Clinical Nutrition ESPEN 43 (2021) 436–441

Contents lists available at ScienceDirect

Clinical Nutrition ESPEN

journal homepage: http://www.clinicalnutritionespen.com

Original article

Association between nutritional status and muscle strength in pediatric cancer patients

Nathalia Farache Tostes [a, *], Danúbia da Cunha Antunes Saraiva [b], Renata Brum Martucci [c]

[a] Oncology Research Fellowship Program of the National Cancer Institute José Alencar Gomes da Silva (INCA). Rio de Janeiro (RJ), Brazil
[b] Nutrition and Dietetic Service, Cancer Hospital I of National Cancer Institute, Rio de Janeiro, Brazil
[c] Nutrition and Dietetic Service, Cancer Hospital I of National Cancer Institute, Rio de Janeiro and Nutrition Institute, State University of Rio de Janeiro, Rio de Janeiro, Brazil

A R T I C L E I N F O

Article history:
Received 7 April 2020
Accepted 12 March 2021

Keywords:
Neoplasms
Children
Adolescent
Muscle weakness
Nutritional status

S U M M A R Y

Background & aims: Cancer provides a catabolic state, leading to weight loss and depletion of lean mass, which is accompanied by loss of muscle strength in pediatric patients. Muscle strength is considered a predictor of nutritional status. The aim was to evaluate the association between nutritional status and muscle strength in pediatric cancer patients hospitalized at the Cancer Hospital I.
Methods: A cross-sectional study was carried out with cancer patients aged 6–19 years hospitalized in the period from February to November 2019. In the first 48 h of hospitalization, anthropometric (body weight, height, mid-upper arm circumference - MUAC, tricipital skinfold - TSF, calculated body mass index – BMI and mid-arm muscle circumference – MAMC) and handgrip strength (HGS) assessments were performed. The statistical analysis for the data correlation was performed using Pearson's coefficient, linear regression, and association by $\chi 2$ test. The HGS values were distributed in quartiles. P-value < 0.05 was considered significant.
Results: The sample consisted of 63 patients, 52.40% male and 47.60% female. The mean age was 13.01 (±3.83; 6.20–19.78) years. The frequency of adequate BMI was 45.60% and the mean HGS was 17.10 kg (±8.93). There was a strong positive correlation between HGS and MAMC and weight ($r = 0.743$; $p < 0{,}001$ and $r = 0.706$; $p < 0{,}001$, respectively), and association with MAMC independently of age and sex. According to quartile distribution, the lowest HGS quartile also showed association with below adequate MAMC ($p = 0.005$).
Conclusions: These results showed muscle strength was associated with nutritional status and low muscle strength was associated with low muscle mass, independently of age and sex.

1. Introduction

Individuals with cancer usually experience weight loss and lean mass depletion [1], which is an independent risk factor for increased morbidity and mortality, length of hospital stay, risk of treatment toxicity, and worsening quality of life [2,3]. Malnutrition is a common complication in pediatric cancer patients [4].

Among the types of cancer that affect the pediatric age group, leukemia is the most common type of cancer in most populations [5–7]. According to the estimates of the National Cancer Institute José Alencar Gomes da Silva [8] for each year of the 2020–2022 triennium, in Brazil, there will be 4310 new cases of cancer in male children and adolescents, and 4150 in female.

Lean mass depletion is accompanied by loss of muscle strength, more appropriately called dinapenia [9]. More recently, dinapenia in children has been studied [10–13], which can be measured by handgrip strength. It has been considered a predictor of nutritional status [14,15], but there is no defined cutoff point for the pediatric population.

According to the European consensus on sarcopenia in older people [16], muscle strength reflects muscle functionality and is the

* Corresponding author. Praça Cruz Vermelha, 23 - Centro, Rio de Janeiro, RJ, 20230-130, Instituto Nacional de Câncer José Alencar Gomes da Silva (INCA), Hospital do Câncer I (HCI). Tel: 3207-1145.
E-mail addresses: nathtostes@gmail.com (N.F. Tostes), danubia.saraiva@inca.gov.br (D. da Cunha Antunes Saraiva), renatabrum@yahoo.com (R.B. Martucci).

https://doi.org/10.1016/j.clnesp.2021.03.009
2405-4577/

first parameter evaluated for diagnosis, which must be confirmed with other methods to measure muscle mass, but it is highly likely that the individual is sarcopenic when presenting muscle strength reduction. Although there is growing research interest in childhood sarcopenia, there is no consensus until the present moment [17]. Thus, this study aims to evaluate the association between nutritional status and muscle strength in pediatric cancer patients hospitalized.

