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Mathematical model for predicting handgrip strength in Quilombola children and adolescents: a cross-sectional study

Modelo matemático para predecir la fuerza de prensión manual en niños y adolescentes Quilombolas: un estudio transversal

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Abstract. Objective: To determine which variables have the ability to predict handgrip strength in Quilombola children and adolescents. Methods: We calculated the sample seeking an R^2 between 0.1 and 0.2 for a single dependent variable (handgrip strength), with 6 predictor variables (age, body mass, stature, Body Mass Index [BMI], fat mass, and lean mass), alpha of 0.05 and beta of 0.80; and included children and adolescents between the ages of 6 and 17 (n=82). We measured handgrip strength using the Jamar dynamometer and built a model and evaluated the association between the predictor variables (i.e., independent, x-axis) and the outcome variable (i.e., dependent, y-axis [dynamometry]) by analysis of variance of mathematically adjusted models (F-value >60, p <0.05). Results: We noted an increasing gain in strength over the years, although between the ages of 11 and 12 and between 13 and 14, there was an apparent loss of strength on the part of Quilombola adolescents, passing from 18.75 to 16.12 and from 23.5 to 19.83, respectively. We observed that the variables age, stature, and lean mass contributed significantly (p <0.05, β coefficient ranging from 3.050 to 3.844) to the performance of the built model (F [7.74] = 62.16, p <0.001; R^2 = 0.84). Conclusion: Age, stature, and lean mass significantly contribute to the performance of the built model. Namely, 84% of the variation in the mean handgrip strength may be explained by the independent variables. Therefore, the predicted handgrip strength, in kg, corresponds to: -29.530 + 1.103 + 0.196 + 0.011 × (age [years] + stature [cm] + lean mass [kg]).
Keywords: Public Health; Vulnerable Populations; Musculoskeletal System; Muscle Strength; Adolescent Nutrition.

Resumen. Objetivo: Determinar qué variables tienen la capacidad de predecir la fuerza de agarre manual en niños y adolescentes quilombolas. Métodos: Calculamos la muestra buscando un R^2 entre 0,1 y 0,2 para una única variable dependiente (fuerza de prensión manual), con 6 variables predictoras (edad, masa corporal, estatura, IMC, grasa y masa magra), alfa de 0,05 y beta de 0,80; e incluyó niños y adolescentes entre 6 y 17 años (n=82). Medimos la fuerza de prensión manual usando el dinamómetro Jamar y construimos un modelo y evaluamos la asociación entre las variables predictivas (es decir, independiente, eje x) y la variable de resultado (es decir, dependiente, eje y [dinamometría]) mediante análisis de varianza de modelos matemáticamente ajustados (valor F >60, p <0,05). Resultados: Se constató una ganancia creciente de fuerza a lo largo de los años, aunque entre los 11 y 12 años y entre los 13 y 14 años hubo una aparente pérdida de fuerza por parte de los adolescentes Quilombolas, pasando de 18,75 a 16,12 y de 23,5 a 19,83, respectivamente. Observamos que las variables edad, estatura y masa magra contribuyeron significativamente (p <0,05, coeficiente β que oscila entre 3,050 y 3,844) al rendimiento del modelo construido (F [7,74] = 62,16, p <0,001; R^2 = 0,84). Conclusión: La edad, la estatura y la masa magra contribuyen significativamente al rendimiento del modelo construido. Es decir, el 84% de la variación en la fuerza media de prensión manual puede explicarse por las variables independientes. Por tanto, la fuerza de prensión prevista, en kg, corresponde a: -29,530 + 1,103 + 0,196 + 0,011 × (edad [años] + estatura [cm] + masa magra [kg]).
Palabras clave: Salud Pública; Poblaciones vulnerables; Sistema musculoesquelético; Fuerza muscular; Nutrición Adolescente.

