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ORIGINAL ARTICLE

Evaluation of the Effectiveness of Using Handgrip Strength in Determining Malnutrition in Adolescents

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We aimed to evaluate the effectiveness of using handgrip strength (HGS) in determining malnutrition in adolescents. Sixty-two participants (10–18 years of age), 33 malnourished and 29 healthy participants, were recruited. A questionnaire was administered, and anthropometric parameters and HGS were measured. Dominant HGS was different in children with (11.6 ± 5.8 nkgF) or without (21.6 ± 5.7 kgF) malnutrition ($P < .001$). Body mass index, triceps/biceps skinfold, neck/waist/wrist circumferences, and arm muscle area were correlated with HGS. According to receiver operating characteristic analysis, dominant (area under the curve [AUC]: 85.9%), and nondominant HGSs (AUC: 83.9%) were possible predictors for malnutrition. HGS may be used as a tool for malnutrition assessment in adolescents. **Key words:** *handgrip*, *HGS*, *malnutrition*, *muscle strength*, *nutrition assessment*, *pediatrics*

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G.D., A.K., and N.Y.A. contributed to the conception and design of the research. Z.K. and C.T.K. contributed to interpretation. G.D. drafted the manuscript. All authors critically revised the manuscript, gave the final approval, and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

The study complied with the World Medical Association Declaration of Helsinki regarding ethical conduct of research involving human subjects. The research was approved by the Ankara University Faculty of Medicine Clinical Research Ethics Committee (03-206-19/January 2019).

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MALNUTRITION is defined by the American Society for Parenteral and Enteral Nutrition (ASPEN) as "the imbalance between need and intake resulting in cumulative insufficiency of energy, protein, and micronutrients that negatively affect growth and development."[1] Malnutrition is known to prolong hospital stay, increase susceptibility to infections, and increase mortality risk.[2] Evaluation of nutritional status in children and early diagnosis of malnutrition are important in preventing complications due to malnutrition.[3]

According to Address Based Population Registration System results, Turkey's total population is over 83 million as of 2020,[4] of which over 22 million are children (0–17 years).[4] Childhood and adolescence are periods in which physiological growth and cognitive and psychological development

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occur rapidly.[5] Nutritional status, which is an essential component of health, becomes more important in a country where the proportion of children is high.[6]

According to the National Nutrition Health Survey, body mass index (BMI)-for-age z scores under −2 for 9 to 11, 12 to 14, and 15 to 18 years old children were reported to be 3.4%, 5.7%, and 2.6%, respectively.[7] On the other hand, according to a study conducted in Turkey in 2018 on hospitalized children, the prevalence of BMI-for-age z scores, weight-for-height z scores, and weight-for-age z score under −2 were found to be 9.5%, 11.2%, and 14.0%, respectively, by Beser et al.[8]

There is a need for a rapid and effective tool for the determination of malnutrition in children in the outpatient setting. Assessing anthropometric methods such as BMI or body weight without knowing whether there is weight loss may not always provide accurate information. Handgrip strength (HGS) is an easy, quick, and inexpensive method that is not affected by the change of body water.[9] Although there are no reference values for children yet, the use of HGS over 6 years old is recommended by the ASPEN.[10,11]

This study was planned and conducted as controlled, cross-sectional research to compare HGS of malnourished adolescents with adolescents with normal nutritional status who were referred to the pediatric gastroenterology outpatient clinic.

METHODS

Study setting and population

This single-center, prospective, controlled, and cross-sectional research was approved by the Ankara University Faculty of Medicine Clinical Research Ethics Committee (03-206-19/January 2019). Written informed consent was obtained from all parents of the participants. Consent was obtained from subjects who could understand the informed consent. This study was conducted in the Ankara University Faculty of Medicine, Department of Pediatric Gastroenterology, between January 2019 and October 2019. Sixty-two participants were recruited: 33 malnourished (case group) and 29 healthy participants (control group). Malnourished adolescents (BMI-for-age z score < -2 and < -3 SD) who could consume an oral diet and did not have any metabolic disease and healthy controls were included from the gastroenterology outpatient clinic. The control group consisted of healthy volunteers with normal nutritional status (BMI-for-age z score between 0 and 0.5 and <85th percentile BMI-for-age) and having no metabolic disease, dehydration, or experiencing acute and involuntary weight loss. Participants between 10 and 18 years of age were included in this study. Exclusion criteria included age below 10 years and greater than 18 years at the time of enrollment.

