DEPENDENCE OF MUSCLE STRENGTH ON BIOLOGICAL MATURATION RATES AND KEY VARIABLES OF PHYSICAL DEVELOPMENT IN TEENAGE BOYS

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Functional abilities of school-age children are affected by a variety of factors, including endogenous. Over the course of a few years, we studied physical development of 182 boys who underwent annual physical examination from the age of 11 to 17. We took basic anthropometric measurements, such as height and weight, tested hand muscle strength and assessed biological maturation and body build. Our study showed that muscle strength in school-age boys suffers a negative influence of such endogenous factors as delayed physical development, body mass deficit, short stature, and asthenic build. Excess weight and low skeletal weight also contribute to decreased muscle strength in teenage boys. Our results can be used to identify teenagers at risk who should be given special attention during PE classes at school or during training sessions before the GTO fitness test.

Keywords: physical development of school-age children, biological maturation rate, hand muscle strength, handgrip test, somatotype

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ЗАВИСИМОСТЬ МЫШЕЧНОЙ СИЛЫ ОТ ТЕМПОВ БИОЛОГИЧЕСКОГО СОЗРЕВАНИЯ И ОСНОВНЫХ ПОКАЗАТЕЛЕЙ ФИЗИЧЕСКОГО РАЗВИТИЯ У МАЛЬЧИКОВ-ПОДРОСТКОВ

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На формирование функциональных возможностей современных школьников влияют различные факторы, в том числе эндогенные. В статье представлены данные об особенностях физического развития 182 мальчиков, каждого из которых обследовали ежегодно с 11 до 17 лет. Изучали основные антропометрические показатели (длину и массу тела), функциональные показатели (мышечную силу кистей рук), показатели биологического развития и особенности телосложения. Исследование показало, что негативное влияние на формирование мышечной силы у мальчиков-подростков оказывает ряд эндогенных факторов: задержка биологического развития, дефицит массы тела, рост ниже среднего и астеноидный тип телосложения. На формировании мышечной силы мальчиков-подростков неблагоприятно сказываются также избыточная масса тела и низкая скелетная масса. Полученные данные позволяют выделить группу риска, детям из которой следует уделять особое внимание при занятиях физкультурой и спортом и при подготовке к сдаче норм ГТО.

Ключевые слова: физическое развитие школьников, темп биологического созревания, мышечная сила кистей рук, динамометрия, соматотипы

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Hand grip strength reflects muscular and nervous health of an individual. Hand grip tests have long been used to assess the functional capacity and physical strength of children during regular medical checkups or pre-training consultations. Studies of physical capacity are becoming increasingly important in light of Order 172 of the President of the Russian Federation dated March 24, 2104 *On the Nationwide Fitness Program GTO* (GTO stands for Ready for Labor and Defense).

There is evidence of new trends in the physical development of children and teenagers towards a larger overall body size, accelerated biological maturation, earlier menarche, and overweight [1–9], as well as reduced functional capacities, including decreased muscle strength [10–13]. In the majority of studies dynamometry scores are analyzed in the context of social and environmental factors [14, 15]. However, the correlation between muscle strength and the physical development of children and teenagers accounting for the population variability remains understudied.

In this work we aimed to investigate how hand muscle strength correlates with physical development and the rate of biological maturation.

METHODS

This longitudinal study recruited 182 Moscow-born Caucasian teenage boys. The boys underwent physical examinations annually, from the time they were 11 till they turned 17 years of age. In terms of general health, the participants fell into health categories 1 and 2.

Physical development and biological maturity of the participants were assessed using a unified anthropometric method and standard techniques [16]. Basic anthropometric measurements were taken (body weight and height) and a functional right-hand grip test was conducted. To assess how balanced the physical development was, we did weight to height scaling using a modified regression technique [17]. Somatoscopy included visual assessment of biological maturity. Based on the maturation rate, the boys were classified as retarded in physical development (biological age lagged behind chronological age); normally developing (biological age coincided with chronological age); and accelerated in their physical development (biological age was ahead of chronological age).

Body build was classified using Darskaya's modification (1975) of the method proposed by Shtephko and Ostrovsky in 1929. Based on the visual assessment of the muscle bulk, bone skeleton, subcutaneous fat distribution, thorax shape, abdomen, back, and legs, we discriminated between the abdominal, thoracic, muscular, asthenic and mixed somatotypes [16].

