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AN INVESTIGATION OF MAXIMAL HAND GRIP STRENGTH RELATED TO BODY MASS INDEX IN HEALTHY CZECH CHILDREN

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ABSTRACT

Hand grip strength is one of the most important markers in muscle strength assessment for many reasons. However, its maximal value in kilograms is highly dependent on body size, which may misrepresent results, especially among children. Therefore, correction by body mass index (BMI) can be used as a suitable approach for its objectification. The aims of this study were to create reference values for the grip to BMI ratio and for hand grip strength for children in the Czech Republic. 554 children of both genders, aged from 4 to 14 years, were included in the current study. Reference values were approximated by Tukey's Hinges percentiles calculation method. The percentile charts were created using the Lambda-Mu-Sigma (LMS) method.

Keywords: dynamometry; grip to BMI ratio; percentiles; Czech children

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INTRODUCTION

Handgrip strength is extensively used with many intentions in practice, usually for hand function assessment or evaluation of physical performance among different populations from children to the elderly. Many studies have shown that handgrip strength is influenced by many factors. The result of handgrip strength testing is directly affected by neural, muscular and skeletal systems, and it is indirectly connected with one's lifestyle. Handgrip strength is widely used in the evaluation of athletes, general populations and patients suffering from many diseases associated with decreasing muscle strength and function. Measurements of maximal handgrip strength are essential to track changes during growth, maturation, aging, rehabilitation and training trials.

It is known that, in children, a correlation exists between weight, height and handgrip strength (Ager et al., 1984; Newman et al., 1984; Hanten et al., 1999; Rauch et al., 2002;

Ertem et al., 2003; Ertem et al., 2005; Ferreria et al., 2011; Montalcini et al., 2016). Ploegmakers et al. (2013) suggested that weight, and especially height, had a strong association with handgrip strength in school children. Both height and weight are easy to measure and are used as independent variables to calculate body mass index (BMI). Considering the relationship between height, weight, and grip strength, McLean et al. (2014) proposed a grip strength to BMI ratio, which is calculated as handgrip strength divided by BMI, to evaluate the elderly clinical population. Since grip strength is correlated with height and weight in children as well, we were inspired by the suggestion set forth by McLean et al. (2014) and believe that such a measurement may be appropriate for school children. However, reference values of handgrip strength as well as grip to BMI need to be established in the Czech Republic.

The main aims of this study were to create reference values for the grip to BMI ratio and for hand grip strength for children in the Czech Republic.

METHODS

Subjects

554 children of both genders, aged from 4 to 14 years, were included in the current study. All participants that were recruited were visitors of a promotional event series called Sportacek (a programme that encourages children to participate in sports) which took place in five cities in the Czech Republic in 2015. Before testing, the children and their legal guardians were acquainted with the study protocols and legal guardians provided written informed consent. The study was carried out with the approval of the Ethics Committee of the Faculty of Physical Education and Sport at Charles University.

Outcome measures

Body height was measured by a SECA 213 portable stadiometer and weight by a SECA 876 digital flat floor scale. Height and weight were used for BMI calculations. Handgrip strength was measured using a Takei A5401 digital hand grip dynamometer. Testing of handgrip strength was performed with the right and left hand, independently, according to standardized procedures, with the humerus positioned at the side and the elbow flexed to 90 degrees. For each trial, subjects were instructed to squeeze the dynamometer with maximal effort for two to three seconds. Participants performed three successive trials for each hand with a few seconds of rest between each trial. The average grip strength of three trials for the right and left hands were calculated and the strongest side was used for analysis.

Data analysis

Descriptive statistics were used to describe the main characteristics of the participants. A Pearson Chi-Squared goodness of fit test was used to test for equal distribution. The normality of data distribution was tested using the Kolmogorov-Smirnov test. Since the data

were not normally distributed for quantitative variables, the median and interquartile range (IQR) was used for the datasets. To determine significant differences between sexes, the data were compared using two-sample Kolmogorov-Smirnov tests. Reference values were approximated using Tukey's Hinges percentiles calculation method. Percentile charts were created by the Lambda-Mu-Sigma (LMS) method (LMS ChartMaker Pro Version 2.54, Medical Research Council, London, UK) (Cole & Green, 1992). Additionally, a multiple regression model for maximal handgrip strength was performed using height, body mass, and age. All statistical calculations were carried out in the IBM SPSS Statistics 21.

RESULTS

250 girls and 304 boys participated in the study and their descriptive statistics are presented in **Table 1**. The median age for girls was 8 (IQR 5) and was 7 (IQR 3) for boys. The girls were significantly taller and heavier than the boys. Although not significantly different, girls were stronger than boys in handgrip strength; however, boys displayed a greater grip to BMI ratio.

