Scientific-Expert Journal of Anthropological Aspects of Sports, Physical Education and Recreation

Submitted: 07/01/2025
Accepted: 18/03/2025
Published: 16/04/2025
UDK: to be registered

Original article

Relationships between maximum Hand Grip Strength and Motor Abilities in primary School Children

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Abstract

The aim of this study was to determine the structure of qualitative relationships between a test for assessing strength status and a battery of tests for assessing motor abilities in primary school children from rural areas. The research was conducted on a sample of 141 students from primary schools, from the first to the eighth grade, in Kušiljevo and Vraćevšnica (central Serbia). The tested sample included 27 girls and 33 boys (from the first to the fourth grade) and 42 girls and 39 boys (from the fifth to the eighth grade). The following variables were used for this research: age, maximum muscle strength of the dominant ($F_{max}D$) and non-dominant hand grip ($F_{max}N$), as well as the total sum ($F_{max}SUM$), sit-and-reach test, standing long jump, sit-ups test, isometric chin-up, and 4x10m running test. Pearson correlation results showed that age correlates with the sit-and-reach (r=0.387, p=0.034), standing long jump (r=0.536, p=0.002), and 4×10 m running test (r=–0.561, p=0.001) in boys from the first to the fourth grade, and with the isometric chin-up test in girls (r=–0.402, p=0.042). Additionally, the absolute value of hand grip strength, regardless of whether it is the result of the dominant, non-dominant, or the sum of both hands, generally does not correlate with any test for assessing motor abilities in the tested sample, except for boys from the fifth to the eighth grade, where a statistically significant correlation was found with the standing long jump (FmaxD: r=0.479, p=0.002; FmaxN: r=0.454, p=0.004; FmaxSUM: r=0.471, p=0.002). When age was controlled through partial correlation analysis, significant relationships between hand grip strength and standing long jump remained only in boys from the fifth to the eighth grade (FmaxD: r=0.459, p=0.004; FmaxN: r=0.425, p=0.009; FmaxSUM: r=0.447, p=0.006). In addition, a significant negative correlation was found between FmaxN and sit-ups in boys from grades 1–4 (r=–0.401, p=0.031), and between FmaxD and 4×10 m running in boys from grades 5–8 (r=–0.331, p=0.046).Since the hand grip strength test is a standardized test for assessing overall body strength, it can be concluded that the standard battery of tests does not cover the entire range of physical, i.e., motor abilities. Based on the obtained results, it can be concluded that the hand grip strength test can be recommended as an addition to testing physical, i.e., motor abilities in primary schools, as a proven and simple screening test for assessing overall body strength

Keywords: Battery of tests, physical fitness, isometric contraction

Citation: Nikolic et al. (2024). Relationships between maximum Hand Grip Strength and Motor Abilities in primary School Children from rural Areas. *SportLogia. 20(*2), xx-xx. doi: registering

E-ISSN: 1986-6119

Introduction

Generally speaking, motor tests are used to assess the motor and physical potential of subjects. In the system of primary and high-school education in the Republic of Serbia, physical and health education includes mandatory monitoring, evaluation, and recording of students' physical abilities, which should be conducted at the beginning and at the end of the school year (Radisavljević & Milanović, 2019). The Eurofit test battery for testing the motor abilities of primary school children has been used for many years to assess the level of development of basic physical abilities in school children in the Republic of Serbia (Adam et al., 1988). However, standard tests cannot always accurately assess students' potential, leading to ongoing debates about new, more appropriate tests. Given that today's school-age children increasingly fail to meet the basic need for movement, the question arises whether their motor abilities are declining and, consequently, whether this poses a health problem for them (Smajić et al., 2017). For this reason, there is a constant need to search for solutions that will yield better results.

A large number of factors can influence the manifestation of physical abilities when talking about primary school children (Suchomel et al., 2016). These include factors such as genetics, type of training, and absolute and relative muscle strength. Muscle strength is defined as the ability to generate force against an external object or resistance (Siff, 2000), and depending on the activity's requirements, muscle strength can be expressed relative to body mass (running, gymnastics), relative to an opponent's body (martial arts, sports games), or relative to an external object (weightlifting, discus throw, javelin throw, etc.).