Associations between muscle strength and muscle/fat mass were studied in 23 boys. Somatometric measurements were taken using conventional anthropometric methods and techniques. Body composition was analyzed on the InBody device (South Korea) for bioelectrical impedance analysis.

Statistical processing was performed using Statistica 6.0 (StatSoft, USA). To estimate significance of differences, Student's t test was applied. Correlations were studied between qualitative characteristics of physical development using Pearson's linear correlation coefficient r to describe correlation strength. At $r < \pm 0.3$, the correlation was either absent or weak; at r ranging from ± 0.5 to ± 0.7 the correlation was moderate; at $r > \pm 0.7$ the correlation was strong.

The study was approved by the Ethics Committee of Pirogov Russian National Research Medical University (Protocol 130 dated December 9, 2013). Informed consent was obtained from the parents and headmasters.

RESULTS

The correlation analysis showed that there was a statistically significant ($p<0.05$) moderate correlation between muscle strength and body height in 11-year old boys; the correlation between muscle strength and body weight also turned out to be significant in this age group. It should be noted that correlation strength declined as the boys grew older (Tables 1, 2).

More pronounced correlations were observed in impedance tests. The analysis revealed the presence of statistically significant ($p<0.05$) strong correlations between muscle strength and basal metabolism parameters ($r = 0.86$) and skeleton mass ($r = 0.86$). Moderate negative correlations were detected between muscle strength and fat mass ($r = –0.52$, $p < 0.05$).

Table 3 presents data on the hand muscle strength of boys grouped by their age. As the boys grew older, muscle strength increased from 15.25 ± 0.86 kg at 11 years of age to 38.66 ± 0.8 kg at 17 years of age, i.e. 2.5 times.

Figure 1 shows age-related dynamics of muscle strength in teenage boys depending on the rate of biological maturation.

The boys whose physical development was accelerated had better muscle strength at the age of 11, scoring even more by the age of 13, in comparison with their peers retarded in

Table 1. Correlations between the main parameters of physical development and hand muscle strength of 11-year-old boys (r; $p < 0.05$)

Parameter	Height	Weight	Right hand muscle strength
Height	1	0.75	0.53
Weight	0.75	1	0.47
Right hand muscle strength	0.53	0.47	1

Table 2. Correlations between the main parameters of physical development and hand muscle strength of 17-year-old boys (r; $p < 0,05$)

Parameter	Height	Weight	Right hand muscle strength
Height	1	0.56	0.47
Weight	0.56	1	0.39
Right hand muscle strength	0.47	0.39	1

Table 3. Age-related dynamics of muscle strength in boys aged 11 to 17 years (M ± m)

Age, years	11	12	13	14	15	16	17
Muscle strength, kg	15,15 ± 0,26	16,85 ± 0,30	19,93 ± 0,58	26,08 ± 0,69	31,49 ± 0,68	35,13 ± 0,60	37,50 ± 0,74

Table 4. Muscle strength in boys belonging to different somatotypes (M ± m)

Parameter	Somatotype				
	asthenic	thoracic	muscular	abdominal	mixed
	1	2	3	4	5
Right hand muscle strength	14.3 ± 0.2	17.04 ± 0.1	18.3 ± 0.2	18.6 ± 0.3	16.2 ± 0.2
p-value	$p < 0.05$ when comparing 1 and 3; $p < 0.01$ when comparing 1 and 4				

physical development. The highest scores in this group were seen at the age of 17. At 11 or 12 years of age, the boys whose development was retarded did not differ significantly from normally developing teenagers in terms of muscle strength, but at 13–15 years they scored less than normally developing or accelerating children. By the age of 16–17, these differences were leveled out and became unreliable.

Figure 2 shows how muscle strength depends on the physical development of the participants (body mass). In all age groups, no significant differences were observed in terms of muscle strength between normally developing and overweight children. The value of the muscle strength of boys with weight deficiency in all age groups except for 14 year old teenagers was significantly lower than that of harmoniously developing children ($p<0.01$, $p<0.05$, respectively).