2. Methods

2.1. Study population and design

A cross-sectional study was carried out with pediatric cancer patients admitted to the pediatric ward of the National Cancer Institute José Alencar da Silva (INCA), from February 2019 to November 2019. Children and adolescents from 6 to 19 years, with confirmed oncological diagnosis of solid and/or hematological tumors were included. The exclusion criteria were: patients admitted to the pediatric ICU (Intensive Care Unit) in a severe clinical condition; patients admitted for bone marrow transplantation; palliative care patients; patients unable to perform anthropometric assessment, either due to the presence of edema, an amputated limb or the impossibility of walking; and patients in contact and/or respiratory isolation.

The sample was stratified by age group: 6–9 years, 10–14 years and 15–19 years. Participants underwent nutritional assessment within the first 48 h of hospitalization. Information regarding diagnosis, hospitalization reason and treatment was obtained from medical records.

2.2. Nutritional assessment

Anthropometry were performed: body weight and height measurements on a digital scale calibrated with a scale of 0.10 kg and stadiometer with a scale of 0.10 cm (Filizola Personal Line, São Paulo, Brazil) with participants wearing light clothes and without shoes; mid-upper arm circumference (MUAC), measured by a flexible, inelastic measuring tape, at the midpoint of the distance between the acromion and the olecranon; tricipital skinfold (TSF), performed at the same midpoint of the MUAC, but in the posterior part of the arm, parallel to the horizontal axis, to assess the adipose reserve through the Lange (Lange, Washington, USA) adipometer with a scale of 1.00 mm; and mid-arm muscle circumference (MAMC), obtained indirectly by measuring the TSF and MUAC using the following calculation: MAMC (cm) = MUAC (cm) - TSF (mm) x $\pi/10$ (where $\pi = 3.14$). MUAC and TSF measurements were obtained in one arm, in three measurements and the value used was the average of these values.

HGS was measured using the Jamar hydraulic hand dynamometer with a scale of 2.00 kg (Sammons Preston TM, Canada) in any time within the first 48 h of hospitalization. Prior to data collection, a warm up section was conducted so that the subjects would get acquainted with the instrument and procedures and choose the best adjustment. Finally, subjects were instructed to grip the dynamometer with maximum strength in response to a voice command. The test was applied with the patient seated, with the shoulder abducted and neutrally rotated, elbow flexed at 90° and forearm and wrist in neutral position. Three measurements were taken in each hand alternately (total of six measurements), with a 1-min pause between them, except in case of venous access or catheter in one of the arms. In this case, three measurements were made on the same hand. The highest value obtained was considered [18].

For the diagnosis of nutritional status, the Body Mass Index (BMI) was calculated by the body weight divided by the height squared. The Z-score calculation of the anthropometric ratios “weight for age”, “height for age” and “BMI for age” was performed using the WHO AnthroPlus software (version 3.2.2, January 2011) and the classification was performed by the growth curves of the World Health Organization [19]. The cut-off point for malnutrition was Z-score < -2 and for nutritional risk it was $-2 \leq$ Z-score < -1 (both below adequate) and ≥ -1 as adequate. The classifications of MUAC, TSF and MAMC were based on the reference tables of FRISANCHO (1981, 1990). It was considered below percentile 5 as bellow adequate and above percentile 5 as adequate for MUAC and MAMC. But it was considered percentiles between 15 and 85 as adequate, below percentile 15 as below adequate and above percentile 85 as above adequate for TSF.

All equipment for assessing the patients' nutritional status were available at the institution.