A sociodemographic questionnaire was provided to the volunteers using the face-to-face interview method. Anthropometric measurements of the adolescents were also obtained. The questionnaire and all anthropometric measurements were carried out by the same research dietitian for each participant.

A post hoc power analysis was carried out to determine whether the study had adequate power. According to the difference between HGS values of case and control groups, the effect size was calculated to be 1.739065 and the post hoc power of the study ($1 - \beta$) was 0.988 ($\alpha = .05$) providing a 98% probability of detecting the observed difference.

Anthropometry

At the time of enrollment, anthropometric measurements including height (cm), body weight (kg), waist circumference (WC) (cm), mid-upper arm circumference (MAC) (cm), wrist circumference (WrC) (cm), neck circumference (NC) (cm), triceps (TSF) and biceps skinfold thickness (BSF) (mm), and HGS (kgF) were performed for each participant by the same investigator. Height was measured using a stadiometer with 0.1-cm accuracy without shoes, with the head aligned in the Frankfort horizontal plane. Weight was measured with 0.1-kg accuracy using a scale wearing minimum clothing and no shoes.

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Waist, wrist, neck circumferences, and MAC were measured using a steel measuring tape. Skinfold thickness measurements were obtained using Holtain skinfold calipers (Holtain Ltd, United Kingdom). All anthropometric parameters were measured once from each volunteer. During the measurements, the National Health and Nutrition Examination Survey procedures were followed.[12] In the evaluation and classification of anthropometric measurements, World Health Organization reference values for children and adolescents 5 to 19 years (2007) were used.[13]

Arm muscle area was determined by using MAC and TSF. Arm muscle area was developed by Frisancho in 1981.[14] Subsequently, bone tissue (−10 and −6.5) was removed from the formula and corrected. Arm muscle area was calculated with this formula[15]:

- Arm muscle area (male) = $[(\text{MAC} - \pi \times \text{TSF})^2 / 4\pi]$ - 10
- Arm muscle area (female) = $[(\text{MAC} - \pi \times \text{TSF})^2 / 4\pi] - 6.5$

HGS was measured with a JAMAR hydraulic dynamometer (Jamar Plus+; Sammons Preston, Rolyon, Bolingbrook, Illinois). The measurement was made while the adolescent was sitting, the elbows were unsupported and flexed at 90 degrees, with both the dominant and nondominant hands gripping the dynamometer with maximum force. The movement was repeated 3 times for both hands and the obtained value was recorded and averaged.[10] To understand the dominant hand, the child was asked to write her/his name in the air, and whichever hand she wrote, that hand was recorded as dominant.[10]

Dietary intake

To examine food intake, a 24-hour dietary recall technique was applied. The amount of food at meals consumed by the adolescents were recorded with the help of the "Turkish Food Photo Catalogue."[16] The amount of food included in the portion of the meals was calculated using the "Standard Food Recipes for Institutions."[17] After the consumed amounts were determined, daily energy, macronutrient, and micronutrient intakes were calculated using the software "Nutrition Information Systems (BeBiS, version 6.1) Program" (İstanbul, Turkey) and their averages were used.

Statistical analysis

In this study, SPSS version 22.0 (Statistical Package for the Social Sciences) (IBM Corp, Armonk, New York) was used for statistical evaluation. In the descriptive analysis of the data, number (n), percentage (%) mean, standard deviation, and median values were used. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine whether the data were normally distribution. Differences in continuous variables were analyzed by the Student's t test if normally distributed. Otherwise, the Mann-Whitney U was used. The Pearson correlation test was used to determine the direction and strength of the relationship between 2 numerical variables. The Pearson χ^2 test and Fisher's exact test were used for comparison of qualitative data. We used a receiver operating characteristic (ROC) curve to compare the overall accuracy of dominant and nondominant HGS. The larger area under the curve (AUC) is, the better the overall diagnostic accuracy. Multiple linear regression analysis for independent variables and HGS was also performed. For all tests, $P < .05$ was considered statistically significant.

