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Gender differences in hand grip strength of children in Bosnia and Herzegovina aged 11 to 14 years. A cross - sectional study

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Abstract: Hand grip strength (HGS) serves as a multifaceted and critical parameter within the domain of motor function and is widely recognized as a pivotal aspect in the comprehensive evaluation of the development of school-aged children. The aim of the research was to determine the values of HGS, the trend of changes and differences between boys and girls aged 11-14 years from Bosnia and Herzegovina. A cross-sectional survey was conducted on a sample of 585 students. The subsample was divided into 307 boys (11y = 81; 12y = 87; 13y = 77; 14y = 62) and 278 girls (11y = 66; 12y = 83; 13 y =79; 14y = 50). Hand muscle strength was measured using the method of isometric dynamometry in laboratory conditions, with a standardized test - Hand grip (according to the American Society of Hand Therapists). The force achieved during the maximum hand grip (dynamometry) was measured with a digital hand dynamometer CAMRY-EH101, USA. Statistically significant differences between male and female respondents were confirmed (for age 12, T = -2.651, p<0.009; for age 13, T =-5.178; p<0.000; for age 14, T =-7.124; p<0.000). In both sexes, the dominance of the strength of the right (dominant) hand than left (non-dominant) hand is evident. The study confirmed a positive trend of strength development in both sexes, as well as gender differences in the HGS test between children aged 12 to 14 years.

Keywords: morphology; physical education, school ages, HGS, differences, genders, development trend

1. Introduction

It has long been known that physical activity is very complex, including subjective and measurable dimensions of motor behavior and motor changes, so locomotor skills of the cranial part of the body are considered among the most important movements that enable the child to manipulate objects in different ways [1]. The hand, as a part of the locomotor apparatus, includes the basic manipulative organ of man, which during life performs various activities of the cranial part of the body. Due to its role in daily life activities, HGS was evaluated most often as an indicator of motor functioning. Some authors [2,3] believe that handgrip strength determines a very reliable and objective method of assessing the

integrity of cranial segments and is a relevant indicator of overall muscle strength and physical condition of children and adolescents. Prasetyo et al. [4] suggest that HGS is a fundamental part of human factors and ergonomics. The identified handgrip strength defines a physiological variable that is influenced by various endogenous factors [5,6], ranking among the best indicators of the morphological-functional, health and nutritional index status of an individual [7,8] and which are significantly correlated with the morbidity of young people, with evident gender differences between adults and adolescents [9]. The critical importance of understanding and monitoring HGS is underscored by its association with premature mortality during adolescence, as evidenced by several studies [10-12]. These studies have established a significant link between low levels of muscle strength, assessed through measures such as knee extension and HGS, and premature mortality, alongside other contributing factors such as abnormal body mass index and blood pressure. Thus, the assessment of hand grip strength not only informs us about immediate motor functioning but also holds implications for long-term health outcomes and overall well-being.

HGS is common in medical clinical practice, as the measurement of HGS contributes to detecting deficiencies, adequate therapeutic guidance and evaluation of treatment outcomes [13-15]. This is particularly present in the clinical anamnesis of various locomotor, neuromuscular and cardiovascular dysfunctions [16]. It is important to test the monitoring of physical and social factors [17,18], indicators of aggressiveness and social competition among adolescents [19].

School ages is characterized by significant changes in the formation of various locomotor movements and maturation of the central nervous system [200]. Developing of muscle strength in children and adolescents brings numerous health benefits [21]. Specifically, in preschool and school children, muscle strength contributes to the development of posture, while sedentary Adolescent muscle fitness is inversely related to cardiorespiratory function, and it is an excellent predictor of better insulin sensitivity in children.