2.3. Statistical analysis

The normality of the data was assessed by Kolmogorov–Smirnov test and was considered normal distribution when $p > 0.05$. Continuous variables were expressed as mean and standard deviation (SD) and categorical variables were presented by absolute and percentage frequency distribution. The Chi-square test was used to analyze categorical variables and ANOVA with Bonferroni post-hoc test or Student's t-test for continuous variables. For non-parametric variables was used Kruskal Wallis and Mann Whitney tests. Sperman's correlation was used to assess the correlation between muscle strength and nutritional status. Sperman's coefficients were classified as: from 0.10 to 0.39 indicates a weak correlation, from 0.40 to 0.69 indicates a moderate correlation and above 0.70 indicates a strong correlation [20].

Univariable and Multivariable linear regression analyses were performed to examine which anthropometric variables were associated with HGS. Multivariable analyses were adjusted for gender and age.

The values of HGS were classified in quartiles (Q1 $\leq$ percentiles 25; Q2: > percentile 25 and $\leq$ percentile 50; Q3: > percentile 50 and $\leq$ percentile 75, Q4 > percentile 75, where Q means quartile) was performed. From this distribution, the chi-square test was performed between HGS percentiles and anthropometric parameters.

The results were considered statistically significant when p-value < 0.05, with a confidence interval of 95%. The SPSS (Statistical Package for Social Sciences) program, version 22, was used to analyze the data.

2.4. Ethical considerations

The study in question is linked to a larger study called “Construction and validation of a nutritional assessment instrument for pediatric cancer patients”. The project has been submitted to the Ethics Committee and approved under CAAE No. 73737317.2.3001.5274.

Those responsible for patients aged 6–17 years signed the Informed Consent. The 18 and 19-year-old patients signed the Informed Consent for adolescent patient together with the parents or responsible for them. The Assent term was signed by patients aged 7–17 years.

3. Results

The sample consisted of 63 patients, 52.40% male and 47.60% female. There were more male than female participants in the age range 6–9 years old (68.80%, p = 0,022) and 10–14 years old (60.70%, p = 0,022). However, the age range 15–19 years old presented more female than male participants (73.70%, p = 0.022). Table 1 shows the general characteristics and the main diagnoses of all patients, stratified by age group. The mean age was 13.01 (SD ± 3.83), with an interval between 6.20 years and 19.78 years.

Most tumors were solid (69.80%), with Central Nervous System (CNS) tumors being the most frequent in the sample (22.20%), followed by Acute Lymphoid Leukemia - ALL (14.30%) and osteosarcoma (11.10%). CNS tumors were also the most frequent for the 10–14 years old and 15–19 years old (25.00% and 31.60%, respectively). In the 6–9 year old age group, the most frequent tumors were ALL (18.80%), Burkitt's Lymphoma (12.50%), Osteosarcoma (12.50%) and Retinoblastoma (12.50%).

Among the tumors in the “other” category, there are tumors that presented 2 times or less. They are: desmoid tumor of the mandible, Ewing's sarcoma, Fibrohistiocytoma, Synoviosarcoma, Teratoma, Hepatocarcinoma, Pheochromocytoma and Willms tumor. Among CNS tumors are: Medulloblastoma, Astrocytoma, Primitive neuroectodermal tumor (PNET), Glioma, Germinoma, Craniopharyngioma, Chordoma clivus and Ependimoma.

The means of anthropometric values for general patients was: weight was 44.87 kg (SD ± 19.53), height was 148.76 cm (SD ± 17.65), BMI was 19.49 kg/m^2 (SD ± 5.30), MUAC was 22.45 cm (SD ± 5.36), TSF was 16.57 mm (SD ± 10.55), MAMC was 17.24 cm (SD ± 3.18), and HGS was 17.10 kg (SD ± 8.93). Table 2 shows the mean and standard deviation of the parameters of nutritional assessment, separated by age range and sex. For male, the 6-9-year

Table 1
General characteristics and main diagnoses for general population and by age group.