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Introduction

Handgrip strength is a robust indicator of biological health in children and adolescents (Fredriksen, Mamen, Hjelle, & Lindberg, 2018). Children and adolescents with high handgrip strength have been reported to have higher bone mineral density. In addition, an inverse relationship has been reported between Handgrip Strength and the presence of obesity, metabolic syndrome, or dyslipidemia (López-Gil, Weisstaub, Ramírez-Vélez, & García-Hermoso, 2021). A systematic review described a substantial improvement in absolute handgrip strength in children and adolescents since 1967. There is a need for international surveillance of handgrip strength, especially in low- and middle-income countries (e.g., Brazil), to more confidently determine true international trends (Dooley et al., 2020). Handgrip strength is also considered an important interpreter of general health and hand function in children, which is mainly influenced by anthropometric determinants, such as age, body mass, stature, BMI, fat, and lean mass (Rostamzadeh, Saremi, Vosoughi, et al., 2021).

Kakaraparthi et al. (2023) showed handgrip strength and its correlation with anthropometric determinants and hand dimensions in children aged 6-12 years. Furthermore, the grip-to-BMI ratio can be used to predict the presence of sarcopenic obesity in children, which may play a role in pediatric health interventions (Gontarev, Jakimovski, & Georgiev, 2020). However, no study has tested the feasibility of constructing a mathematical model to predict handgrip strength in Quilombola children and adolescents, making it difficult to establish normative handgrip strength data specific to a given population in research or clinical settings, as noted in the literature (Rostamzadeh, Saremi, Abouhossein, Vosoughi, & Molenbroek, 2021a).

This gap suggests the following research question: which of these variables are relevant for predicting handgrip strength in Quilombola children and adolescents? Therefore, the hypothesis of this study was that basic biological variables statistical performance to predict handgrip strength. As such, our objective was to determine which variables have the ability to predict handgrip strength in Quilombola children and adolescents.

Methods

Study design

A cross-sectional study approved by the Brazilian Ethics Committee (report number: 56954116.2.0000.5516), Universidade Federal do Tocantins and developed in Quilombola communities in the state of Tocantins. The study was conducted in the Quilombola community of Barra do Aroeira, located 96 km from the capital city of Palmas, Tocantins, northern region of Brazil, and 12 km from the urban area of the municipality of Santa Tereza do Tocantins.

Participants and Sample Size

We calculated the sample using the software Ene 3.0®, seeking an R^2 between 0.1 and 0.2 for a single dependent variable (handgrip strength), with 6 predictor variables (age, body mass, stature, BMI, fat, and lean mass), alpha of 0.05 and beta of 0.80; thus, the sample was estimated at 82 participants. Thus, all children and adolescents between the ages of 6 and 17, enrolled in the current year 2022, at the Horácio José Rodrigues Municipal School, located within the Terra Quilombola Barra do Aroeira (Tocantins, Brazil), were invited to participate in the research, a total of 116 subjects. After the invitation, the consent of those in charge and the participants, and absences on the day of data collection, the sample loss was 34, leaving 82 subjects able to participate in the study.

The participants were enrolled in primary school in the early stages of schooling. There is a local social context in which children of different ages and levels occupy the same classroom, under the guidance of only one teacher. This is due to the difficulties of the Brazilian education system, combined with the social vulnerability of the country's Quilombola communities, which culminate in a lack of teachers, difficult access to the community, low wages, precarious working conditions, and overall social and political problems.

Eligibility Criteria

We included children and adolescents between the ages of 6 and 17, residents and descendants of the Barra do Aroeira community in Santa Teresa, Tocantins state (Brazil), enrolled in the Horácio José Rodrigues Municipal School, with their guardian signing the Free and Informed Consent Form and the consenting child/adolescent signing the Free and Informed Assent Form.

Data measurement

Anthropometric parameters were measured. Stature was assessed using a wall stadiometer (Seca 206)®, and body mass was assessed using the digital weight scale, duly measured to calculate BMI using the formula body mass/stature $(m)^2$. A four-electrode tetrapolar device was used, with two conductors attached to the hand and foot and two receivers attached to the wrist and ankle (Monteiro & Fernandes Filho, 2002).