Previous research [22] has indicated that hand grip strength (HGS) is frequently utilized to evaluate hand function in children. However, the utilization of normative grip strength data for follow-up assessments is complicated by the influence of growth and neuromuscular maturation. Shim et al. [23] propose that the establishment and delineation of normative HGS values within a population of healthy children would provide fundamental benchmarks for restoring normal function and averting early locomotor dysfunction in children. It is noteworthy that low HGS values during childhood may carry adverse health implications later in life [24,25]. The repercussions of declining strength are frequently associated with structural alterations in muscles and bones and specific degenerative changes in the joints [26]. Several studies [27-29] have demonstrated that the HGS test can facilitate the assessment of acute alterations in nutritional status and aid in the evaluation and prognosis of muscle strength in conditions such as juvenile idiopathic arthritis, congenital myotonic dystrophy, and traumatic hand injuries. In these contexts, various factors, including height, weight, bone density, and muscle mass, exert influence on hand grip strength in children [17]. Hand grip strength tends to increase with chronological ages, with higher values typically observed in the dominant hand, and significant differences between genders have been documented [13, 22,30,31].

At the beginning and during puberty, there are differences in strength between the sexes manifested in different motor activities. Given the link between muscle strength and health, examining changes in childhood and between boys and girls is of particular interest. For this reason, several studies provide normative data for grip strength in school children from different countries (England, Sweden, Italy, Spain, Serbia, Philippines, Iran, etc.), still are missing for the population of school children from Bosnia and Herzegovina. Given the fact that variations in some demographic characteristics significantly affect grip

strength [32], it is of great importance to determine the norm of grip strength for each geographic region of BIH-RS. In addition to reference intervals or normative ranges, which enable clinicians to objectively interpret clinical tests to distinguish disease from healthy individuals [33].

The aim of this research was to show the HGS values, the trend of changes and the differences between the sexes on a sample of healthy students from Bosnia and Herzegovina (the entity Republic Srpska-RS), aged 11 to 14. It is hypothesized that statistically significant gender disparities in HGS will be observed among school-aged children aged 11 to 14 years in the region of Bosnia and Herzegovina (BIH). Specifically, it is anticipated that male participants will manifest higher HGS values compared to their female counterparts within this specified age a cohort.

2. Materials and Methods

2.1. Participants.

The total sample size was 128 participants. A cross-sectional study of hand muscle strength was conducted on 585 healthy school children from Bosnia and Herzegovina (Republic Srpska entity), comprising 307 boys and 278 girls between the ages of 11 and 14 years. Exclusion criteria were: confirmed history of neurological, orthopaedic and metabolic diseases; hand injuries or previous hand surgery; complaints of weakness or pain during the 6-month preceding the study. Data collection was carried out between April and May 2021. Characteristics of study participation were included in Table 1.

Table 1 Characteristics of study participants (ages, genders, hand dominance)

		Boys			Girls		
			Dominant Hand			Dominant Hand	
Age years)	N total	N	Right	Left	N	Right	Left
11	147	81	78	3	66	63	3
12	170	87	83	4	83	80	3
13	156	77	72	4	79	73	6
14	112	62	60	2	50	46	4
Total N	585	307	294	13	278	262	16

At the time of measurement, all subjects were medically fit for testing and familiar with the testing protocol. Inclusion criteria were that there was no restriction of movement in the upper extremities, such as inflammatory joint diseases or neurological disorders. The research was carried out in accordance with the professional and ethical standards of the Declaration of Helsinki [35]. Written parental consent was obtained from all respondents that their children could participate in the research.

2.2. Study Design

The research started with familiarizing the subjects with the purpose of HGS measurement, and the missing participants were removed. The measurements were taken in the morning from 9:00 to 11:30 a.m, during 10 days in the physical education hall. The muscular force of the flexors of the fingers of the hand was measured by the method of isometric dynamometry in laboratory conditions where a standardized test - hand grip

was used. The testing procedure was conducted following the defined recommendations of the American Society of Hands Therapists [36]. The force realized at maximum hand grip (dynamometry) was measured using a digital hand dynamometer CAMRY-EH101, USA (Figure 1). The results are expressed in kilograms (kg) with a measurement accuracy of 0.01 kg. Calibration of the instrument was performed periodically during the study.