Variables	General	6–9 years	10–14 years	15–19 years
Sex**				
Male	33 (52.40%)	11 (68.80%)	17 (60.70%)	5 (26.30%)
Female	30 (47.60%)	5 (31.30%)	11 (39.30%)	14 (73.70%)
Total	63 (100.00%)	16 (100.00%)	28 (100.00%)	19 (100.00%)
Age (years) - Mean (SD)	13.01 (3.83)	8.03 (1.14)	12.80 (1.56)	17.50 (1.58)
Hospitalization reason				
Emergency	33 (52.40%)	6 (37.50%)	15 (53.60%)	12 (63.20%)
Elective	30 (47.60%)	10 (62.50%)	13 (46.40%)	7 (36.80%)
Total	63 (100.00%)	16 (100.00%)	28 (100.00%)	19 (100.00%)
Tumor types				
Solids	44 (69.80%)	10 (62.50%)	20 (71.40%)	14 (73.70%)
Hematological	19 (30.20%)	6 (37.50%)	8 (28.60%)	5 (26.30%)
Total	63 (100.00%)	16 (100.00%)	28 (100.00%)	19 (100.00%)
Diagnoses				
ALL	9 (14.30%)	3 (18.80%)	4 (14.30%)	2 (10.50%)
AML	1 (1.60%)	0 (0.00%)	0 (0.00%)	1 (5.30%)
Hodgkin's lymphoma	3 (4.80%)	1 (6.30%)	1 (3.60%)	1 (5.30%)
Non-Hodgkin's lymphoma	4 (6.30%)	0 (0.00%)	3 (10.70%)	1 (5.30%)
Burkitt's lymphoma	2 (3.20%)	2 (12.50%)	0 (0.00%)	0 (0.00%)
CNS tumors	14 (22.20%)	1 (6.30%)	7 (25.00%)	6 (31.60%)
Thyroid carcinoma	2 (3.20%)	1 (6.30%)	1 (3.60%)	0 (0.00%)
Osteosarcoma	7 (11.10%)	2 (12.50%)	3 (10.70%)	2 (10.50%)
Rhabdomyosarcoma	3 (4.80%)	1 (6.30%)	2 (7.10%)	0 (0.00%)
Oro/nasopharynx	5 (7.90%)	0 (0.00%)	3 (10.70%)	2 (10.50%)
Retinoblastoma	2 (3.20%)	2 (12.50%)	0 (0.00%)	0 (0.00%)
Others	11 (17.50%)	3 (18.80%)	4 (14.30%)	4 (21.10%)
Total	63 (100.00%)	16 (100.00%)	28 (100.00%)	19 (100.00%)

**P-value < 0.05, using the Chi-square test. SD: standard deviation; ALL: Acute Lymphoid Leukemia; AML: Acute Myeloid Leukemia; CNS: central nervous system.

Table 2
Mean and standard deviation (SD) of nutritional assessment parameters for the entire sample, by age group and separated by sex.

Nutritional Assessment	General (Male, n = 33)	6–9 years	10–14 years	15–19 years	p-value
Weight (Kg)	40.63 (20.38)	25.24 (5.33)	47.34 (18.76)	63.57 (27.94)	0.001[a]
Height (cm)	145.45 (20.54)	123.09 (6.42)	157.37 (12.72)	167.83 (1.89)	<0,001[a]
BMI (Kg/m^2)*	18.26 (5.20)	16.53 (2.45)	18.70 (5.58)	22.43 (9.33)	0.011[a,c]
MUAC (cm)	21.36 (5.56)	18.36 (2.37)	22.25 (5.86)	24.97 (7.15)	0.051
TSF (mm)*	13.50 (10.39)	12.36 (5.83)	13.90 (11.72)	14.67 (14.94)	0.103
MAMC (cm)	17.12 (3.21)	14.46 (1.30)	17.89 (3.00)	20.36 (2.66)	<0.001*
HGS (Kg)	17.00 (10.58)	7.64 (3.07)	20.88 (10.51)	24.40 (7.54)	<0.001*
Nutritional Assessment	**General (Female, n = 30)**	**6–9 years**	**10–14 years**	**15–19 years**	**p-value**
Weight (Kg)	49.27 (17.91)	30.02 (5.18)	46.49 (14.10)	58.81 (17.45)	0.004[a,b]
Height (cm)	152.20 (13.58)	130.60 (6.01)	152.70 (11.11)	160.11 (6.91)	<0.001[a]
BMI (Kg/m^2)	20.75 (5.18)	17.51 (1.99)	19.69 (4.38)	22.82 (5.90)	0.106
MUAC (cm)	23.64 (4.94)	19.52 (2.10)	21.96 (3.61)	26.42 (5.08)	0.006[b]
TSF (mm)	19.93 (9.81)	15.20 (7.28)	17.55 (8.04)	23.50 (11.03)	0.161
MAMC (cm)	17.38 (3.19)	14.75 (1.82)	16.45 (2.09)	19.04 (3.45)	0.012[a,b]
HGS (Kg)	17.20 (6.84)	11.60 (3.58)	15.82 (5.62)	20.29 (7.23)	0.030[a,b]

