in the absence of the ability to measure waist circumference or body fat percentage during the study.

Our study also revealed a tendency to increase the BMI index with increasing age, the highest values of which were found in the group of 16-year-olds. At the same time, the average BMI values in all age groups remained within normal values. An increase in the risk of overweight with age should be an unfavorable signal and requires intervention by physical education teachers and medical professionals.

Among the examined children and adolescents, the highest percentage of body fat was found in the group of children aged 9 years. In addition, statistical analysis showed a wide variation in the weight indicators of children in this age group (21-61 kg), and the median BMI values were 34 kg, which exceeds the global average. This indicates a high prevalence of excess weight in children of this age category.

The 20-meter progressive shuttle run is the most common test used to assess the cardiorespiratory fitness of children and adolescents during exercise. This test is part of such test batteries as Eurofit, FitnesGramm, and AlfaFit, which are used to assess the physical fitness of children and adolescents in Europe, the United States, and Australia [28, 29]. However, among teachers and researchers in the field of physical culture in Kazakhstan, as well as other Central Asian countries, this test has not gained enough popularity. To assess the cardiorespiratory fitness of children and adolescents in educational institutions of Kazakhstan, Kyrgyzstan, and Uzbekistan, specialists use running exercises at various distances. So, in Kazakhstan, the tests of the First President provide for running for 1000m, 2000m and 3000m. In Kyrgyzstan, the assessment of overall endurance is made using the 1500m run [30], and running for 1000m, 2000m, 3000m and 5000m is used for this purpose in Uzbekistan [31]. The type of control test is selected in accordance with the age and gender of students.

It should be noted that in the scientific segment of the Central Asian countries, there are no works devoted to the study of the reliability and informative value of these tests, as well as studies related to the development of evaluation tables for the above-mentioned running tests.

As a result of the analysis of the data obtained, we revealed a tendency to deterioration of general endurance in children aged 9-17 years with age. This is evidenced by the revealed trend towards a decrease in VO_2 max indicators with an increase in the age of the surveyed children and adolescents. The lowest VO_2 max values were found in the group of 17-year-olds.

It is known that aerobic performance depends primarily on the level of motor activity of an individual. It is possible that the deterioration of cardiorespiratory endurance with age is a consequence of a decrease in motor activity, which was mentioned in the works of a number of authors [32-34]. Studies have found that the decline among girls was higher at a younger age at baseline (9-12 years), and among boys it was higher at an older age (13-16 years). In addition, the number of participants in team sports decreased with increasing age. With age, there was also a significant decline in most sports among boys and girls. This suggests that as teenagers get older, their interests may change, which leads to the fact that some of them stop engaging in physical activity. These results suggest that it is important to promote PhA more effectively among adolescents, using different strategies depending on age and gender [35, 36].

The authors found that in the period from 13-16 years of age, boys have a decrease in motor activity and involvement in team sports. In girls, this trend was detected much earlier, at the age of 9-12 years. As children and adolescents grow older, their interests change and their motivation to exercise decreases. The authors suggest taking this fact into account and organizing a wide range of activities to promote motor activity and increase the involvement of children and adolescents in classes.

The effectiveness of testing results also depends on the students' own interest in this process [37]. Thus, in the worksof A. Garn and H. Sun (2009), an opinion was expressed about the collision of the relationship between the degree of focus on achieving a high result, revealed by the questionnaire, and the result itself. Students who reported the greater effort they put into completing the 20 m progressive shuttle run, the better the test results were [38]. In our study, the motivation factor for taking fitness tests was not taken into account. In further studies, it is necessary to take this fact into account and conduct additional research on the level of motivation when accepting standards.

As a result of the study, we did not receive unambiguous confirmation of the relationship between indicators of physical development and cardiorespiratory endurance. This dependence was found only in the age periods from 9 to 12 years, as well as from 16 to 17 years. Physical development indicators such as weight, BMI, waist circumference, waist-to-height ratio, and fat mass negatively correlated with the results of progressive 20m shuttle running, such as the number of stages, number of shuttles, distance covered, total running time, and VO_2 max.

The most significant relationships between indicators of physical status and motor abilities were found in 9-year-old children. In this group, BMI, waist circumference, waist-to-height ratio, and body fat percentage correlated with the results of a 20m progressive shuttle run. The relationship between these indicators varied from moderate to strong. In the group of 10-year-old boys, the degree of dependence between the above indicators varied from weak to moderate.

The data obtained by us are consistent with the results of a study conducted by Vladan Pelemiš V., Kojić F.., Živanović V.., Milanović S.. (2023), in which it was found that anthropometric indicators significantly correlate with the motor abilities of boys aged 10 years. According to the authors, the most significant associations were found between BMI, fat mass in the area of the triceps, biceps, subcapular and abdominal zones, and tests for coordination, explosive strength and aerobic endurance (10x5 shuttle run, long jump from a standstill and progressive shuttle run). At the same time, the authors confirmed the conclusion that excessive fat deposition negatively affects the results of physical tests, primarily related to weight gain and endurance [39].

Vandoni M, et al. (2021) came to the conclusion that there is a link between endurance and physical development parameters, which revealed the presence of a correlation between body mass, fat mass and BMI indicators and indicators of cardiorespiratory fitness of younger schoolchildren, revealed by the results of a 6-minute run [40]. The results of running for 6 minutes correlated with BMI (-0.322; $P<0.05$), weight, and body fat percentage (-0.268; $P<0.05$).

Our study also revealed that in the next two age periods, the degree of correlation between anthropometric and dynamic indicators decreased, and for some indicators it was completely absent. So, in the group of children aged 11-12, the relationship with the results of progressive shuttle running for 20 m was found only with BMI and body fat percentage.

A surprising fact is that in the age groups of 13-15 years, no significant relationship was found between the indicators characterizing the anthropometric and motor status.

The age period of 13-15 years is a difficult period in which rapid transformations occur in the body of adolescents. This age is a transitional phase between childhood and adulthood, where all the negative conditions, such as lack of sufficient physical activity, can affect the health of a teenager. In addition, the difference in the rate of puberty and the influence of many other factors may explain the large individual differences in physical development indicators and the lack of a reliable correlation between the studied indicators.

In the group of 16-17-year-olds, a significant correlation was found between BMI and body fat percentage.

The results of our research contradict the data obtained by Moliner-Urdiales D (2011) when studying the relationships between fitness test results and various components of physical development. The authors found a significant negative correlation between fat content, as determined by the sum of six skinfold measurements and dual-energy X-ray absorptiometry, on the one hand, and the results of a 20-meter shuttle run in adolescents aged 12.5-17.5 years, on the other. [41]. At the same time, the authors did not find a link between cardiorespiratory fitness and waist circumference. This indicator correlated only with the results of wrist dynamometry, which indicates the presence of a negative relationship between strength indicators and the level of central fat.

Conclusion. In the age groups from 9 to 12 and from 16 to 17 years, BMI and body fat percentage are reliable predictors of the level of cardiorespiratory fitness. The most significant relationships between indicators of physical status and motor abilities were found in 9-year-old children.

Body mass index correlates with waist circumference, waist-to-height ratio, and the percentage of fat detected by the sum of folds in the triceps and subcapular areas, which is evidence of the reliability of this indicator in assessing the presence of overweight and obesity in children and adolescents aged 9-17 years.

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