Association between Handgrip Strength and Raw BIA Variables in Adolescents Aged 14-17 Years

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Abstract: Raw BIA (bioelectrical impedance analysis) variables such as phase angle (PhA) or impedance ratio (IR=the ratio between impedance-Z at high frequencies and Z at low frequencies), are both thought to be a proxy of muscle quality in terms of water distribution (ECW/ICW ratio), body cell mass and cellular integrity. So far, few studies have tested the relationship between handgrip strength (HGS) and body composition in adolescents. Our study aimed to analyze the variability in raw BIA variables and their association with HGS in 117 male (age 15.7±0.8 years, stature 171.8±7.3 cm, body weight 65.8±10.6 kg, standardized body mass index=BMI-SDS +0.57±0.9) and 130 female adolescents (age 16.0±0.7 years, stature 160.8±5.6 cm, weight 57.3±8.0 kg, BMI-SDS +0.38±0.9). BIA was performed for the whole body and separately for upper limbs and lower limbs, while HGS was measured to assess the isometric strength of upper limbs. HGS was significantly correlated ($r>0.500$) with whole-body IR and PhA, and this association was even stronger with upper-limb IR and PhA. In addition, a quite strict correlation emerged between HGS and whole-body BI index at 250 kHz (index of fat-free mass). In multiple regression analysis BI indexes along with IRs or PhAs were independent predictors of HGS, whereas gender and age were not. In conclusion, this study gives some information about the use of HGS and raw BIA variables in the first two decades of life, suggesting a new approach to assess nutritional status in prevention and public health nutrition.

1 INTRODUCTION

The assessment of handgrip strength=HGS (maximal isometric grip force task) is a commonly applied method for evaluating muscle strength in general population and in patients suffering from various diseases, which may be applied both in public health nutrition and clinical nutrition (Beaudart et al., 2019).

Changes in muscle strength occur from childhood to adolescence due to muscle mass and function development; for instance, variations of HGS in children can be ascribed to an increase in both muscle mass and muscle section strength (Neu et al., 2002). Interestingly, a recent study conducted on approximately two million children and adolescents has found an increasing trend of absolute gripping force from 1967 to 2017 (Dooley et al., 2020).

The literature has indicated that HGS is a predictor of bone strength in children (Hyde et al., 2020) and that in the first two decades of life measuring HGS allows to identify early abnormalities and prevent low muscle mass in adulthood (Orsso et al., 2019). In addition, low muscle mass and strength have been associated in children and adolescents with both an increased risk of cardiometabolic diseases (Kim et al., 2015; Peterson et al., 2016) and metabolic syndrome (Kang et al., 2020), and alterations in bone parameters (Dorsey et al., 2010) and neurodevelopment (Kar et al., 2008; Ramel et al., 2016).

In children and adolescents HGS is influenced by several factors including preferred limb, age, gender, stature, body weight, and body composition (De Souza et al., 2014; Silverman, 2015; Montalcini et al., 2016). In human nutrition and prevention, body compartments are commonly assessed using bioelectrical impedance analysis (BIA) with respect to fat-free mass (FFM), body fat (FM), body cell mass (BCM), total body water (TBW), extracellular water (ECW) and intracellular water (ICW) (Kyle et al., 2004). Research is now focused on directly-measured raw BIA variables such as phase angle (PhA) or impedance ratio (IR=the ratio between impedance-Z

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at high frequencies and Z at low frequencies), which are thought to be indexes of water distribution (ECW/ICW ratio), BCM and cellular integrity (Earthman et al., 2007; Gonzalez et al., 2016; de Blasio et al., 2017). IR and PhA have also been shown to be directly related to muscle strength and physical activity (de Blasio et al., 2017; Mundstock et al., 2019). More specifically, PhA was associated to HGS (Martins et al., 2020) and to cardiorespiratory fitness in the first two decades of life (Langer et al., 2020), and it was used in assessing body composition in young and adolescent athletes (de Araújo Jerônimo et al., 2020). To extend these findings, we aimed to evaluate in healthy adolescents the relationships of HGS with raw BIA variables (PhA and IR), which were measured for the whole body and in addition on upper limbs and lower limbs, separately.