ANOVA with Bonferroni post-hoc test. BMI: body mass index; MUAC: mid-upper arm circumference; TSF: tricipital skin fold; MAMC: mid-arm muscle circumference of the arm; HGS: handgrip strength. P-value different between all age groups by ANOVA with Bonferroni *post hoc* test or Kruskal Wallis (*), except.

[a] Between 10-14 years and 15–19 years.

[b] Between 6-9 years and 10–14 years.

[c] Between 6 and 9 years and 15–19 year.

Table 3
Quartiles of HGS for each age group and sex.

Male				
Age range	Q1	Q2	Q3	Q4
6–9 years	≤4.00	4.01–8.00	8.01–10.00	>10.00
10–14 years	≤11.00	11.01–16.00	16.01–32.00	>32.00
15–19 years	≤19.00	19.01–20.00	20.01–32.00	>32.00
Female				
Age range	**Q1**	**Q2**	**Q3**	**Q4**
6–9 years	≤8.00	8.01–12.00	12.01–15.00	>15.00
10–14 years	≤12.00	12.01–16.00	16.01–20.00	>20.00
15–19 years	≤17.00	17.01–18.00	18.01–26.50	>26.50

Q: quartilhes.

Table 4
Correlation of HGS with anthropometric measurements.

Variables	General		6–9 years		10–14 years		15–19 years	
	r^2	p	r^2	p	r^2	p	r^2	p
HGS X Weight	0.783	<0.001	0.627	0.009	0.669	<0.001	0.405	0.120
HGS X BMI	0.466	<0.001	0.564	0.023	0.428	0.033	0.325	0.220
HGS X MUAC	0.604	<0.001	0.539	0.031	0.482	0.009	0.437	0.062
HGS X TSF	0.148	0.246	0.104	0.700	0.079	0.690	0.077	0.755
HGS X MAMC	0.761	<0.001	0.549	0.028	0.640	<0.001	0.639	0.003

Spearman's correlation; HGS: hand grip strength; BMI: body mass index; MUAC: mid-upper arm circumference; TSF: tricipital skin fold; MAMC: mid-arm muscle circumference.

age group had lower MAMC and HGS, when compared to the others. For female, on the other hand, there was only a difference between the lowest and the highest age group.

When the genders are compared, the TSF was higher for female than for male in the general population ($p = 0.001$, Mann Whitney). However, in the different age groups, only HGS ($p = 0.039$) and height ($p = 0.045$) presented higher values for female than for male in the age group of 6–9 years old. In both sexes, the HGS was higher in the older age groups, but it was only significant in the 6–9 year old age group compared with the other two age groups ($p < 0.001$). This also occurs with male patients ($p = 0.001$ when compared with age range 10–14 years, and p-value = 0.002 when compared with age range 15–19 years), but in females there is only a statistical difference between the age groups of 6–9 years and 15–19 years ($p = 0.037$).