Figure 1. CAMRY- Digital Hand Dynamometer, 200lb, EH101, USA

2.3. Statical software

Statical software (G*Power, v3.1.9.7, Heinrich-Heine-Universität, Düsseldorf, Germany) was used to calculate the sample [34]. The combination of tests used in the statistical software to calculate the sample size was as follows: (a) x2 tests, (b) goodness-of-fit tests: Contingency tables y (c) a priori: Compute required sample size – given α, power, and effect size. Tests considered two tails, effect size w = 0.50, α-error probability = 0.05, power (1-β error probability) = 0.8.

2.4. Statistical analysis

Basic central and dispersion parameters (Mean, SD, Mean Difference, CI difference 95%) were calculated for each variable. The Kolmogorov-Smirnov test was applied to confirm normality ($p>0.05$). The homogeneity of variance was tested with Levene's test. The data were analyzed using an independent student's T- test and statistical significance was set at level $p<0.01$. Statistical procedures and analyses were conducted using the statistical soft STATISTICA 10.0 for Windows (StatSoft, Inc., Tulsa).

3. Results

The general values of HGS for the sample of pupils under study are presented in Table 2. This table contains the fundamental statistical parameters for the analyzed sample which includes both male and female school pupils. The homogeneity of sample variance was assessed using Levene's test ($p>0.05$). The results obtained for hand grip strength (HGS) when comparing male and female respondents within the 11-14-year age group revealed significant differences ($p<0.01$), as detailed in Table 2 and illustrated in Figures 2 and 3. In essence, the numerical outcomes of the T-test both registered and substantiated the disparities in HGS observed between the genders within the same age cohort of subjects. At the age of 11, almost identical average values of HGS were recorded for both sexes, with slightly better results for male compared to female subjects, HGSRH (21.85±3.70kg vs. 21. 18±4.56kg) and HGSLH (20.98±3.72kg vs. 20.04±4.20kg). No statistically significant differences were recorded at this age.

It is evident that, with the age of the examinees, increased strength (HGS for both arms) is observed, but with a greater increase in boys compared to girls, which consequently determines the presence of statistically significant differences (mean±SD, male vs. female): for age 12, HGSRH (27.38±5.77kg vs. 25.10±5.42kg) for T-test = -2.651; p<0.009) i HGSLH (26.83±6.00kg vs. 23.98±5.43kg) for T-test= -3.243; p<0.001); for ade 13, HGSRH (32.44±7.44kg vs. 27.01±5.71kg) for T-test =-5.178; p<0.000); HGSLH (30.41±6.70kg vs. 25.12±5.46kg) for T-test =-5.413; p<0.000); for age 14, HGSRH (38.97±10.10kg vs. 27.63±5.44kg) for T-test =-7.124; p<0.000); HGSLH (37.20±8.80kg vs. 26.22±5.04kg) for T-test = -7.858; p=0.000).

In both genders, the dominance of strength (HGS) of the right hand compared to the left hand is evident. In men, the ratio is 95.76% (RH) vs. 4.24% (LH), and in women 94.24 (RH) vs. 5, 76% (LH) who declared about the dominant hand, so it can be said that this result was expected. A positive trend of increase in the average strength values of students aged 11 to 14 years was recorded for the female sample (RH 6.45kg vs. LH 6.18kg) and the male sample (RH=17.12kg vs. LH=16.21kg). It is visible that the increase in strength is almost three times greater in male than in female subjects.

With increasing age of children, the range of results within the same sample also changes between right and left hands, with the difference being greater for the right hand in both genders (Table 2).