2 METHODS

This cross-sectional study included two hundred and forty-seven adolescents participated in the study: 117 males (age 15.7±0.8 years, stature 171.8±7.3 cm, body weight 65.8±10.6 kg, standardized body mass index=BMI-SDS +0.57±0.90) and 130 females (16.0±0.7 years, 160.8±5.6 cm, 57.3±8.0 kg, BMI-SDS +0.38±0.90).

All parents/guardians signed the informed consent form authorizing participation in the survey and adolescents signed the assent. The target population was adolescents of both sexes aged 14–17 years enrolled in two different high schools in Naples. All participants were healthy and free of any lesion or impairment in the upper limbs. The participants avoided exercising 12 hours before testing; they were studied in the morning after an overnight fasting, by the same operator and following standard procedures.

Body weight was measured to the nearest 0.1 kg using a platform beam scale and stature to the nearest 0.5 cm using a stadiometer (Seca 216; Seca, Hamburg, Germany). BMI-SDS was then calculated in according to the World Health Organization=WHO growth reference for school-aged children and adolescents (de Onis et al., 2007).

Concerning BIA, Z and PhA were measured at frequencies between 5 and 250 kHz (HUMAN IM TOUCH analyzer, DS MEDICA, Milano). BIA data for the whole body and separately for upper limbs and lower limbs (segmental BIA) were considered as follows: 1) bioimpedance indexes at 5 and 250 kHz (BI index=stature^2/Z), as markers of ECW and FFM, respectively; 2) IR= the ratio between Z at 250 kHz and Z at 5 kHz; 3) PhA at 50 kHz. BIA variables were considered for statistical analysis as the mean of measures on right and left body sides. FFM and FM were calculated using the equations proposed by Sun et al. (2003).

Handgrip strength (HGS) was determined using a Dynex dynamometer (MD systems Inc. Ohio USA) to assess isometric strength of upper limbs. The maximum value (whole body) considering three attempts on the preferred limb and three attempts on the non-preferred limb of the body was used for analysis. The adolescents were standing during the entire test with the arm straight down at the side and performed 3 maximal isometric contractions (each lasting 5 seconds) with each hand, with a 1 minute rest between preferred limb tests (Gerodimos et al., 2017).

2.1 Statistical Analysis

Results are expressed as mean±standard deviation. Statistical significance was pre-determined as $p<0.05$. All statistical analyses (independent t-test, partial correlation, multiple regression) were performed using the Statistical Package for Social Sciences (SPSS) version 24. The Kolmogorov-Smirnov test was employed to determine the normality of data distribution.

3 RESULTS

The general characteristics of the study groups are summarized in Table 1. Male adolescents were taller and heavier than the female ones. FFM (from BIA) was significantly higher in males, even after adjustment for body weight ($p<0.001$).

Table 1: Individual characteristics and body composition in 117 male and 130 female adolescents.

	Male adolescents	Female adolescents
Age (age)	15.7±0.8	16.0±0.7[a]
Weight (kg)	65.8±10.6	57.3±8.0[a]
Stature (cm)	171.8±7.3	160.8±5.6[a]
BMI-SDS	+0.57±0.90	+0.38±0.86
FFM (kg)	54.2±7.4	42.1±4.1[a]
FM (kg)	11.5±5.9	15.2±6.0[a]
FM (%)	16.8±7.1	25.8±7.6[a]

mean±standard deviation;
BMI-SDS=standardised body mass index, FFM=fat-free mass, FM=fat mass;
a=p<0.05 between genders

With respect to raw BIA variables (Table 2), BI indexes were higher in male compared to female adolescents at both 5 and 250 kHz (whole body +31.9% and +34.1%, upper limbs +35.4% and +38.2%, lower limbs +29.0% and +31.1%, respectively); this was true even after controlling for body weight ($p<0.001$).