There are various tests that assess and measure muscle strength, and one of the tests considered the gold standard is the hand grip strength test (Gallup et al., 2007; Norman et al., 2011; Dopsaj et al., 2019). The hand grip strength test can be applied in various areas of research (Kljajić et al., 2012), and there are studies that have used this test in different sports disciplines, both in recreational and elite athletes (Koley et al., 2010; Gerodimos, 2012; Iermakov et al., 2016). Additionally, this test can be used in rehabilitation to diagnose musculoskeletal injuries and monitor the effects of rehabilitation treatment (Bohannon, 2001; Beloosesky et al., 2010). There is scientific evidence that this test is very reliable in assessing physical abilities, as well as genetic, biological, and behavioral potentials of a person. There is also evidence that this test can reliably assess general strength in children, adolescents, and the elderly, relative to gender (Frederiksen et al., 2002; Wind et al., 2010; Atkinson et al., 2012; Marković et al., 2018; Dopsaj et al., 2019; Lim et al., 2020; Vaidya & Nariya, 2021). Since the hand grip strength test is used in the assessment of physical abilities, it can also show the correlation with other motor tests in the school battery (Matsudo et al., 2014).

The aim of this paper was to determine the relationships between the test for assessing overall strength and a battery of tests for assessing motor abilities in primary school children. The main hypothesis is that there will be correlations between the handgrip test and the long jump (Matsudo. 2014), but it will be interesting to see if there will be correlation with other tests.

Methods

Participants

The research was conducted on a sample of 141 primary school students from the first to the eighth grade. The sample consisted of students from rural areas of the Republic of Serbia, specifically from the "Desanka Maksimović" Primary School in Vraćevšnica, Gornji Milanovac municipality, and the "Vožd Karadjordje" Primary School in Kušiljevo, Svilajnac municipality. The tested sample included 27 girls (F_{1-4}), aged 8.76±1.06 years, weight 30.9±9.54 kg, height 135.12±10.65 cm, 33 boys (M_{1-4}), aged 8.54±1.09 years, weight 34.38±11.51 kg, height 135.15±10.14 cm (from the first to the fourth grade), and 42 girls (F_{5-8}), aged 12.33±2.08 years, weight 52.84±14.95 kg, height 158.83±9.29 cm, 39 boys (M_{5-8}), aged 12.83±1.31 years, weight 55.05±16.52 kg, height 161.51±11.47 cm (from the fifth to the eighth grade). Students were divided

into groups according to educational age categories, i.e., lower and upper primary school grades (Newman et al., 1984; Haager-Ross et al., 2002; Radisavljević & Milanović, 2019). Before the start of testing, school management, as well as students and their parents, were informed about the protocol and purpose of the testing, and all gave verbal consent for its implementation.

Measurements and Procedures

Hand Grip Strength

The protocol of the isometric hand grip strength test was conducted with standardized equipment for upper grades, and adapted equipment for lower grades (Sports Medical Solutions, All4gym d.o.o., Serbia), according to standardized procedures (Trajkov et al., 2018; Zarić et al., 2018; Dopsaj et al., 2019). This test was chosen as a highly referential and simple to implement, even in young individuals, with a very high level of reliability (intraclass correlation coefficient from 0.938 to 0.977 for maximum force values (Marković et al., 2018)).

The testing protocol involved explaining the realization of the test to each child, and verbal instructions were given during the testing procedure. Each participant was familiarized with the equipment and performed a specific warm-up (2 randomized attempts at medium intensity). After familiarization and specific warm-up, participants were tested with two randomized attempts with each hand alternately, with a 2-minute break between individual attempts. Instructions for the test were: grip as hard and as fast as possible and hold for at least 2 seconds (Marković et al., 2020). If the participant did not adequately perform the test during the regular procedure according to the assessor's evaluation, the test was performed a third time. A specially designed software-hardware system for isometric measurement (Sports Medical Solutions Isometrics, ver. 3.4.0) was used for data collection. All results for the applied test were recorded in a specialized database, and the best attempts of measured maximum forces were selected for final analysis.