Table 2. The difference in the between the female and male children (HGS)

Age	Parameters (kg)	Gender	Mean (min.-max.)	SD	Range	Mean Difference	95% CI difference	T-test	Sig. p<0.01; (2-tailed)	Levene's Test	
										F	p
11 year	HGS RH	F	21.18 (12.00-31.70)	4.56	19.70	-0.73	-2.07-0.62	-1.066	0.299	2.540	0.113
		M	21.85 (10.50-31.60)	3.70	21.10						
	HGS LH	F	20.04 (11.80-31.50)	4.20	19.70	-0.96	-2.25-0.33	-1.470	0.149	0.914	0.341
		M	20.98 (10.40-29.20)	3.72	18.80						
12 year	HGS RH	F	25.10 (13.70-40.70)	5.42	27.00	-2.28	-3.97-0.58	-2.651	0.009	0.794	0.374
		M	27.38 (13.90-42.20)	5.77	28.30						
	HGS LH	F	23.98 (12.30-41.80)	5.43	29.50	-2.85	-4.58-1.11	-3.243	0.001	1.707	0.193
		M	26.83 (14.20-40.70)	6.00	26.50						
13 year	HGS RH	F	27.01 (15.00-41.20)	5.72	26.20	-5.50	-7.60-3.40	-5.178	0.000	5.714	0.018
		M	32.44 (15.10-49.90)	7.44	34.80						
	HGS LH	F	25.12	5.46	25.70	-5.29		-5.413	0.000	3.565	0.061

		M	(12.30-38.00) 30.41 (13.70-44.40)	6.70	30.70	-7.22- -3.36				
14 year	**HGS RH**	**F**	27.63 (11.90-40.10)	5.44	28.20	-11.38	-14.54-8.21	-7.124	0.000	16.032	0.139
		M	38.97 (18.40-63.80)	10.10	45.40						
	HGS LH	**F**	26.22 (15.10-36.90)	5.04	21.80	-10.94	-13.69—8.17	-7.858	0.000	13.537	0.180
		M	37.20 (21.80-58.00)	8.80	36.20						

M – male, F –female, HGS LH - Hand grip strength for left hand, HGS RH - Hand grip strength for right hand, SD – standard deviation, T-test – Student test, F – value of Levene's test , *Sig. p<0.01

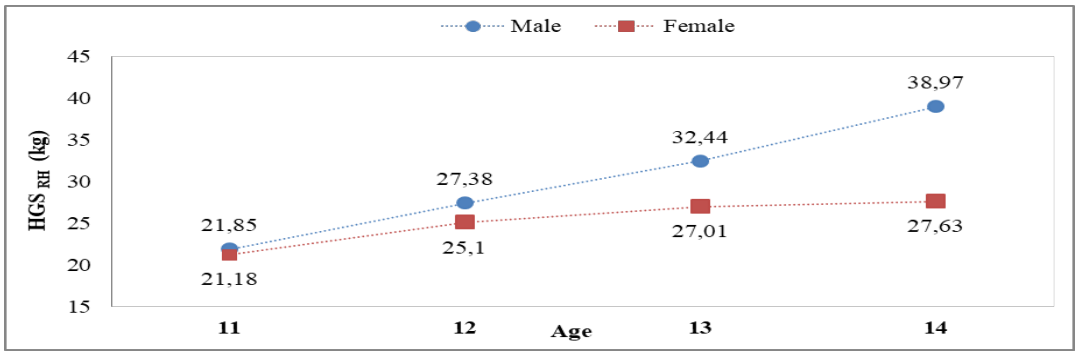

Figure 2 Trend line of average by age HGS (Right hand)