There were also significant variations between genders in IRs, which were lower in males, and PhAs (in males, +4.9% for the whole body, +12.9% for upper and +3.5% for lower limbs) (Table 3).

Table 2: Bioimpedance indexes (BI indexes) calculated for the whole body in 117 male and 130 female adolescents.

	BI index (cm^2/kHz)	
frequency of measure	Male adolescents	Female adolescents
5 kHz	49.6±8.0	37.6±5.4[a]
50 kHz	57.4±10.2	42.9±6.7[a]
250 kHz	66.9±12.2	49.9±7.9[a]

mean±standard deviation;
a=p<0.05 between genders

We assessed muscle strength by measuring HGS (Table 4). A statistical difference emerged between genders for the whole body, preferred limb and non-preferred limb (in all cases around +28% in males). After adjustment for body weight the differences were reduced but still present (adjusted means: whole body 35.5 vs 29.2 kg, preferred limb 35.1 vs 28.8 kg, non-preferred limb 32.9 vs 27.4 kg).

The association of HGS with stature, weight, and BMI-SDS was first evaluated by partial correlation, after adjusting for group. HGS (whole body, preferred limb and non-preferred limb) was weakly ($r<0.300$) associated with stature, body weight and BMI-SDS.

Table 3: Impedance ratio (IR= Z 250 kHz/Z 5 kHz) and phase angle (PhA) at 50 kHz measured on the whole body and limbs in 117 male and 130 female adolescents.

	Male adolescents	Female adolescents
IR		
Whole body	0.745±0.027	0.755±0.022[a]
Upper limbs	0.756±0.028	0.770±0.021[a]
Lower limbs	0.741±0.032	0.752±0.030[a]
Phase angle (degrees)		
Whole body	6.82±0.85	6.50±0.80[a]
Upper limbs	5.16±0.90	4.57±0.72[a]
Lower limbs	9.21±1.22	8.90±1.19[a]

mean±standard deviation;
a=p<0.05 between genders

Strong correlations ($r>0.500$) emerged with whole-body IR and PhA, and even stronger with upper-limb IR and PhA (Table 5). Interestingly, a weaker correlation emerged for BI index at 5 kHz while a higher correlation was observed between HGS and whole-body BI index at 250 kHz (data not show).

Table 4: Handgrip strength in 117 male and 130 female adolescents for the whole body, preferred limb and non- preferred limb.

Handgrip strength (kg)	Male adolescents	Female adolescents
Whole body	36.4±10.5	28.4±7.4[a]
Preferred limb	35.9±10.4	28.0±7.3[a]
Non-preferred limb	34.0±10.3	26.5±7.4[a]

mean±standard deviation;
a=p<0.05 between genders

Multiple regression analysis (on the whole body) showed that BI indexes along with IR or PhA were independent predictors of HGS, whereas gender and age were not.

Table 5: Partial correlation of handgrip strength (HGS) with impedance ratio (IR=Z 250 kHz/Z 5 kHz) and phase angle (PhA) for the whole body and upper limbs.

Handgrip strength (kg)	IR whole body	IR upper limb	PhA whole body	PhA upper limb
Whole body	-0.625*	-0.672*	0.645*	0.712*
Preferred limb	-0.620*	-0.669*	0.640*	0.706*
Non-preferred limb	-0.610*	-0.644*	0.638*	0.695*

*=p<0.05

4 DISCUSSION

This study shows that HGS was significantly related to whole-body raw BIA variables in both male and female adolescents, and even more strictly to upper-limb IR and PhA.

As first point, FFM and FM (from BIA) significantly differed between genders with a consistent higher FFM in males and a higher FM in females, in agreement with that is commonly known on body composition in the second decade of life (Wang et al., 2014; Schmidt et al., 2018).

Then, we looked at those raw BIA variables such as IR or PhA that are likely to be related with water distribution (ECW/ICW ratio), BCM and cellular integrity (Earthman et al., 2007; Gonzalez et al., 2016; de Blasio et al., 2017). They have also been shown to be significantly associated with HGS (Martins et al., 2020) and cardiorespiratory fitness in children and adolescents (Langer et al., 2020).