We also discovered that muscle strength was dependent on body height. In all age groups, muscle strength of teenagers who were shorter than the average was significantly weaker than in other boys ($p < 0.01$, $p < 0.05$; see Table 3). The boys who were taller than the average or just tall scored better in

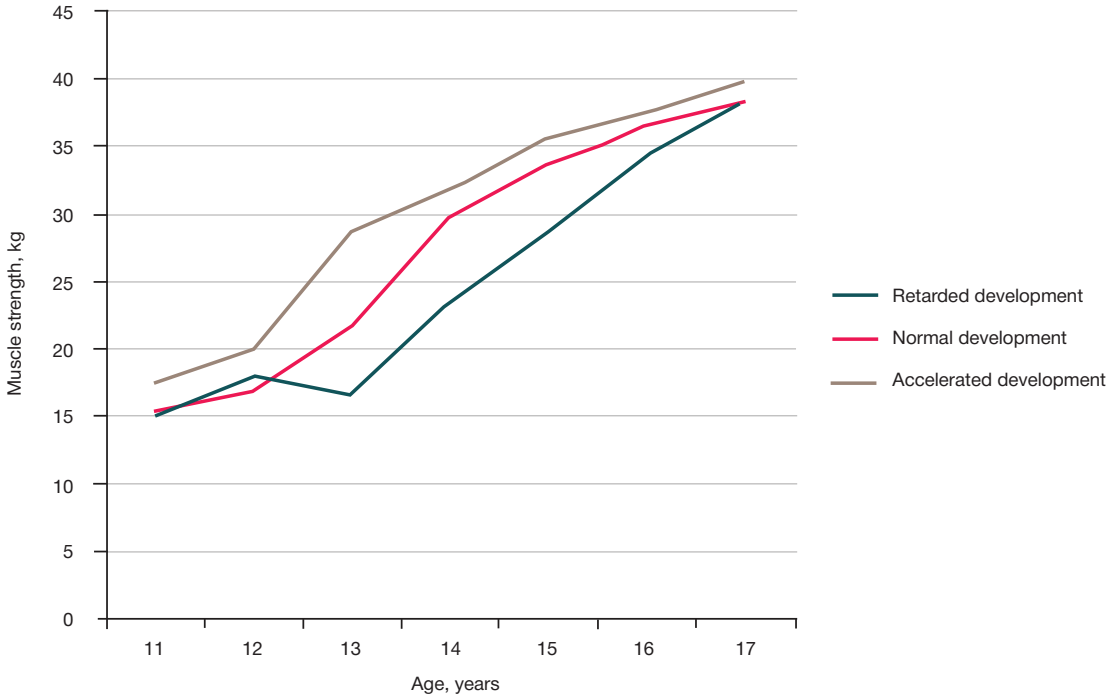

Fig. 1. Age-related dynamics of muscle strength measured in teenage boys with regard to their biological development