Regarding anthropometric classifications, 81.30% (n = 13/16) of the population presented an appropriate weight for age, 94.20% (n = 49/52) presented an adequate height for age and 45.60% (n = 26/57) presented an adequate BMI. The frequency of adequate MUAC, TSF and MAMC for general population was 58.70% (n = 37/63), 50.80% (n = 32/63) and 55.60% (n = 35/63), respectively. In the age group of 6–9 years, for male and female patients, 18.20% and 20.00%, respectively, had MUAC below adequate, 27.30% and 20.00%, respectively, presented TSF and MAMC below adequate. In the age group of 10–14 years, in the male and female population, respectively, 47.10% and 27.30% had MUAC below adequate, 47.10% and 45.50% had MAMC below adequate, 17.70% and 18.20% had TSF below adequate. Lastly, the frequency of male and female population of the age group 15–19 years old was, respectively, 60.00% and 28.60% for MUAC below adequate, 60.00% and 42.90% for MAMC below adequate, 20.00% and 7.10% for TSF below adequate.

Table 3 shows the distribution in quartiles of HGS, separated by sex and age range. Of the 26 children with low MAMC, 20 had an HGS below the Q2 (median), and of the 37 children with adequate MAMC, 20 had an HGS above the Q2 ($p = 0.005$). This significance was maintained to the age group 6–9 years old. There was no association between the HGS quartiles and the other parameters.

Table 4 shows the correlation between HGS and anthropometric measurements. The correlation between HGS and weight was strong and significant for the total sample, but it was moderate when stratified by age group, except in the 15–19 age group, which didn't presented significance. The correlation between HGS and MAMC was also strong and significant for the general population and moderate for the others age ranges. There was moderate to weak correlation between HGS and BMI and MUAC. None of correlation with TSF was significant. In the age group of 15–19 years there was only one moderate correlation between HGS and MAMC.

Table 5 presents the association between HGS and anthropometric variables using univariable and multivariable linear regression. The HGS was associated to all variables, except TSF, and the association was maintained when adjusted by age (years) and sex. The variable that was most associated with HGS was MAMC. It explains 60.00% of HGS, regardless of age and sex, and each cm of MAMC increases the HGS by 1.56 kg.

Table 5
The association between HGS and anthropometric variables using univariable and multivariable linear regression.

	Wheight (kg)	BMI (Kg/m^2)	MUAC (cm)	TSF (mm)	MAMC (cm)
1 Univariable					
R^2	0.50	0.23	0.32	0.04	0.55
B	0.33	0.85	0.95	0.18	2.09
IC 95%	0.24–0.43	0.43–1.26	0.60–1.30	−0.04–0.39	1.61–2.57
p-value	<0.001	<0.001	<0.001	0.102	<0.001
2 Multivariable					
R^2	0.59	0.52	0.50	0.43	0.60
B	0.25	0.55	0.57	0.08	1.56
IC 95%	0.14–0.36	0.18–0.92	0.21–0.94	−0.10–0.26	0.96–2.17
p-value	<0.001	0.004	0.003	0.377	<0.001

Multivariable ajusted by age (years) and gender.

4. Discussion

In the study, the highest prevalence was of solid tumors and a strong correlation of HGS with MAMC and weight was found, as well as a statistically significant relationship of the distribution of HGS in percentiles with MAMC, evidencing that most of the patients that presented MAMC below adequate had HGS below Q2 and most of them who had MAMC adequate, presented HGS above Q2. Also, it was found association between HGS and MAMC independent of age and sex.

Leukemia and lymphomas are known to be the most common types of cancer in the pediatric population [5–7]. Despite this, the current study had a higher prevalence of children with solid tumors (69.80%). This is probably due to the low turnover of the pediatric hematology ward of Cancer Hospital I, which has few beds, and in which most patients are admitted multiple times for chemotherapy protocols, in addition to having a prolonged hospital stay.

In the current study, the sample presented adequate nutritional status according to all anthropometric parameters, and was compatible with the study by Moreira et al. (2019), who assessed the nutritional status of pediatric patients newly diagnosed with Acute Lymphoblastic Leukemia [21]. These findings were also consistent with those of Jensen et al. (2017) and Lifson et al. (2017) in relation to anthropometric indexes, however they differed from this second author when it comes to the classifications of MUAC, TSF and MAMC, whose findings showed a higher prevalence of malnutrition [11,22]. However, in the current study, despite the general population presenting the appropriate classification for such measures, when the sample was stratified, it was possible to observe that certain age groups presented classifications below the appropriate level, especially male sex.

