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Gender differences in hand grip strength of the child athletes by using absolute, ratio and allometric scaling methods.

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Abstract

The purpose of this study was to determine gender differences in hand grip strength of the child athletes using absolute, ratio and allometric scaling methods. 75 male (age: 10.47 ± 1.11 years) and 65 female (age: 10.51 ± 1.13 years) healthy and physical active child athletes aged 8-10 years volunteered to participate in this study. Arm volume measurements of the child athletes were conducted using a water displacement method. Right and left hand grip strength was measured with hand dynamometer.
A dependent t-test was used to make a gender-based comparison of hand grip strength in absolute and proportion to body size. There were no significant strength differences found between boys and girls in terms of absolute, ratio scaling and allometric scaling methods related to arm volume (p>0.05). However, maximum hand grip strength of the boys was higher than girls both ratio scaling and allometric scaling methods related to body mass (p<0.05).

Keywords: Gender, Hand grip, Child athletes.

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Introduction

Strength of the hand grip is often used as an indicator of overall physical strength [1,2], general health status [3], hand and forearm muscle performances [4] and as an index of nutritional status [5,6]. Hand grip strength can be used in both children [2,5,7] and adults [1,3]. It is influenced by many factors including age, gender, handedness, motivation, position of extremity during test and body size [8-11]. In several studies, it is shown that anthropometric variables, such as height, weight [2,12-15], hand length [16,17], hand width [17], body mass index [2], body surface area [12] correlate with grip strength.

One of the problems encountered in comparing the strength measurement is allowing for the effect of body size. Body size is an important factor in determining individual's muscle strength, but how strength measurements should be normalized for differences in body size are controversial [18]. Various scaling models have been used for the normalization of performance measurement. The most widely used of these models are ratio scaling, linear regression, ANNOVA and allometric scaling [19]. Allometric scaling is the most accepted model to normalization of data through the removal of the direct influence of body size [20,21]. Allometric scaling is the nonlinear regression model fitted to data set [22]. In this model, it is believed that relationship between depended (performance or physiological variables) and independent anthropometric variables is curvilinear and passes through the origin [23].

Methods

Participants

A total of 130 child athletes from basketball, volleyball and handball (65 girls and 75 boys) volunteered to participate in this study. Physical characteristics of girls and boys are presented in Table 1. Age, height, right and left arm volume of the boys were similar to girls while body mass of girls significantly higher than those of boys (p<0.05). Subjects were informed about the study and signed informed consent form. Before the data were collected participants were familiarized with test procedures.

Table 1. Physical characteristics of boys and girls.

Variables	Girls (mean ± sd)	Boys (mean ± sd)	t
Age (years)	10.51 ± 1.13	10.47 ± 1.11	0.216
Height (cm)	149.78 ± 11.37	148.81 ± 12.57	0.476
Body mass (kg)	46.10 ± 11.87	38.50 ± 12.05	3.749*
Right arm volume (l)	1.249 ± 0.373	1.132 ± 0.400	1.784
Left arm volume (l)	1.234 ± 0.377	1.120 ± 0.393	1.746

Anthropometric measurements

Heights of the children were measured by a wall-mounted stadiometer (Holtain Ltd, Crymych, Wales). Body mass was measured by using a scale (Tanita HD 358 Japan) with participants wearing short and T-shirt.

The volume of right and left arm was measured using a water displacement method. A cylindrical volumeter with a depth of 70 cm and a radius of 10 cm was used to measure the volume of the each arm as shown in Figure 1. The volumeter was placed on a flat surface and filled with warm water (25-28˚C) to the level of the spout. After the water stopped overflow from the spout, each arms of the participants were signed with a permanent pencil at the level of the axilla. Participants were immersed their arms into the volumeter and kept them in a vertical position. When the top of the volumeter contact with the axilla, participant was instructed to maintain their positions until the water stopped dripping from the spout. Overflow water was collected in a plastic container and measured with 500 ml graduated cylinder. All the volumetric measurements were taken between 09:00-12:00 a.m.