RESULTS

A total of 62 participants between the ages of 10 to 18 years were included in this study. Malnutrition was present in 33 participants (25 females and 8 males). Healthy participants consisted of 16 females and 13 males. Characteristics of the participants are presented in Table 1. The mean age and parental education level were not significantly different between the groups. However, the number of siblings was higher in the control group than in the case group ($P = .01$). When the average nutrient intake obtained from food consumption records was examined, energy and

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Table 1. Characteristics of the Participants According to Malnutrition Status

	Case Group (n = 33) n (%)	Control Group (n = 29) n (%)	*P*
Sex			
Male	8 (24.2)	13 (44.8)	$\chi^2 = 2.920$
Female	25 (75.8)	16 (55.2)	$P = .087$[a]
Age, ± SD, y	13.7 ± 2.2	13.4 ± 2.3	$P = .677$[b]
Age group, y			
10–14	20 (60.6)	18 (62.1)	$\chi^2 = 0.014$
15–18	13 (39.4)	11 (37.9)	$P = .906$[a]
Mother's educational status			
Noneducated	1 (3.0)	5 (17.3)	$\chi^2 = 5.747$
Primary school	19 (57.6)	12 (41.3)	$P = .121$[c]
High school	10 (30.3)	6 (20.7)	
University	3 (9.1)	6 (20.7)	
Father's educational status			
Noneducated	... (...)	2 (6.9)	$\chi^2 = 3.079$
Primary school	8 (24.2)	6 (20.7)	$P = .317$[c]
High school	20 (60.6)	14 (48.3)	
University	5 (15.2)	7 (24.1)	
Number of siblings			
Median (Q_1–Q_3)	1.0 (1.0–3.0)	2.0 (2.0–3.0)	$P = .011$[b]
Min-max	0–4.0	1.0–7.0	
Nutrient intake			
Energy, kcal	1069.2 ± 457.8	1100.3 ± 358.4	$P = .769$[b]
Carbohydrate, g	129.2 ± 75.5	140.9 ± 66.6	$P = .522$[b]
Protein, g	39.7 ± 18.4	45.8 ± 18.3	$P = .194$[b]
Fat, g	42.5 ± 15.9	37.8 ± 14.5	$P = .234$[b]
Fiber, g	7.9 ± 4.5	8.8 ± 3.7	$P = .443$[b]
Cholesterol, mg	163.7 ± 133.7	242.5 ± 177.1	$P = .051$[b]
Vitamin A, μg	361.8 ± 242.2	409.1 ± 242.3	$P = .446$[b]
Vitamin E, mg	5.4 ± 4.6	5.9 ± 4.9	$P = .654$[b]
Thiamine, mg	0.4 ± 0.2	0.5 ± 0.2	$P = .026$[b]
Riboflavin, mg	0.8 ± 0.4	0.9 ± 0.3	$P = .557$[b]
Vitamin B_6, mg	0.8 ± 0.3	0.6 ± 0.3	$P = .048$[b]
Folic acid, μg	119.1 ± 60.7	155.4 ± 69.4	$P = .033$[b]
Vitamin C, mg	23.5 ± 18.3	38.2 ± 23.5	$P = .007$[b]
Calcium, mg	551.9 ± 295.7	504.7 ± 218.4	$P = .483$[b]
Magnesium, mg	136.9 ± 67.6	136.7 ± 43.8	$P = .989$[b]
Iron, mg	4.8 ± 2.6	5.8 ± 2.3	$P = .130$[b]
Zinc, mg	5.4 ± 2.5	5.6 ± 2.0	$P = .726$[b]
Phosphorus, mg	653.0 ± 280.6	668.5 ± 229.8	$P = .814$[b]

[a]Pearson χ^2.
[b]Independent sample *t* test.
[c]Fisher's exact test.

macronutrients intakes were not different between the groups, but folic acid, vitamin C, and thiamine intake were significantly higher in the control group than in the case group.