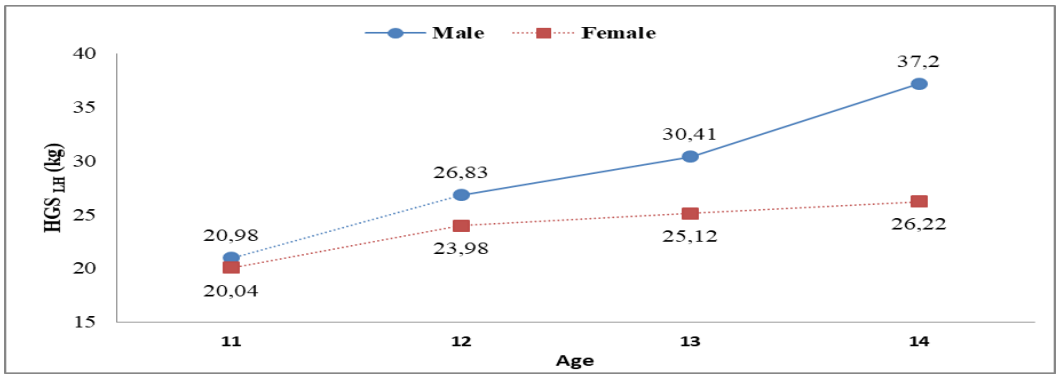

Figure 3 Trend line of average by age HGS (Left hand)

4. Discussion

The aim of the current research is to determine the values of HGS, the trend of changes and differences between the genders in a sample of school children, aged 11-14 years. The presented results confirmed significant differences in HGS between the genders, at the age of 12, 13 and 14 years, while the age of 11 did not record statistically significant differences in HGS (Table 2). The relevance of this study is contained in the fact that this is the first study in BIH on the population of school-aged respondents (11-14 years), because there is an evident lack of data on reference values HGS. There are also no recorded studies conducted in RS entity (BIH) that defined genders differences between school-aged children in the HGS test.

In children, the HGS is a relatively simple test that is increasingly used in experimental and epidemiological studies [37,38], in clinical practice and fitness control in children [39]. According to Wind et al. [2], the HGS test serves as an adequate tool for a quick indication of general muscle strength due to its significant relationship with the overall muscle strength of the entity. It is an indicator of general health and is often evaluated in examinations of normal motor functions as an indicator of the level of nutrition [40]. HGS can vary in age and genders, so depending on that, a good understanding of this matter is necessary during the growth and development of a young organism, where the positive effects of muscle conditions among children and adolescents defined new guidelines and recommendations [41].

The period covered by the current research is particularly interesting, the period that characterizes the puberty phase, when numerous morphological, motoric and functional changes occur in both genders. A more intensive growth of the longitudinal dimensions of the skeleton is noted, with a higher percentage in boys. This period is characterized by the growth of specific motor skills, which coincide with the sensitive periods of growth and development of the organism. Muscle mass accounts for about 32% of the total body mass of an individual. Cardiovascular and neuromuscular systems improve, and primary motor forms show increased values, among which speed, strength, and HGS stand out [42].

In our study, the grip strength of the dominant and non-dominant hand recorded increasd with age in boys and girls where the maximum values of HGS also recorded significant differences between boys and girls, recording a significant trend of increasing strength, which is in accordance with previous studies [2,13,30,31,33]. HGS is a significant characteristic in the development of children [31], also top athletes and school-age athletes, in terms of minimal injuries to the cranial part of the locomotor apparatus [43]. It should be pointed out that the characteristics of HGS are predictable and in direct correlation with anthropological dimensions, degree of training and state of health at the time of testing [44].

According to Pavlović, & Vrcić [44], male persons have higher maximum HGS strength in dominant and non-dominant hands than female persons. Larger muscle mass, which defines greater muscle contractile potential, is most often cited as a factor of difference, while women show greater muscular endurance and perform physical tasks with greater energy efficiency. It was found that the grip strength of the right (dominant) hand is 10% higher than the left (non-dominant) hand for the entire sample, in both genders (Table 2), which is consistent with the results in the literature [13,17,33,45]. Our results align with the evidence of previous studies regarding the differences between men and women related to the school age of the respondents.