Tukey's Hinges percentiles, which are presented in **Tables 2** to **5**, show that handgrip strength and grip to BMI ratio increased with age in both genders. This is shown also in **Figure 1**. In the multiple regression models, weight had the strongest influence on handgrip strength, while age had the second strongest influence. According to the standardized coefficients Beta, gender played the weakest role in determining handgrip strength. The regression equation for handgrip strength is as follows: handgrip strength = 0.886 · Age + 6.006 · Height + 0.287 · Body mass + 1.269 · Sex − 9.543 (**Table 6**). Regression model for grip to BMI ratio show different results in this case the height was strongest independent variable (Beta = 0.709). The equation was as follows: grip to BMI = 0.055 · Age + 1.408 · Height − 0.009 · Body mass + 0.070 · Sex − 1.209 where age is in years, height in m, weight in kg and girls = 0 and boys = 1 (**Table 7**).

Table 1. Descriptive statistics for the sample population

	Girls	**Boys**	***p* value**
N = 554	250 (44.9)	304 (55.1)	0.019[a*]
Age (yr)	8 (5)	7 (3)	0.001[b*]
Height (m)	1.33 (0.3)	1.30 (0.2)	0.006[b*]
Weight (kg)	28.8 (15.8)	26.7 (12.3)	0.007[b*]
BMI (kg/m^2)	16.5 (2.9)	16.2 (2.1)	0.129[b]
Handgrip max (kg)	14.2 (9.0)	13.5 (7.8)	0.331[b]
Grip to BMI ratio (kg/kg/m^2)	0.82 (0.4)	0.85 (0.4)	0.623[b]

Note: Statistical differences were calculated as follow:
[a] Pearson Chi-Square Goodness of Fit test; in this case the data are presented as a number (percentage); [b] Kolmogorov-Smirnov test; in this case the data are presented as a median (IQR); Statistical significance * $p < 0.05$

Table 2. Girls' handgrip strength – Tukey's Hinges percentiles

	4	5	6	7	8	9	10	11	12	13	14
75	8.6	9.6	11.4	14.0	15.0	16.6	19.4	22.9	27.6	28.5	31.9
50	6.5	8.1	9.6	12.6	13.7	14.3	17.0	19.8	22.8	25.5	29.4
25	6.1	7.0	8.3	11.0	12.8	12.9	15.3	17.2	18.7	22.3	27.2

Table 3. Boys' handgrip strength – Tukey's Hinges percentiles

	4	5	6	7	8	9	10	11	12	13	14
75	8.7	10.6	12.5	15.1	16.9	18.3	21.6	22.7	25.9	34.9	42.5
50	7.1	8.9	9.9	12.8	14.1	16.4	18.9	20.3	23.7	28.1	37.5
25	6.1	7.7	9.1	10.4	12.4	15.0	16.9	19.1	20.5	25.5	35.1

Table 4. Girls' grip to BMI ratio – Tukey's Hinges percentiles

	4	5	6	7	8	9	10	11	12	13	14
75	0.56	0.58	0.73	0.83	0.90	0.96	1.20	1.28	1.31	1.49	1.55
50	0.44	0.53	0.60	0.78	0.81	0.85	1.10	1.15	1.16	1.37	1.51
25	0.41	0.47	0.52	0.71	0.76	0.78	0.84	1.12	1.14	1.16	1.31

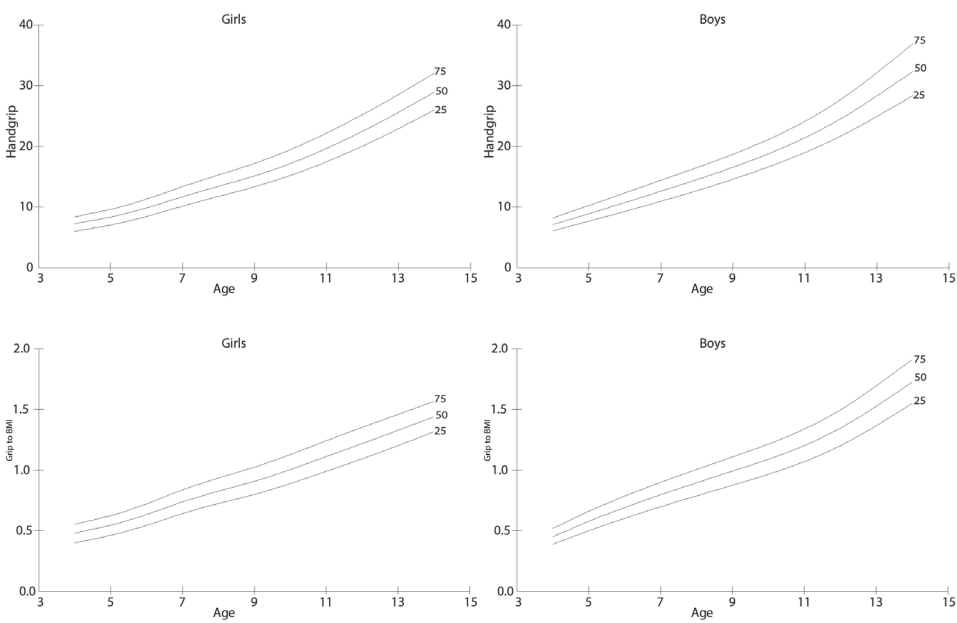

Figure 1. Percentile charts for handgrip strength and strength to BMI ratio in both sexes