Anthropometric measurements of the case and control groups are compared in Table 2. While there was no significant difference in height between the 2 groups, other

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Table 2. Anthropometric Measurements of the Participants According to Malnutrition Status[a]

	Case Group (n = 33)	Control Group (n = 29)	Total (n = 62)	*P*
Body height, cm	153.7 (11.9)	154.5 (10.7)	153.8 (11.5)	.983[b]
Height-for-age *z* score	−0.3 (1.3)	−0.15 (1.0)	−0.2 (1.1)	.150[b]
Body weight, kg	37.1 (6.7)	48.8 (10.5)	41.7 (10.2)	<.001[b]
BMI, kg/m^2	15.5 (1.4)	20.1 (2.9)	17.7 (3.2)	<.001[b]
BMI-for-age *z* score	−2.0 (−2.5 to −2.0)	0.5 (0.0 to 0.5)	−2.0 (−2.0 to 0.5)	<.001[c]
Mid upper-arm circumference, cm	18.9 (2.3)	21.9 (4.0)	20.0 (3.5)	.003[b]
Triceps skinfold, mm	9.6 (2.9)	13.8 (2.9)	11.3 (3.6)	<.001[b]
Biceps skinfold, mm	5.7 (1.9)	9.1 (2.5)	7.1 (2.8)	<.001[b]
Waist circumferences, cm	58.2 (4.7)	65.3 (6.1)	61.0 (6.4)	<.001[b]
Neck circumferences, cm	28.0 (26.0–29.0)	30.0 (28.5–32.0)	28.0 (26.5–30.5)	.003[c]
Wrist circumferences, cm	14.0 (13.0–14.9)	15.0 (15.0–16.0)	14.4 (13.0–15.0)	<.001[c]
Arm muscle area, mm	20.3 (6.0)	25.0 (14.4)	22.5 (10.9)	.018[b]
Dominant handgrip strength, kgF	11.6 (5.8)	21.6 (5.7)	14.3 (6.7)	<.001[b]
Nondominant handgrip strength, kgF	10.0 (6.0–14.0)	20.0 (18.0–22.0)	14.0 (8.0–20.0)	<.001[c]

Abbreviation: BMI, body mass index.

[a]Continuous variables were presented as mean with standard deviation (SD) if normally distributed and as median with (Q_1–Q_3) if not normally distributed.

[b]Independent sample *t* test.

[c]Mann-Whitney *U* test.

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measurements were higher in the control group ($P < .05$) (Table 2). The mean of dominant HGS was 11.6 ± 5.8 and 21.6 ± 5.7 kgF ($P < .001$) for the case and control groups, respectively, whereas the mean non-dominant HGS was 10.0 kgF for the case group and 20.0 for the control group ($P < .001$).

Figure 1 shows ROC curve analyses for both genders. For both dominant and nondominant HGS, it was found that AUC was above 75.0% (moderate accuracy) in both genders. Dominant HGS ROC analyses have higher AUC than nondominant HGS in males, females, and both genders (Figure 1).

The cut-off points obtained as a result of ROC analysis are shown in Table 3. The recommended dominant and nondominant HGS cut-off points are 13.0 and 13.5 kgF for males, 13.0 and 11.5 kgF for females, 13.0 and 11.5 kgF for the total population, respectively (Table 3).

Correlations of BMI-for-age *z* scores and anthropometric measurements with dominant HGS and nondominant HGS are shown in Figure 2A and Figure 2B, respectively. A significant relationship at $P < .01$ level was found in all binary correlations. The first 3 strongest relationships with HGS are body weight ($r = 0.758$ for the dominant hand; $r = 0.724$ for the nondominant hand), WC ($r = 0.747$ for the dominant hand; $r = 0.669$ for the nondominant hand) and NC ($r = 0.711$ for the dominant hand; $r = 0.659$ for the nondominant hand) (Figure 2A)

Multiple linear regression was used to predict HGS based upon age, sex, height, MAC, TSF, BSF, WC, NC, WrC, energy, and macronutrients intake. A significant regression was found with an R^2 value of 0.660. Malnutrition status was a significant predictor of HGS. Multiple linear regression analysis is shown in Table 4.