The results of the study show a significant difference in the strength of both hands with each increasing year of age in favor of the older group, except for the age between 11 years (Table 2). At this age, no significant differences in HGS were found between boys and girls, probably due to similar body composition before puberty. According to Moleanaar et al. [22] the difference in grip strength between boys and girls is not the same for every age, which was also confirmed in our research. Even at a younger age, significant differences were recorded [9], which recorded greater grip strength in boys than in girls, which is especially visible after 11 years [5,13,17,22]. It is evident that HGS is a very simple, non-invasive, cheap, reliable indicator of muscle strength of the upper body and is a good way to assess the strength of the upper body in children, where the obtained results can be used to analyze the relationship of muscle strength with age and genders [46]. The current study confirms the relevant values of the causes of school children, the positive trend of strength development, their maximum value as well as the significant differences of arithmetic means in the HGS test between the genders (age 12-14 years for $p<0.001$). Differences in strength between the dominant and non-dominant hand were also

confirmed in both male and female subjects (Table 2). In general, our study notes a positive trend of strength gains from 11-14 years of age in both genders (Figure 2,3), which is consistent with previous results [9,13,17,22,30,31]. The increase in strength (for both arms) is almost three times more significant in men compared to women, which is on average about 16.60 kg for the male and 6.30 kg for the female sample, which is a consequence of pronounced changes in the growth and development of the organism, i.e. the puberty period, level of physical activity of the individual, health status, sex hormones (testosterone) and other endogenous-exogenous factors [6]. The results of the current study show significantly better results for the same age, both genders than Brazilian [13], Iranian [47], Dutch [48], and English causes [49]. Also, the findings of our study are in line with the results of much more extensive research (CHMS, HELENA, IDEFICS) where significant differences were found depending on the genders and age of the respondents [50-52]. An important result of our investigation was a significantly higher maximum HGS in boys than in girls, which records a positive trend with age periods, especially in 12, 13, 14 years. In addition to anthropometric parameters (Height, Mass, BMI) that were not taken into consideration in this study and are a significant predictor of genders differences in HGS, an significant concept of differences manifests itself from the fetal period and then in hormonal functioning, under the influence of estradiol and testosterone, visible before puberty, especially growth hormone, which probably leads to differences in HGS, in favor of boys. where primarily sexual dimorphism in body composition is essentially a consequence of the action of sex hormones.

The obtained results of the study represent relevant reference values for our population, the so-called Geographical regions of BIH-RS. The availability of HGS reference values is an essential determinant in numerous situations for planning interventions aimed to improve children's fitness when HGS is used as an index of children's physical condition, especially those with low HGS and previously confirmed that HGS is a significant predictor of morbidity [10,53], nutritional status [54-56] and is helpful for screening patients with neuromuscular disease. Morphological and motor research must be approached in an interdisciplinary context to highlight the determined factors and their impact [57-66]. Therefore, the availability of these HGS data of BIH-RS children can help detect deficiencies in children, children who need specific dietary treatments or the risk of some clinical complications [67], and also a reliable guideline for future planned fitness activities of children in terms of intensity and load.

The limitations of this study may include: the study primarily compared hand grip strength between boys and girls. It did not explore potential variations within these genders categories, such as the influence of other factors like physical activity levels, nutrition, or socioeconomic status. This study utilized a cross-sectional design, which captures data at a single time. Longitudinal research could provide insights into how hand grip strength changes over the time and the factors that influence these changes.

5. Conclusions

This is the first study conducted on the school population in Bosnia and Herzegovina (Republic Srpska entity) that analyzes the HGS of children of both genders. The results of the study detected and confirmed a positive trend of strength development in both genders, as well as genders differences between children aged 11 to 14 years. Statistically significant gender differences in mean HGS values at the ages of 12, 13, and 14 years were found. Significant differences in the maximum results of the dominant and non-dominant hand within the same genders and between different genders are evident. It has been confirmed that HGS is primarily influenced by genders. The study is significant because it provides current data related to the reference values of children BIH.

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