Motor Test Battery

The testing of motor abilities was conducted using the procedure of a standardized battery of tests used in the school system of the Republic of Serbia (Radisavljevic-Janic & Milanovic, 2019).

Variables

The basic morphological characteristics of the students were recorded, including body weight (BW) expressed in kg, body height (BH) expressed in cm, and body mass index (BMI) expressed in kg/m^2. For these purposes, a digital scale with a measurement accuracy of up to 0.1 kg was used (for measuring body weight), an anthropometer according to Martin (for measuring body height), while BMI was calculated according to the standardized procedure.

The following variables defined the space of the analyzed physical and motor abilities:

1. Age
2. Hand grip strength - maximum muscle strenght of the dominant (F_{maxD}) and non-dominant hand (F_{maxN}), as well as the total sum of both hands (F_{maxSUM}), expressed in newtons (N);
3. Sit-and-reach test (SR) - a test assessing the flexibility of the lower spine and hamstring muscles, expressed in centimeters (cm);
4. Standing long jump (SLJ) - a test assessing leg muscle strength, expressed in centimeters (cm);
5. Sit-up test (SU) - a test assessing endurance in abdominal muscle strength in 30 s;
6. Isometric chin-up test (ICU) - a test assessing endurance in arm flexor muscle strength, expressed in seconds;
7. 4 x 10 m sprint (4x10m) - a test assessing repeated sprint speed, expressed in seconds.

The research was conducted in accordance with current ethical standards and with the approval of the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade, under the number 484–2. All measurements were carried out by master professors of physical education and sport.

Statistical analyses

Basic descriptive and statistical parameters (mean value and standard deviation) were calculated for all variables. The relationship between the criterion variable (hand grip strength) and other motor ability tests was determined using Pearson's correlation, with the significance level set at $p < 0.05$. In addition, a partial correlation analysis was performed, controlling for age, in order to examine the relationships between the variables independently of the effect of age. All analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS) (version 24.0; IBM Corporation, New York, USA).

Results

Table 1 presents the basic descriptive indicators for age and morphological variables, while Table 2 shows the basic descriptive indicators for the tested variables. Tables 3 and 4 display the results of Pearson's correlation according to school age groups and gender, while tables 5 and 6 display the result of Pearson's correlation between the variables independently of the effect of age.

Table 1: Descriptive indicators of anthropometric variables for the sampled boys (M) and girls (F).

	Age (years)	BW (kg)	BH (cm)	BMI (kg/m^2)
F_{1-4}	8.8 ± 1.1	30.9 ± 9.5	135.1 ± 10.6	16.6 ± 3.2
M_{1-4}	8.5 ± 1.1	34.4 ± 11.5	135.1 ± 10.1	18.4 ± 4
F_{5-8}	12.3 ± 2.1	52.8 ± 14.9	158.8 ± 9.3	20.6 ± 4.3
M_{5-8}	12.8 ± 1.3	55.1 ± 16.5	161.5 ± 11.5	20.8 ± 4.5

F_{1-4} - Female (1. to 4. Grade), M_{1-4} - Male (1. to 4. Grade), F_{5-8} - Female (5. to 8. Grade), M_{5-8} - Male (5. to 8. Grade), BW - Body weight, BH - Body height, BMI - Body mass index.

Table 2: Descriptive indicators of strength and motor variables for the sampled boys (M) and girls (F).

	F_{max}D (N)	F_{max}N (N)	F_{max}SUM (N)	SR (cm)	SLJ (cm)	SU (n)	ICU (s)	4x10m (s)
F_{1-4}	107 ± 37	97 ± 32	204 ± 67	3 ± 6	110 ± 16	17 ± 4	11 ± 9	13.3 ± 0.8
M_{1-4}	133 ± 57	124 ± 51	288 ± 200	2 ± 5	116 ± 24	18 ± 4	19 ± 19.7	13 ± 1.4
F_{5-8}	212 ± 61	194 ± 55	406 ± 113	4 ± 7	136 ± 28	19 ± 4	14.8 ± 14.8	12.3 ± 1
M_{5-8}	267 ± 104	249 ± 94	516 ± 197	1 ± 6	149 ± 35	21 ± 6	23.3 ± 22.9	11.6 ± 1.1