DISCUSSION

To the best of our knowledge, this is the first study in Turkey recommending HGS

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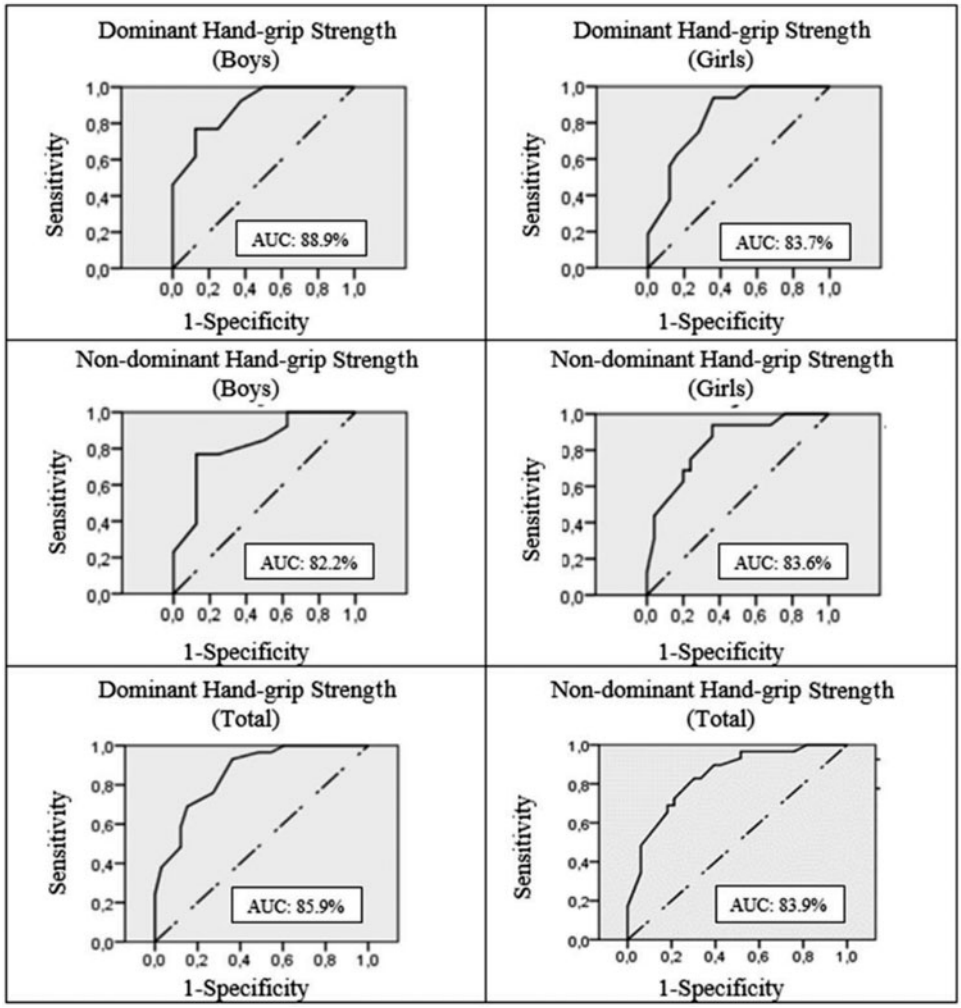


Figure 1. Receiver operating characteristic curves for identifying malnutrition. AUC indicates the area under the curve.

cut-off points for the diagnosis of malnutrition and comparing HGS with other anthropometric measurements. Our study investigated the use of HGS in diagnosing malnutrition in adolescents. HGS is easy to measure, requires simple and inexpensive equipment, and is less prone to error.[18] In our cohort, HGS was highly correlated in diagnosing malnutrition.

In this study, which was completed on 62 adolescents (33 cases and 29 controls), the diagnosis of malnutrition established by using the BMI-for-age z score, according to the ASPEN recommendations.[11] There was no significant difference between the case and control groups in terms of gender, age, parental education, energy, and macronutrients intake.