Statistical analysis

Regarding the assumptions of this mathematical analysis of linear regression, we observed a linear relationship between variables, independent residuals (Durbin-Watson test = 1.74), absence of outliers (≤3 standard-deviations), normal distribution of residuals, and the presence of homoscedasticity. Afterward, we performed a multiple linear regression with an alpha of 0.05 for all tests through the International Business Machines Corporation (IBM)® Statistical Package for the Social Sciences (SPSS)® Statistics for Windows®, version 20.0, Armonk, NY, USA (Edwards, Muller, Wolfinger, Qaqish, & Schabenberger, 2008; Nakagawa, Johnson, & Schielzeth, 2017; Saunders, Russell, & Crabb, 2012a).

We measured handgrip strength using the Jamar dynamometer®, each participant performed the handgrip 3 times, and, shortly after, the mean between the 3 attempts was calculated. Subsequently, we built a model and evaluated the association between the predictor variables (i.e., independent, x-axis [age, body mass, stature, BMI, fat in percentage, fat in kg, and lean mass in kg]) and the outcome variable (i.e., dependent, y-axis [dynamometry]) by analysis of variance of mathematically adjusted models (F-value >60, $p < 0.05$) (Edwards et al., 2008; Nakagawa et al., 2017; Saunders et al., 2012a).

In the analysis of variances, we considered the null and alternative hypotheses of the respective test (H0: constructed model = model without predictor; H1: constructed model ≠ model without predictor). Thus, we accept and report only the corrected models with a significance level <0.05 and coefficient of determination adjusted for the independent variables (R^2) > 0.80, whose explanation indicates that the performance of the built model is capable of explaining the dependent variable. The R^2 increases proportionally as we add new variables to the regression, so it is possible to have models with irrelevant variables and a high R^2 (to avoid this we use the adjusted R^2) (Edwards et al., 2008; Nakagawa et al., 2017; Saunders, Russell, & Crabb, 2012b).

Identifying the corrected models with a significance level <0.05, we performed multiple linear regression on each of them. Through the univariate model, we built a term of the main effects of the independent variables on the dependent variables. Therefore, the association among them had a mathematically randomized predictive power. To obtain the beta coefficients of each of the associations between variables, we evaluated the parameter estimates considering null and alternative hypotheses (H0: beta coefficient = 0; H1: beta coefficient ≠ 0). Therefore, the significance of the beta coefficient ($p < 0.05$) represents the performance significance of the independent variable and covariates (Edwards et al., 2008; Nakagawa et al., 2017; Saunders et al., 2012b).

Results

A total of eighty-two children and adolescents were evaluated for handgrip strength. The distribution of Quilombola children and adolescents by handgrip strength, stratified by age, is presented as mean, standard deviation, minimum, and maximum (Table 1).

Regarding handgrip strength (Table 2), we observed that the variables age, stature, and lean mass significantly contribute ($p < 0.05$, β coefficient ranging from 3.050 to 3.844) for the performance of the built model (F [7.74] = 62.16, $p < 0.001$; $R^2 = 0.84$).

Namely, 84% of the variation in the mean handgrip strength may be explained by the independent variables.Therefore, the predicted handgrip strength, in kg, corresponds to: -29.530 + 1.103 + 0.196 + 0.011 × (age [years] + stature [cm] + lean mass [kg]).

Table 1.
Distribution of Quilombola children and adolescents by handgrip strength (n=82).

Age (years)	Mean ± Standard Deviation (Min-Max)
6	6.81 ± 2.69 (02-12)
7	8.50 ± 0.95(07-10)
8	11.50 ± 2.76 (08-18)
9	12.00 ± 2.72 (09-17)
10	13.90 ± 5.53 (10-22)
11	18.75 ± 3.11 (13-24)
12	16.12 ± 7.88 (11-27)
13	23.50 ± 5.28 (17-31)
14	19.83 ± 5.3 (18-32)
15	25.00 ± 12.02 (24-37)
16	23.66 ± 5.5 (29-41)
all	16.10 ± 8.37 (02-41)

Table 2.
Model for handgrip strength in Quilombola children and adolescents (n=82): R^2=0.84, F=62.16, p <0.001.