Results are available not only on whole-body PhA but also, for the first time, on IR and segmental BIA. Difference between genders emerged for IRs and PhAs, which were more marked with regard to upper limbs (for instance, PhA in males, +4.9% for the whole body, +12.9% for upper limbs and +3.5% for lower limbs). This finding was in line with the previous study by Schmidt et al., (2018) on whole-body PhA.

HGS, is a reliable index of musculoskeletal fitness varies in children and adolescents (Castro-Pinero et al., 2010), depending on factors such as age, gender, stature, weight, preferred limb and body composition (De Souza et al., 2014; Silverman, 2015; Montalcini et al., 2016). We used a Dynex dynamometer to determine isometric strength of upper limbs in male and female adolescents from fourteen to seventeen years old. A statistical difference occurred between male and female adolescents for the whole body, preferred limb and non-preferred limb, as previously described by Omar et al. (2015).

To the best of our knowledge, a single study has so far yielded evidence on the direct association between HGS and whole-body PhA (Martins et al., 2020). Our results showed that all raw BIA variables were direct predictors of HGS. This was the case of BI index at high frequency (250 kHz), which is known to be strictly related to TBW and FFM (Kyle et al., 2015). Interestingly, a weaker correlation emerged for the BI index at 5 kHz, which is likely to be an index of ECW (Kyle et al., 2015). There was also a correlation of HGS with whole-body IR and PhA, which was even stronger with the corresponding upper-limb values. These findings were further supported by the fact that in multiple regression analysis BI indexes along with IRs or PhAs were independent predictors of HGS, whereas gender and age were not.

5 CONCLUSIONS

In conclusion, HGS is clearly associated with BI indexes (marker of FFM), IR and PhA (markers of the anatomical structure of the muscle).This study gives information about the use of HGS and raw BIA variables in the second decade of life. Further studies are needed to evaluate the reliability and effectiveness of such approach to assess nutritional status in children and adolescents.

REFERENCES

Beaudart, C., et al., 2019.Assessment of Muscle Function and Physical Performance in Daily Clinical Practice. *Calcif Tissue Int*, 105:1–14.

Castro-Pinero, J. et al., 2010. Criterion-related validity of field-based fitness tests in youth: a systematic review. *Br J Sports Med*, 44:934–43.

de Araújo Jerônimo, A. F.; et al., 2020. Phase Angle from Bioelectric Impedance and Maturity-Related Factors in Adolescent Athletes: A Systematic Review. *Sustainability*, 12, 4806.

de Blasio, F., et al., 2017. Raw BIA variables are predictors of muscle strength in patients with chronic obstructive pulmonary disease. *Eur J ClinNutr*, 71(11):1336 –40.

de Onis, M., et al., 2007. Development of a WHO Growth Reference for School-Aged Children and Adolescents. *Bull World Health Organ*, 85:660–7.

De Souza, M. A., et al., 2014. Normative data for handgrip strength in healthy children measured with a bulb dynamometer: across-sectional study. *Physiotherapy*, 100:313–18.

Dooley, F. L., et al., 2020. A Systematic Analysis of Temporal Trends in the Handgrip Strengthof 2,216,320 Children and Adolescents Between 1967 and 2017. *Sports Med*, https://doi.org/10.1007/s40279-020-01265-0.

Dorsey, K. B., et al., 2010. Greater lean tissue andskeletal muscle mass are associated with higher bone mineral content inchildren. *Nutr Metab (Lond)*, 7:41.

Earthman, C., et al., 2007. Bioimpedance spectroscopy for clinical assessment of fluid distribution and body cell mass. *Nutr Clin Pract*, 22:389–405.

Gerodimos, V., et al., 2017. Static and Dynamic Handgrip Strength Endurance: Test-Retest Reproducibility. *J Hand Surg Am*, 42:e175-e184.

Gonzalez, M. C, et al., 2016. Phase angle and its determinants in healthy subjects: influence of body composition. *Am J ClinNutr*, 103:712–6.