Body weight, TSF, BSF, WC, and WrC were significantly lower in the case group ($P <$ .001). In a study by Amoussou Lokossou et al,[19] in Benin with 408 participants, a statistically significant relationship was found between malnutrition and WC. In another study conducted by Bell et al[20] in Australia in 2020, it was found that children with

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Table 3. Estimation of the Optimal Cut-off Point of Handgrip Strength for Identifying Malnutrition

	Cut-off Points	Sensitivity	1 − Specificity
Boys			
Dominant handgrip	*13.0*	0.923	0.375
strength	15.0	0.769	0.250
	21.0	0.615	0.125
Nondominant	12.5	0.769	0.250
handgrip strength	*13.5*	0.769	0.125
	19.0	0.538	0.125
Girls			
Dominant handgrip	10.5	0.938	0.480
strength	*13.0*	0.938	0.360
	17.0	0.625	0.160
Nondominant	9.0	0.938	0.480
handgrip strength	*11.5*	0.938	0.360
	15.5	0.688	0.240
Total			
Dominant handgrip	*13.0*	0.931	0.364
strength	15.0	0.759	0.273
	19.0	0.586	0.273
Nondominant	7.5	0.966	0.727
handgrip strength	*11.5*	0.897	0.394
	14.5	0.724	0.212

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malnutrition had lower MAC and TSF than well-nourished children ($P < .001$, $P < .001$). While the dominant HGS was 11.6 ± 5.8 kgF in malnourished adolescents, it was found to be 21.6 ± 5.7 kgF in the control group. An important difference, approaching 2 times, was found between them ($P < .001$). A similar difference was seen for the nondominant HGS. Gontarev et al[21] in a study conducted in Macedonia found that there was a significant difference in HGS measurements in children aged 6 to 14 years by comparing stunted children with children with normal nutrition status defined according to the Pediatric Subjective Global Nutrition Assessment ($P < .001$).[21]

In our study, the suitability of using HGS in the diagnosis of malnutrition was determined in both genders (AUC > 75%). As a result of ROC analysis, the recommended cut-off point to assess malnutrition for the dominant HGS for males and females is found as 13.0 kgF. It is thought that the small sample size may have caused the lack of difference between the genders. A larger, population-based study is needed to validate this number as the cut-off point. In the literature, it has been observed that only 5 countries have determined normative reference values for children and adolescents so far.[22-26]

In this cohort, MAC, TSF, BSF, WC, NC, WrC, weight, and height are found to be significantly correlated with HGS of both dominant and nondominant hands ($P < .01$). This strong correlation between HGS and anthropometric measurements that are frequently used in the definition of malnutrition is promising for the clinical use of HGS. Similar results were reported in a study of 787 children aged 6 to 10 years.[27] Ploegmakers et al[28] showed significant correlations between HGS and weight/height in children up to 15 years of age.

It was shown that the HGS of the well-nourished adolescents was 0.445 kgF more than the adolescents with malnutrition ($P = .005$). However, no significant relationship was found between adolescents' energy and macronutrient intake and HGS. It is possible that the reason HGS was found to be

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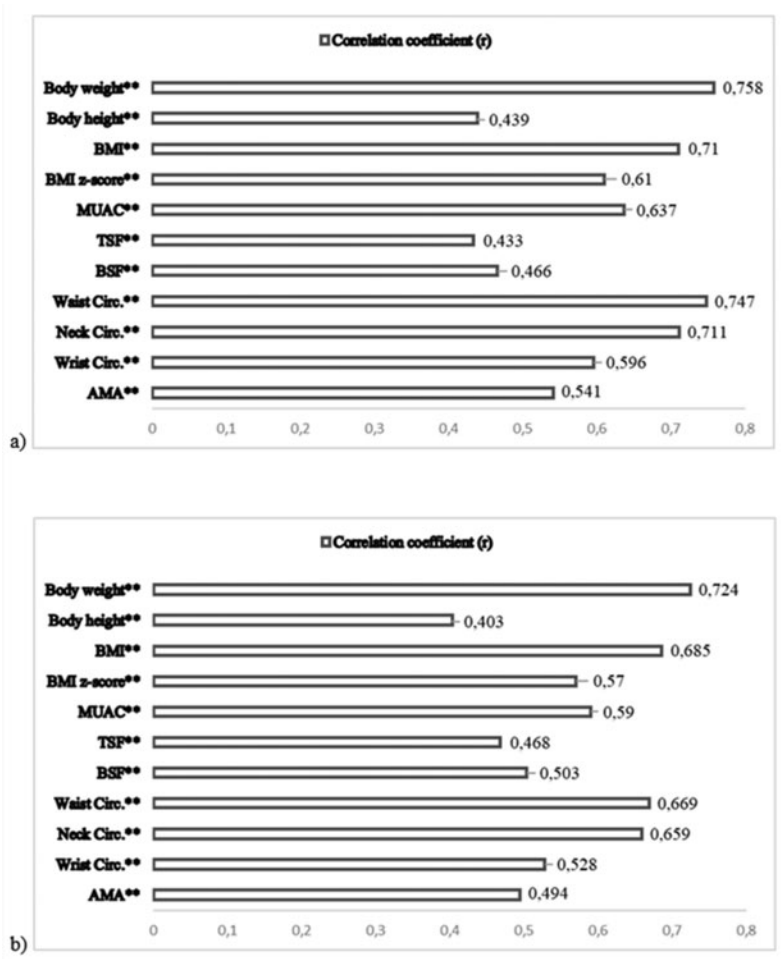