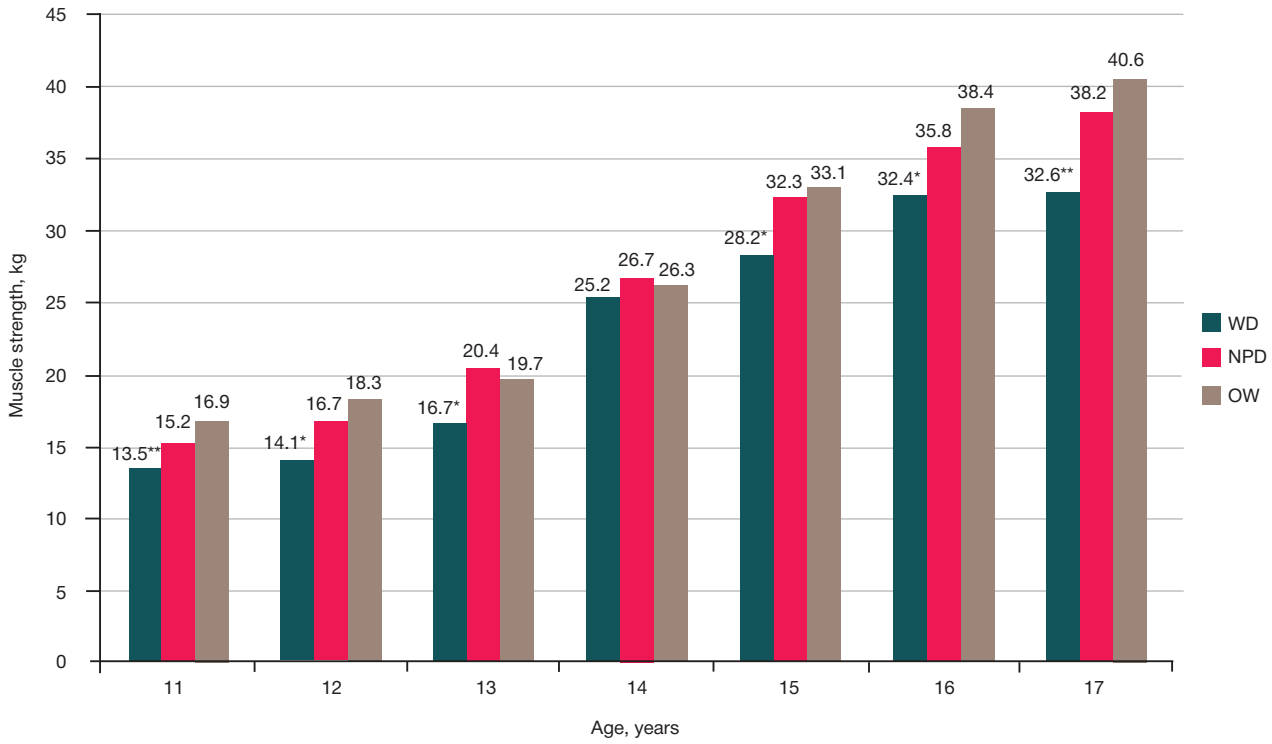

Fig. 2. Parameters of muscle strength of teenage boys depending on weight
* — $p < 0.05$, ** – $p < 0.01$
NPD — normal physical development, WD — weight deficiency, OW — overweight.

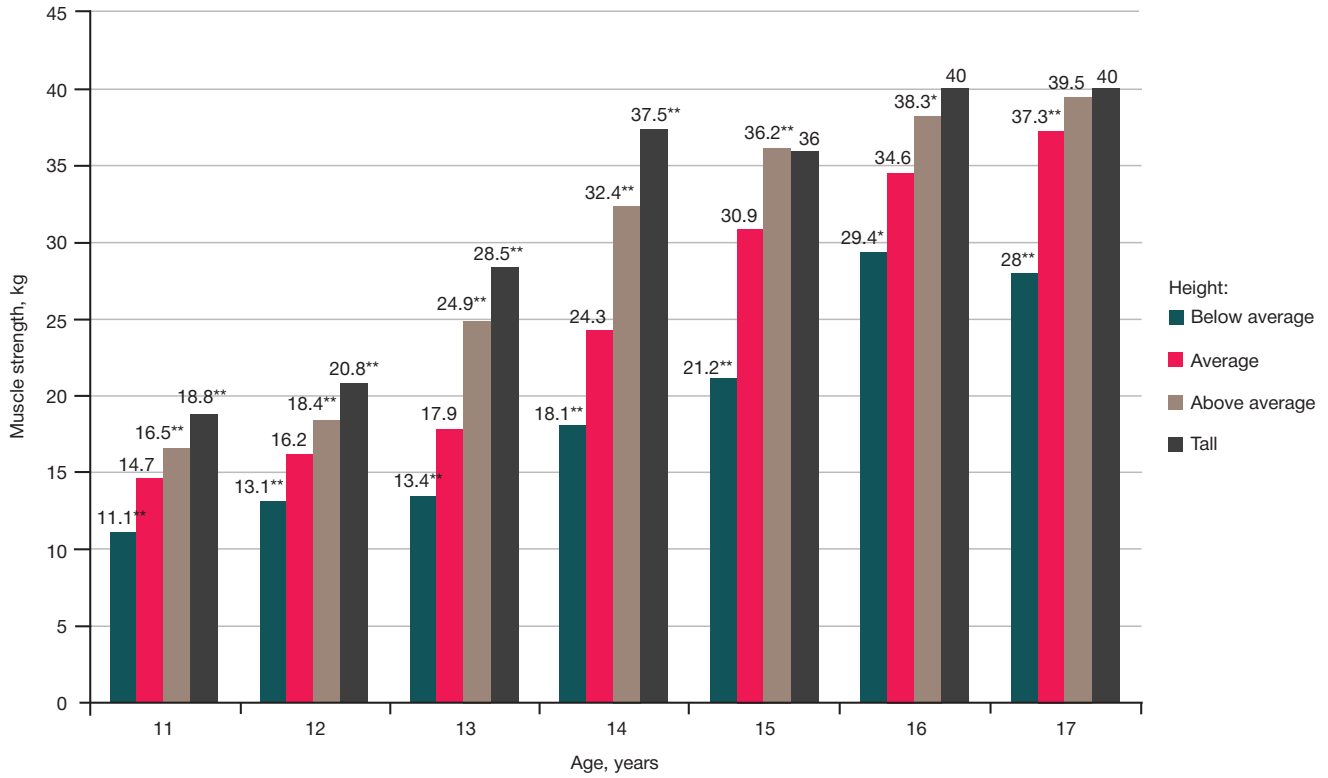

Fig. 3. Parameters of muscle strength of teenage boys depending on height
* — p < 0,05, ** — p < 0,01.