Variables	Unstandardized Coefficients		Standardized Coefficients	t-value	p-value	95% Confidence Interval for β	
	β	Std. Error	β			Lower Bound	Upper Bound
Age (years)	1.10	0.28	0.38	3.847	<0.001*	0.532	1.674
Body mass (kg)	0.01	0.01	0.09	1.612	0.111	-0.001	0.011
Stature (cm)	0.19	0.05	0.37	3.320	0.001*	0.078	0.313
BMI (kg/m^2)	0.01	0.01	0.08	1.424	0.159	-0.001	0.003
Fat (%)	0.01	0.01	0.04	0.694	0.490	-0.008	0.017
Fat (kg)	-0.01	0.01	-0.09	-1.238	0.219	-0.038	0.009
Lean mass (kg)	0.01	0.01	0.17	3.050	0.003*	0.004	0.018

* Variable that contributes significantly to the performance of the built model.

Discussion

In the present study, the variables: age, stature, and lean mass contributed significantly to the performance of the constructed model. There was 84% of the variation in mean handgrip strength that could be explained by the independent variables: age, stature, and lean mass.

Handgrip strength is an important indicator of physical fitness in children and adolescents. In the present study, an increasing increase in strength was observed over the years, except at ages 11 and 12 and 13 and 14 years, where there was a decrease, ages where a greater increase was expected. In the study by Trajkovic et al (2021), there were no significant differences between the ages of 4 and 5 years and 8 to 9 years. This finding corroborates the present study, as the average strength for 8- and 9-year-old children was 11.50 and 12.00, respectively, an increase in strength of only 0.5.

Other studies show a tendency for strength to increase over the years. This is expected because strength capacity tends to increase during the growth phase and peaks at around 19 years of age (Omar, Alghadir, Zafar, & Al Baker, 2018; Rostamzadeh, Saremi, Abouhossein, Vosoughi, & Molenbroek, 2021b; Trajković et al., 2021). Regarding the difference in strength between boys and girls, Rostamzadeh et al (2021), in a study of Iranian children and adolescents, describe that the strength of boys was significantly greater than that of girls, but emphasize that this difference in strength was observed from 11 years of age. Based on the results of this work, it is observed that the greatest increases in strength occurred between the ages of 12 and 13 years and between the ages of 14 and 15 years, which may be related to strength gains during the pubertal period.

Comparing the results of this study with the results of the study by Rostamzadeh et al (2021), it is clear that the overall mean strength was lower in the Quilombola population than in the Iranian population. This is of concern because, based on the conclusion of the work of Rostamzadeh et al, the strength results of the Iranian population were lower than the results of other studies, i.e., if the handgrip strength of Iranian children and adolescents is lower than the results of other studies, it means that the Barra do Aroeira Quilombola population suffers from a deficit in handgrip strength. It was observed that the severity of osteogenesis imperfecta affected handgrip strength and locomotor function in Brazilian children and adolescents, as assessed by the mobility domain. Comparing osteogenesis imperfecta types, the higher the severity of osteogenesis imperfecta, the lower the handgrip strength. Highlighting the clinical relevance of this assessment (Coêlho, Luiz, Castro, & David, 2021).

It is important to note that although there are associations between handgrip strength and markers of health, no research could be identified that examined whether increasing handgrip strength would lead to improvements in health. If an increase in handgrip strength truly represents an improvement in long-term health, then handgrip exercises may need to be incorporated into physical activity programs during the growth/development phase (Abe, Thiebaud, Ozaki, Yamasaki, & Loenneke, 2022).

Our study has limitations that should be addressed, such as we do not know the influence of arm length, brainstem height, maturation stage, and motor tests on handgrip strength. We suggest additional studies in this regard.

Conclusion

Age, stature, and lean mass significantly contribute to the performance of the built model. Namely, 84% of the variation in the mean handgrip strength may be explained by the independent variables. Therefore, the predicted handgrip strength, in kg, corresponds to: -29.530 + 1.103 + 0.196 + 0.011 × (age [years] + stature [cm] + lean mass [kg]).

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