Table 5. Boys' grip to BMI ratio – Tukey's Hinges percentiles

	4	5	6	7	8	9	10	11	12	13	14
75	0.53	0.68	0.79	0.92	1.10	1.10	1.20	1.23	1.35	1.77	2.20
50	0.47	0.58	0.68	0.79	0.86	1.00	1.16	1.18	1.22	1.48	1.90
25	0.36	0.50	0.59	0.70	0.79	0.90	0.92	1.00	1.12	1.40	1.83

Table 6. Multiple regression model for maximal handgrip strength

	Unstandardized Coefficients		Standardized Coefficients	t	*p* value	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	–9.543	2.130		–4.481	<0.001**	–13.727	–5.359
Age	0.886	0.116	0.348	7.609	<0.001**	0.657	1.115
Sex	1.269	0.238	0.095	5.322	<0.001**	0.801	1.738
Height in m	6.006	2.465	0.145	2.437	0.015*	1.164	10.848
Weight in kg	0.287	0.028	0.466	10.436	<0.001**	0.233	0.341

Note: Adjusted R Square = 0.836; Statistical significance * $p < 0.05$, ** $p < 0.001$

Table 7. Multiple regression model for grip to BMI ratio

	Unstandardized Coefficients		Standardized Coefficients	t	*p* value	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	–1.209	0.122		–9.939	<0.001**	–1.448	–0.970
Age	0.055	0.007	0.453	8.323	<0.001**	0.042	0.068
Sex	0.070	0.014	0.109	5.127	<0.001**	0.043	0.097
Height in m	1.408	0.141	0.709	10.001	<0.001**	1.131	1.684
Weight in kg	–0.009	0.002	–0.289	–5.438	<0.001**	–0.012	–0.005

Note: Adjusted R Square = 0.767; Statistical significance ** $p < 0.001$

DISCUSSION AND CONCLUSION

The main aims of this study were to create reference values for handgrip strength and grip strength to BMI ratio for children in the Czech Republic. From the multiple regression model, it appears as though maximal handgrip strength as well as grip to BMI ratio are highly dependent on all implicit independent variables – age, gender, height and weight with weight and age being the most influential, while height and gender were less influential. In our sample, there was no evidence of a statistically significant difference in

handgrip strength between sexes. BMI values alone were statistically similar in both sexes. However, although girls were stronger in handgrip strength, they were weaker in grip to BMI ratio, which was interesting. It seems that dividing handgrip strength by BMI might bring a novel approach to the measurement of muscle strength in children, which is different from the isolated handgrip strength measures.

The fact that maximal handgrip strength was related to BMI in the present study (i.e. grip strength-to-BMI ratio) was in accordance with the results of similar studies where correlations between BMI and grip strength were found (Jette et al., 1990; Chong et al., 1994; Ertem et al., 2005; Rantanen et al., 2000; Apovian et al., 2002). The increasing differences in grip strength to BMI ratio between boys and girls from 12 years in the present study agreed with Neu et al. (2002) and other studies which associate increases in hand grip strength with gender during maturation and growth (Ploegmakers et al., 2013; Mathiowetz et al., 1986), especially as the effect of sex hormones begins to play a role in the maturation process.

It has also been suggested that males are stronger than females in all age groups, and that hand dominance does not significantly affect handgrip strength performance (Mathiowetz et al., 1984; Ferreira et al., 2011). Additionally, Mathiowetz et al. (1984) found a high correlation between handgrip strength and age while gender and age as well as height and weight may also influence handgrip strength (Rauch et al., 2002; Newman et al., 1984; Ploegmakers et al., 2013). Those findings are usually used to generate reference values for different groups (Mathiowetz et al., 1986; Hogrel, 2015).

In conclusion, the data from the present study show that body mass and age play a greater role in estimating hand grip strength than gender and height in children. It is important to note that the subjects in the present study were recruited from an organized activity programme, possibly indicating that the children examined in the present study may be more active than their sedentary peers. Therefore, future research should investigate whether the same relationships exist between anthropometric measures and grip strength in sedentary children, or in active children from different countries.

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