F_{1-4} - Female (1. to 4. Grade), M_{1-4} - Male (1. to 4. Grade), F_{5-8} - Female (5. to 8. Grade), M_{5-8} - Male (5. to 8. Grade), F_{max}D - maximum muscle strenght of the dominant hand, F_{max}N - maximum muscle strenght of the non-dominant hand, F_{max}SUM - maximum muscle strength, total sum of both hands, SR - Sit-and-reach test, SLJ - Standing long jump, SU - Sit-up test, ICU - Isometric chin-up test, 4x10m - 4 x 10 m sprint

Table 3: Correlation between hand grip strength and battery of motor ability tests for students in grades 1-4

		SR (cm)		**SLJ (cm)**		**SU (n)**		**ICU (s)**		**4x10m (s)**	
		M	F	M	F	M	F	M	F	M	F
	r	**.387**	-.226	**.536**	-.036	.163	-.222	.168	**-.402**	**-.561**	-.379
Age	*p*	.034	.268	.002	.863	.390	.276	.375	.042	.001	.056
	r	.286	-.369	.266	.059	-.178	-.207	-.127	-.250	-.233	-.226
F_{max}D	*p*	.125	.063	.156	.776	.347	.310	.504	.218	.215	.266
	r	.250	-.297	.298	-.026	-.195	-.122	-.074	-.167	-.287	-.251
F_{max}N	*p*	.182	.140	.110	.899	.302	.553	.696	.414	.124	.215
	r	.054	-.343	.208	.020	-.194	-.171	-.114	-.216	-.070	-.243
F_{max}Sum	*p*	.778	.086	.269	.925	.305	.403	.548	.289	.713	.232

M - male, F - Female, F_{max}D - maximum muscle strenght of the dominant hand, F_{max}N - maximum muscle strenght of the non-dominant hand, F_{max}SUM - maximum muscle strength, total sum of both hands, SR - Sit-and-reach test, SLJ - Standing long jump, SU - Sit-up test, ICU - Isometric chin-up test, 4x10m - 4 x 10 m sprint

Table 4: Correlation between hand grip strength and battery of motor ability tests for boys (M) and girls (F) in grades 5-8.

		SR (cm)		**SLJ (cm)**		**SU (n)**		**ICU (s)**		**4x10m (s)**	
		M	F	M	F	M	F	M	F	M	F
	r	-.059	-.049	.186	.127	.138	.011	.106	-.049	-.048	-.024
Age	*p*	.721	.760	.257	.423	.401	.944	.521	.758	.521	.882
	r	.062	.121	**.479**	.180	.296	.007	.141	-.121	-.289	-.022
F_{max}D	*p*	.707	.447	.002	.253	.068	.965	.394	.445	.074	.893
	r	.088	.002	**.454**	.063	.285	-.066	.119	-.179	-.264	.000
F_{max}N	*p*	.593	.991	.004	.691	.079	.680	.470	.256	.104	.998
	r	.075	.066	**.471**	.128	.293	-.029	.131	-.152	-.280	-.012
F_{max}Sum	*p*	.649	.679	.002	.420	.070	.859	.425	.335	.085	.941

M - male, F - Female, F_{max}D - maximum muscle strenght of the dominant hand, F_{max}N - maximum muscle strenght of the non-dominant hand, F_{max}SUM - maximum muscle strength, total sum of both hands, SR - Sit-and-reach test, SLJ - Standing long jump, SU - Sit-up test, ICU - Isometric chin-up test, 4x10m - 4 x 10 m sprint

Table 5: Correlation between hand grip strength and battery of motor ability tests for students in grades 1-4 (Age control)

	SR (cm)		**SLJ (cm)**		**SU (n)**		**ICU (s)**		**4x10m (s)**	
	M	F	M	F	M	F	M	F	M	F
r	.053	-.301	-.120	.095	**-.373**	-.103	-.310	-.037	-.200	.018