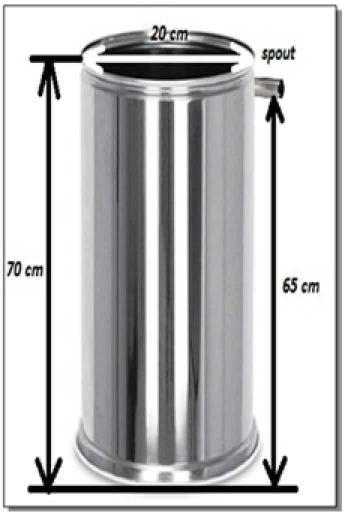

Figure 1. *Cylindrical volumeter for measuring arm volume Hand grip Strength Measurements.*

The grip strength of both right and left hands was measured using a digital hand dynamometer (TKK 5401, Takei Scientific Instruments, Japan) in a standing position with the shoulder adducted and elbow in full extension. The subjects were asked to squeeze the dynamometer with as much force as possible with both right and left hands. Three attempts were made by all subjects and the better performance was recorded.

Data analysis

Hand grip strength values of male and female participants were allometrically corrected according to their body size. To this end, relations between the dependent variables (Right Hand grip Strength (RHS) and Left Hand grip Strength (LHS)) and independent variables (Body Mass (BW), Right Arm Volume (RAV), Left Arm Volume (LAV)) were analysed using nonlinear allometric model of "$y=aX^b$". In this formula: "y" refers to dependent variables (Right Hand grip Strength (RHS) or Left Hand grip Strength (LHS)); "a" to proportional coefficient; "X" to independent variables (Body Mass (BW), Right Arm Volume (RAV) or Left Arm Volume (LAV)); and "b" to exponent (allometric exponent). Natural logarithm of the dependent and independent variables were taken in the non-linear allometric model and were converted into the linear form of "(ln); $\ln y=\ln a+b \ln X+\ln \varepsilon$". In this formula: "ln y" refers to dependent variable; "ln a" to the point where the line intersects with the y-axis; "b" to line curve; "ln X" to independent variable; and "ln ε" error term. Allometric model was developed for the independent variables having common b exponent for both groups. For this purpose, after the allometric model was converted into a linear one, Group x ln X interaction term was included in the model together with Group (g) (girls=0, boys=1) variable, giving the following equation:

$$\ln y = \ln a + cG + d (G \times \ln X) + b \ln X + \ln \varepsilon$$

In this equation, significance of both G x ln BM, G x ln RAV and G x ln LAV terms were tested separately for both Right Hand grip Strength (RHS) and Left Hand grip Strength (LHS). Since normal distribution of dependent and independent variables is a pre-condition for allometric model, normality of variables was tested using Kolmogorov-Smirnov One Sample Test after logarithmic conversion of strength values and body size values. No variable was found to statistically significantly deviate from the normal distribution ($p>0.05$). After the variables were inserted into the model, G x ln BM, G x ln RAV and G x ln LAV and Left Hand grip Strength (LHS) interaction terms were found to be statistically insignificant for Right Hand grip Strength (RHS) and Left Hand grip Strength (LHS) ($p>0.05$). In other words, relations between Right Hand grip Strength (RHS)-Body Mass (BM), Right Hand grip Strength (RHS)-Right Arm Volume (RAV), Right Hand grip Strength (RHS)-Left Arm Volume (LAV), Left Hand Grip Strength (LHS)-Body Mass (BM), Left Hand Grip Strength (LHS)-Right Arm Volume (RAV), Left Hand Grip Strength (LHS)-Left Arm Volume (LAV) and curves of the lines representing these relations were found to be similar between the groups. Since "G x ln BM, G x ln RAV" and "G x ln LAV" interaction terms of Right Hand grip Strength (RHS) and Left Hand grip Strength (LHS) were insignificant for the formula equation, these terms were excluded from the model to produce the following equation;

$$\ln y = \ln a + cG + b \ln X + \ln \varepsilon$$

95% confidence intervals of the b exponents of the terms included in the developed models were calculated. In addition, error terms of the models were analysed to check whether the strength variables were freed from body size. Kolmogorov-Smirnov One Sample Test was used to test the normal distribution of error terms. In all models, error terms were found to show normal distribution ($p>0.05$). Differences between the handgrip strength values of girls and boys were examined after the strength variables (independent variables) of the groups were free from the body size as a result of allometric model ((y/Xb) (y: Right Hand grip Strength (RHS) and Left Hand grip Strength (LHS); X: Body mass, Right Arm Volume (RAV) and Left Arm Volume (LAV), b: exponent)) [24].