Figure 2. Correlations between handgrip strengths and anthropometric measurements. (A) Correlations between dominant handgrip strengths and anthropometric measurements. (B) Correlations between nondominant handgrip strengths and anthropometric measurements. $^{**}P < .01$. AMA indicates arm muscle area; BMI, body mass index; BSF, biceps skinfold; Circ., Circumference; MUAC, mid upper-arm circumference; TSF, triceps skinfold.

significantly related to malnutrition status and the relationship could not be shown with dietary intake may be due to the disadvantages of the method used (24-hour recall). Therefore, studies that follow the diet with a real-time recording method are needed. Agrawal and Nande[29] studied 400 adolescents between the ages of 10 to 15 years and showed HGS increased with an increase in energy and carbohydrate intake in females and with an increase in fat intake in males ($P < .01$).

LIMITATIONS

The biggest limitation of the study is sample size; larger and population-based studies are needed to validate 13-kgF HGS as a cut-off point to define malnutrition. Moreover, 24-hour dietary recall technique was applied to evaluate dietary intake. Although a face-to-face method was used together with the parent and the adolescent, it is known that this technique has some disadvantages, such as overreporting intake.[30]

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Table 4. Multiple Linear Regression Analysis (Dependent Variables, Dominant Handgrip Strength)

Independent Variable	Standardized Coefficients, β	Standard Error	t	P	95% Confidence Interval
Malnutrition status	0.445	2.215	3.009	*.005*	2.165 to 11.169
Age	0.048	0.451	0.351	.728	−0.759 to 1.076
Sex	−0.139	1.693	−1.277	.210	−5.603 to 1.278
Height	0.142	0.093	0.994	.327	−0.096 to 0.281
MAC	0.027	0.354	0.166	.869	−0.661 to 0.779
TSF	−0.188	0.351	−1.122	.270	−1.106 to 0.319
BSF	0.074	0.457	0.440	.663	−0.728 to 1.131
WC	0.216	0.209	1.220	.231	−0.170 to 0.679
NC	0.341	0.498	1.783	.083	−0.124 to 1.898
WrC	−0.056	0.769	−0.393	.697	−1.865 to 1.261
Energy intake	6.693	0.140	0.857	.397	−0.165 to 0.404
Protein intake	−1.150	0.560	−0.897	.376	−1.641 to 0.636
Fat intake	−2.220	1.256	−0.843	.405	−3.612 to 1.494
Carbohydrate intake	−4.833	0.573	−0.851	.401	−1.652 to 0.677
Adjusted R^2: 0.660 Standard error: 4.30835 $P < .001$					

Abbreviations: BSF, biceps skinfold; MAC, mid-upper arm circumference; NC, neck circumference; TSF, triceps skinfold thickness; WC, waist circumference; WrC, wrist circumferences.

CONCLUSION

BMI, MAC, TSF, BSF, WC, NC, WrC, height, and weight are significantly correlated with HGS in adolescents. According to ROC analyses, dominant and nondominant HGSs are useful for identifying malnutrition in females and males. These findings show that HGS can be used in clinical practice for a faster and easier diagnosis of malnutrition in adolescents.

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