F_{max}D	*p*	.783	.144	.535	.652	.046	.625	.101	.859	.299	.933
	r	-.002	-.216	-.079	-.009	**-.401**	-.008	-.245	.049	-.124	-.070
F_{max}N	*p*	.991	.299	.685	.965	.031	.969	.200	.815	.522	.738
	r	-.113	-.269	.002	.047	-.282	-.060	-.197	-.004	.192	-.025
F_{max}Sum	*p*	.560	.194	.993	.823	.138	.776	.306	.986	.317	.907

M - male, F - Female, F_{max}D - maximum muscle strenght of the dominant hand, F_{max}N - maximum muscle strenght of the non-dominant hand, F_{max}SUM - maximum muscle strength, total sum of both hands, SR - Sit-and-reach test, SLJ - Standing long jump, SU - Sit-up test, ICU - Isometric chin-up test, 4x10m - 4 x 10 m sprint

Table 6: Correlation between hand grip strength and battery of motor ability tests for students in grades 5-8 (Age control)

		SR (cm)		**SLJ (cm)**		**SU (n)**		**ICU (s)**		**4x10m (s)**	
		M	F	M	F	M	F	M	F	M	F
	r	.107	.199	**.459**	.124	.266	.000	.108	-.113	**-.331**	-.013
F_{max}D	*p*	.527	.225	.004	.452	.111	.1	.524	.937	.046	.937
	r	.137	.038	**.425**	-.012	.252	-.101	.081	-.197	-.294	.021
F_{max}N	*p*	.420	.818	.009	.941	.132	.541	.632	.901	.078	.901
	r	.123	.128	**.447**	.062	.262	-.049	.096	-.158	-.316	.003
F_{max}Sum	*p*	.470	.436	.006	.762	.117	.767	.570	.336	.056	.987

M - male, F - Female, F_{max}D - maximum muscle strenght of the dominant hand, F_{max}N - maximum muscle strenght of the non-dominant hand, F_{max}SUM - maximum muscle strength, total sum of both hands, SR - Sit-and-reach test, SLJ - Standing long jump, SU - Sit-up test, ICU - Isometric chin-up test, 4x10m - 4 x 10 m sprint

Discussion

The aim of this paper was to determine the relationships between the test for assessing overall strength and a battery of tests for assessing motor abilities in primary school children. Based on the results, it can be concluded that significant correlations were found between the criterion space, i.e., measured values of age the sit-and-reach (r=0.387, p=0.034), standing long jump (r=0.536, p=0.002), and 4×10 m running test (r=–0.561, p=0.001) in boys from the first to the fourth grade, and with the isometric chin-up test in girls (r=–0.402, p=0.042). Also, significant correlations were found between hand grip strength in both dominant and non-dominant hands, and long jump, only in boys from fifth to eighth grade (FmaxD: r=0.479, p=0.002; FmaxN: r=0.454, p=0.004; FmaxSUM: r=0.471, p=0.002). After controlling for the effect of age, these correlations remained statistically significant (FmaxD: r=0.459, p=0.004; FmaxN: r=0.425, p=0.009; FmaxSUM: r=0.447, p=0.006). Additionally, significant partial correlations were found in boys from first to fourth grade between non-dominant hand grip strength and sit-ups (FmaxN: r=–0.401, p=0.031), and in boys from fifth to eighth grade between dominant hand grip strength and 4×10 m running (FmaxD: r=–0.331, p=0.046). No statistically significant correlations were found among girls between the measured criterion variable, i.e., hand grip strength results and the results of motor tests, so it can be told that the main hypothesis is just partly proven.

One possible explanation why statistically significant relationships were not found between maximum hand grip strength and other tests could be due to the nature of the muscle contraction type during the execution of these tests as muscle contraction in dynamic and static conditions are two different phenomena (Masuda et al. 1999). Hand grip strength was measured under isometric conditions, while other tests (i.e., standing long jump, sit-up test, 4x10m) were conducted dynamically, using the subject's own body weight as

resistance. Considering that there are essentially two different types of loads covered by these tests such as maximal power output (standing long jump, 4x10m), and local muscular endurance (sit-ups, isometric chin-up) it could be concluded that the maximum hand grip strength test does not explain the variation in school test battery. Another reason for not achieving statistically significant correlations, lie in the varying biological ages of students, as it is well known that biological age can significantly differ from chronological age (Rogol et al., 2000). As we can see from the results in partial correlation, there are signifacant results in more variables, sit – ups, and 4x10m sprint.