A dependent t test was used to compare differences between the handgrip strength values (absolute, ratio-scaled and allometrically-scaled to body size) of girls and boys.

Results

Absolute and ratio-scaled hand grip strength of girls and boys related to body mass, left arm volume and right arm volume were presented in Table 2. There were no significant strength differences found between boys and girls in terms of absolute and ratio scaling methods related to right and left arm volume ($p>0.05$). However, boys had greater right and left hand grip strength values than their girls' counterparts in related to body mass ($p<0.05$) as shown in Table 2.

Table 2. *Hand grip strength of the girls and boys expressed in absolute terms and ratio scaled to body mass, left and right arm volume.*

Variables	Girls mean ± sd	Boys mean ± sd	t
RHS (kg)	18.15 ± 5.18	17.75 ± 6.89	0.38
LHS (kg)	17.13 ± 4.84	16.97 ± 6.99	0.163
RHS/BM ($kg.BM^{-1}$)	0.40 ± 0.10	0.47 ± 0.17	-2.986*
LHS/BM ($kg.BM^{-1}$)	0.38 ± 0.09	0.45 ± 0.15	-3.236*
RHS/RAV ($kg.l^{-1}$)	15.19 ± 4.69	16.05 ± 3.82	-1.201
LHS/LAV ($kg.l^{-1}$)	14.44 ± 4.11	15.35 ± 3.66	-1.386

*p<0.05

RHS: Right Hand Grip Strength (kg); LHS: Left Hand Grip Strength (kg); BM: Body Mass (kg); RAV: Right Arm Volume (liter); LAV: Left Arm Volume (liter).

Common allometric formulas for girls and boys were constructed from the independent variables that include common b exponent for both groups. Common allometric formulas derived from right arm volume, left arm volume and body mass for right and left hand grip strength are presented in Table 3. Common b exponents derived for Right Hand Grip Strength (RHS) were $RAV^{0.69}$ (95% confidence interval=0.56-0.82) and $BM^{0.81}$ (95% confidence interval=0.65-0.95), derived for LHS were $LAV^{0.76}$ (95% confidence interval=0.63-0.88) and $BM^{0.87}$ (95% confidence interval=0.72-1.01) as shown in Table 3.

Table 3. *Allometric formulas for Right Hand Grip Strength (RHS) and Left Hand Grip Strength (LHS) derived from Right Arm Volume (RAV), Left Arm Volume (LAV) and Body Mass (BM).*

ln RHS=(2.73 ± 0.03)+(0.04 ± 0.04) G+(0.69 ± 0.06) ln RAV
ln LHS=(2.67 ± 0.03)+(0.13 ± 0.05) G+(0.76 ± 0.07) ln LAV
ln RHS=(-0.21 ± 0.28)+(0.12 ± 0.05) G+(0.81 ± 0.07) ln BM
ln LHS=(-0.48 ± 0.28)+(0.13 ± 0.05) G+(0.87 ± 0.07) ln BM

*p<0.05

RHS: Right Hand Grip Strength (kg); LHS: Left Hand Grip Strength (kg); BM: Body Mass (kg); RAV: Right Arm Volume (liter); LAV: Left Arm Volume (liter).

Allometrically scaled hand grip strength of girls and boys related to body mass, left arm volume and right arm volume were presented in Table 4. When the right hand grip strength and left hand grip strength values allometrically scaled to right arm value and left arm value, there were no significant grip strength differences found between boys and girls ($p>0.05$). However, When the right hand grip strength and left hand grip strength values allometrically scaled to body mass, maximum right and left hand grip strength scores of the boys were higher than girls ($p<0.05$) as shown in Table 4.