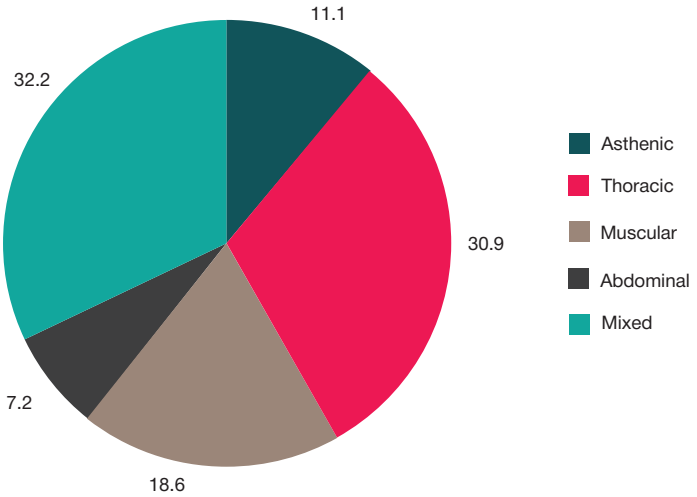

Fig. 4. Percentage of schoolchildren with different builds

hand grip tests than their peers at 11–16 years of age and 11–14 years of age, respectively (p < 0.01). In older age groups these differences were insignificant.

Somatotyping (Fig. 4) revealed that 42 % of boys belonged to the weak types (asthenic and thoracic); 25.8 % of the participants belonged to the relatively strong (muscular and abdominal) types; 32.2 % had mixed somatotypes. The analysis of muscle strength in children with different somatotypes showed that a somatotype significantly affects muscle strength. Asthenic children scored less than their peers who belonged to the muscular and abdominal types.

DISCUSSION

Studies conducted in different regions of our country are evident of a downward trend in muscle strength in modern children and teenagers. It has been established that in the Moscow region both boys and girls have worse dynamometry scores in comparison with the children tested in the 1960s and 1980s, and these differences are significant (p < 0.01) [15]. Low values of parameters reflecting the functional capacity of children mean that these children may not be able to meet the GTO requirements, risking their health or even life when attempting to pass this fitness test.

Among endogenous factors affecting muscle strength are the rate of biological maturation and body build [18–20]. Our findings demonstrate that decelerated rates of biological development and asthenic builds negatively affect muscle strength in teenage boys. In our study, average values of muscle strength in teenagers retarded in their physical development at the age of 13 to 15 were significantly lower than in other groups. At the same time, those boys had caught up with their peers in terms of muscle strength by the age

of 17. Dynamometric measurements in boys with the asthenic somatotype demonstrated significantly lower values than in those with the muscular and abdominal types.

While analyzing the influence of other endogenous factors on muscle strength in teenagers and children, we found out that (im)balanced physical development and height (stature) also affect the studied parameter. Boys with weight deficiency and shorter than average height in all age groups scored less than others in terms of muscle strength. In our sample there were no really short boys but we assume they also have reduced functional abilities.

Research studies suggest that about 40 % of all high-school children nowadays may not be able to pass the GTO fitness test [21–25], which brings the need for improving physical education at schools. Based on our findings, we can identify a group at a risk of reduced functional abilities. This group includes boys of asthenic body type, those with weight deficiency, short height and also teenagers retarded in their biological development at puberty. Teenagers at risk should receive special attention during PE classes at school and in the run up for GTO.

CONCLUSIONS

The conducted study has detected a negative effect of a few endogenous factors on the muscle strength of teenage boys, including retarded biological development, weight deficiency, short height, and the asthenic build. Muscle strength is also affected by high fat and low skeleton masses.

The obtained results have allowed us to identify a group at a risk of reduced functional capacities and to propose practical recommendations aimed at facilitating normal physical development of schoolchildren, that can be used by medical workers, teachers, parents and children themselves.

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