Hyde, N. K., 2020. The Association Between Muscle Mass and Strength in Relation to Bone Measures in a Paediatric Population: Sex-Specific Effects. *Calcif Tissue Int*, https://doi:10.1007/s00223-020-00699-y

Jackson, A. A., et al., 2013. Body composition assessment in nutrition research: value of BIA technology. *Eur J ClinNutr*, 67, S71–S78.

Kang, Y., et al., 2020. Handgrip Strength Among Korean Adolescents With Metabolic Syndrome in 2014–15. *J Clin Densitom*, 23:271–277.

Kim, S., and Valdez, R., 2015. Metabolic risk factors in U.S. youth with low relative muscle mass. *Obes Res Clin Pract*, 9:125e32.

Kar, B. R., et al., 2008. Cognitive development in children withchronic protein energy malnutrition. *Behav Brain Funct*, 4:1e12.

Kyle, U. G., et al., 2004. Bioelectrical impedance analysis—part II: utilization in clinical practice. *Clin Nutr*, 23, 1430–53.

Kyle, U. G., et al., 2015. Body composition during growth in children: limitations and perspectives of bioelectrical impedance analysis. *Eur J Clin Nutr*, 69, 1298–305.

Langer, R. D., et al., 2020. Phase angle is associated with cardiorespiratory fitness and bodycomposition in children aged between 9 and 11 years. *Physiol Behav*, 215,112772. https://doi.org/10.1016/j.physbeh.2019.112772

Martins, P. C. et al., 2020.Association between phase angle and isolated and grouped physical fitness indicators in adolescents. *Physiol Behav*, 217,112825. https://doi.org/10.1016/j.physbeh.2020.112825.

Montalcini, T., et al., 2016. Gender difference in handgrip strength of Italian children aged 9 to 10 years. *Ital J Pediatr*, 42:16.

Mundstock, E. et al. 2019. Association between Phase Angle from Bioelectrical Impedance Analysis and Level of Physical Activity: Systematic Review and Meta-Analysis. *Clin Nutr*, 38: 1504–10.

Neu, C. M., Rauch F., Rittweger J., Manz F., and Schoenau, E., 2002. Influence of puberty on muscle developmentat the forearm. *Am J Physiol Endocrinol Metab*, 283: 103–07.

Omar, M. T. A., Alghadir, A., and Al Baker, S., 2015. Norms for hand grip strength in children aged 6–12 years in Saudi Arabia, *Dev Neurorehabil*, 18:1, 59–64.

Orsso C.E., et al.,2019. Low muscle mass and strength in pediatrics patients: Why should wecare? *ClinNutr*, 38:2002–15.

Peterson, M. D, Zhang, P., Saltarelli, W. A., Visich, P. S., and Gordon, P. M., 2016. Low musclestrength thresholds for the detection of cardiometabolic risk in adolescents. *Am J Prev Med*, 50:593e9.

Ramel, S. E., et al., 2016. Greater early gains in fat-free mass, but not fat mass, are associated withimproved neurodevelopment at 1 year corrected age for prematurity in verylow birth weight preterm infants. *J Pediatr*, 173:108e15.

Schmidt, S. CE, Anja Bosy-Westphal, A., Niessner, C., and Woll, A., 2018. Representative body composition percentiles from bioelectricalimpedance analyses among children and dolescents. TheMoMostudy. *Clin Nutr*, 38, 2712e2720.

Silverman, I. W., 2015. Age as a moderator of the secular trend for grip strength in Canada and the United States. *Ann Hum Biol*, 42(3):199–209.

Sun S. S., et al., 2003. Development of Bioelectrical Impedance Analysis Prediction Equations for Body Composition With the Use of a Multicomponent Model for Use in Epidemiologic Surveys. *Am J Clin Nutr*, 77:331–40.

Wang, L., Stanley Sai-chuen Hui, S., and Heung-sang Wong, S., 2014. Validity of Bioelectrical Impedance Measurement in Predicting Fat-Free Mass of Chinese Children and Adolescents. *Med Sci Monit*, 20: 2298–310.