The results of this study show that the tested physical abilities are within the range of previous research (Momčilović et al. 2019), where authors reported that the average standing long jump distance for 10-year-old boys was 124.5 ± 22.2 cm. In this study, boys of the same age jumped on average 131 ± 17.5 cm, indicating less variability on average, suggesting a higher sample homogeneity. Regarding girls of the same age, the same authors found that they averaged 116 ± 19.6 cm, while in this study, girls averaged 110 ± 18.1 cm in standing long jump distance.

When we talk about maximum hand grip strength, older school-age boys from England have an average maximum hand grip strength of 300 ± 71 N, while boys of the same age in this study showed slightly lower results at 267 ± 105 N. Similarly, girls in this study also showed weaker results compared to their peers from England, with a maximum hand grip strength of 212 ± 61 N compared to 240 ± 50 N for English girls (Cohen et al., 2010). On the other hand, our 10-year-old children showed greater strength compared to their peers from Italy (Montalcini et al., 2016). Boys from Italy had a maximum hand grip strength of 152 ± 30 N, while boys from this study had 186 ± 61 N. For girls, these values were 138 ± 40 N for Italian girls vs. 143 ± 41 N in gilrs f this study.

Regarding the obtained correlations in this research, the same results were found by Matsudo et al. (2014). They found statistically significant correlations between maximum hand grip strength and the standing long jump for boys ($p=0.004$) and girls ($p=0.002$). They had a sample of 233 children from 10 to 17 years of age. Their boys had maximum muscle strength in total sum of both hands 452 ± 25.7 N, compared to 402 ± 58.2 N for boys in our research. The results for SLJ were similar. They jumped in average 134.6 ± 7.9 cm, compared to 132.5 ± 29.5 cm. When we talk about girls, results were the same. For HG, they measured 430.5 ± 43.6 N compared to 305 ± 40 N for girls in our research. For SLJ, hey jumped in average 122.1 ± 7.6 cm, compared to 123 ± 22 cm. The bigger values in their results in their research can be explained by older children in their sample. But considering that the same method was used when measuring HG strength, we can relate our correlations to their.

The results of this study indicate that there are no statistically significant correlations between the used criterion and motor tests among boys and girls from grades 1 to 4, nor among girls from grades 5 to 8. This can may be explained by previous studies Matsudo et al. 2014) having participants who were mostly older than 12 years old, whereas studies focusing on hand grip strength in younger school-aged children are still limited in number to draw definitive conclusions.

Limitations

Although maximum muscle strength has not been found to be a general predictor for other tests in the motor ability battery, other contractile characteristics such as rate of force development (RFD) and time to reach maximum force are not tested in this research, but may potentially be better predictors in assessing these tests. Therefore, there is significant scope for further research in this regard. Additionally, the values presented in this study are absolute, and it would be interesting to normalize them relative to the weight of the participants. Furthermore, the results presented in this study are from school-age children in rural areas, so

it would be intriguing to explore the quality, relationships, and differences between measured tests among children in rural versus urban environments.

Conclusion

Based on the results obtained, we can conclude that a statistically significant correlation exists only among boys in grades 5 to 8, specifically with the standing long jump test. This indicates that the standardized battery of tests does not cover the entire spectrum of motor abilities in terms of load type. Given that grip strength testing is relatively simple and practical to conduct, there is a basis for recommending its inclusion in expanding the elementary school test battery. In the future, it will be necessary to explore other methods such as measuring other contractile characteristics (RFD) and normalizing the data, which leaves space for future research.

Acknowledgements: The authors acknowledge the participants for their contribution to the study. This study received no external financial assistance. None of the authors have any conflict of interest.

Conflict of interest: All authors declare that they have no conflict of interest relevant to the content of this article.

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