Table 4. *Hand grip strength of the girls and boys expressed in allometrically scaled to body mass, left and right arm volume.*

Variables	Girls mean ± sd	Boys mean ± sd	t
$RHS/BM^{0.81}$ ($kg.kg^{-1}$ $BM^{0.81}$)	0.82 ± 0.20	0.93 ± 0.29	-2.579*
$LHS/BM^{0.87}$ ($kg.kg^{-1}$ $BM^{0.87}$)	0.62 ± 0.14	0.71 ± 0.22	-2.919*
$RHS/RAV^{0.69}$ ($kg.l^{-1}$ $RAV^{0.69}$)	15.89 ± 4.33	16.35 ± 3.91	-0.66
$LHS/LAV^{0.76}$ ($kg.l^{-1}$ $LAV^{0.76}$)	14.92 ± 3.86	15.57 ± 3.84	-0.983

*p<0.05

RHS: Right Hand Grip Strength (kg); LHS: Left Hand Grip Strength (kg); BM: Body Mass (kg); RAV: Right Arm Volume (liter); LAV: Left Arm Volume (liter).

Discussion

The purpose of this study was to determine gender differences in hand grip strength of the child athletes (10-12 years old) using absolute, ratio and allometric scaling methods. The findings of this study demonstrated that there were no significant differences in both absolute right hand grip and left hand grip strength scores between boys and girls. Similarly, when hand grip strength values were normalized for arm volume, ratio and allometrically scaled maximum hand grip strength scores of the boys and girls were similar. However, When the hand grip strength values scaled to body mass as a rationally and allometrically, maximum right and left hand grip strength scores of the boys were higher than girls.

Studies examining handgrip strength between genders produce conflicting results. While some studies suggest that absolute handgrip strength values of males are higher than those of females [6,25,26], some others express no statistically significant difference between genders [27]. Effects of age as well as maturity level should be ignored when analysing strength differences between groups. Various studies have shown a significant increase in handgrip strength of both girls and boys with the transition from childhood to adolescence [7,9,16,25]. However, girls become adolescents generally at earlier ages than boys. Therefore, significant increases in the absolute handgrip strength values of girls to have become adolescent may be higher than those of the pre-adolescence boys at the same chronological age. In their study on handgrip strength of the adolescent girls and boys aged 11-14 years, [9] found that absolute handgrip strength values of the girls aged 11 years was higher than those of the same-aged boys, but this difference was not statistically significant. However, handgrip strength values of males significantly higher than female counterparts after the 11 years old due to hormonal reasons. It is stated that the effect of growth and testosterone hormones on handgrip strength is greater in boys than in girls [6,28].

In addition to maturity level and age, body size should be taken into consideration to make a correct comparison between the performance values of groups. Jaric et al. stated that body size has important effects on muscle strength and, as a result, expression of strength values in relation to body size would be a more appropriate approach to be adopted in comparison of athletes' performance values [18]. Different methods can be used in scaling performance values to body size. Among these methods, the most commonly used are ratio scaling and allometric scaling.

Ratio scaling method divides performance (i.e. strength) values directly by body size [29]. This is one of the methods mostly widely used to free performance variables from the effects of body size [22]. In other words, the purpose of this method is to normalize the performance increase brought by increase in body mass. This thought is supported by the following findings of the present study: strength values of girls are higher than those of boys in absolute terms, at a statistically insignificant level though, and strength values of boys are higher than those of girls when body mass factor is considered. However, ratio scaling method is criticised since it assumes a linear relation between the performance variables and body size and, as a result, produces disadvantageous results for those with heavier bodies (to penalize heavier individuals) [30].

Allometric scaling is another method used in analyses of performance values of groups. Allometric scaling method is the most valid approach which ensures data normalization by eliminating body size effects [20]. Since it removes scaling-induced performance score disadvantages of heavier individuals, it is more effective than ratio scaling method [24]. This study produced no statistically significant difference between the genders when strength values were scaled to arm volume both proportionally and allometrically. However, when the strength were scaled to body mass, strength values produced by boys were found to be higher than those of girls in both methods although the difference between the groups was reduced by the allometric method as shown in Tables 2 and 4. Some studies analysing the performance differences between groups suggest that performance difference between the groups decrease [19] and some other studies state that this difference totally disappears after allometric scaling [19,20,31]. However, these studies make comparisons on the basis of different performance variables (power, strength etc.).

Conclusion

When the handgrip strength of girls and boys aged 8-10 years was scaled to arm volume via absolute, ratio scaling and allometric scaling methods, no statistically significant difference was found between the groups, while boys were recorded to have statistically significantly higher handgrip strength values than girls when this strength is scaled to body mass. Although allometric scaling method decreased the strength value difference between the groups, it did not have any effect on the statistical results.

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