Many authors have considered HGS as an indicator of nutritional status, sarcopenia and bone fragility [14,23]. The findings of this article show that the HGS is higher in the older age goup, but it was not significant between the 10–14 year old and 15–19 year old, evidencing that probably there is a significant increase from the school to the adolescent phase, slowing down from 10 years old. Another study also observes this phenomenon, but the author points out that the greatest increase in HGS occurs between 9 and 11 years in girls and between 13 and 14 years in boys [12]. Ploegmakers et al. (2013) found that HGS also increases with age, accelerating above 12 years in boys and from 11 years in girls [13]. Both studies were conducted with healthy children and adolescents.

In assessing the correlation of HGS with anthropometric parameters, a strong correlation was observed with weight, which was not maintained in any of the three age groups, and with MAMC, which persisted only in the 10 to 14 age group. Moreover, it was found association between HGS and MAMC independently of age and sex. In addition, by distributing the HGS in quartiles, it was possible to identify a significant association between the adequacy of the MAMC and the percentile of HGS to the general population. These results point that HGS can reflect the nutritional status related to muscle mass. Three other authors found a relationship between HGS and muscle mass, either through MAMC or BIA [11,12,24].

According to Marrodán Serrano et al. (2009), in addition to the correlation with MAMC, correlations were also found with height, age, weight, MUAC, total arm area and muscular arm area for males, but only weight, age, MAMC and height for the women [12]. However, when the effects of age and height are eliminated, the correlations with the other parameters are not maintained. De Souza et al. (2014), in a study also carried out with healthy children, identified a correlation between HGS and height, weight and fat-free mass, obtained through BIA [24]. Ploegmakers et al. (2013) observed an association between HGS and weight, in addition to age, height and sex [13].

Bouma et al. (2016), in a study with children after hematopoietic cell transplants, observed that patients with malnutrition, classified according to BMI for age, had lower HGS values than those who had an adequate or high BMI for their age. In addition, he observed that children with HGS below the 10th percentile, had a significant association with BMI, indicating that this may possibly be a good cutoff point for this population [10].

It is important to note that the weight in patients with solid tumors may be overestimated due to the presence of the tumor mass. However, there was a correlation of strength with other anthropometric parameters, whether moderate or strong.

The HGS in this study was distributed in quartiles, but it was not possible to diagnose dinapenia, since there is no cutoff point validated for the pediatric population with cancer in Brazil. The studies that define cutoff points use varied methodologies, which requires a representative sample [10,14,25,26]. Steffl; Chrudimsky; Tufano (2017) proposes the use of an index created from the ratio between HGS and BMI and concludes, through the data, that this ratio is able to identify children at risk of being diagnosed with sarcopenic obesity [26]. All of these studies were carried out with healthy children.

No studies were found to assess HGS and its relationship with anthropometric parameters in pediatric cancer patients. In recent years, a lot of research has been done evaluating sarcopenia in children, however, such studies do not evaluate HGS, but muscle mass through CT (computed tomography) or DEXA (Dual Energy X-Ray Absorptiometry). This shows the innovative character of the research and its relevance to clinical practice, since HGS is an easy-to-use and low-cost method.

Nevertheless, some limitations must be considered. The sample of the study is small and patients from the emergency room were included. Often the HGS of these children may be reduced due to symptoms that led them to seek care and not to malnutrition related to the disease and treatment.

5. Conclusion

The study demonstrated a positive and strong correlation between HGS and MAMC for general population and 10 to 14 age group, and between HGS and weight for general population. Besides that, HGS was associated with anthropometric variables of nutritional status, mainly related to lean mass, independent of age and sex. However, further studies are still needed, mainly to define a cutoff point for each age group.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaraction of Competing intrest

The authors declare no conflict of interest.

Acknowledgments

All the authors contributed with conception and design of study, data collection and analysis, preparation manuscript, drafting and revision of the manuscript and approval of the final version. We would like to thank the Oncology Research Fellowship Program of the Brazilian National Cancer Institute (INCA).

References

[1] Arends J, Bachmann P, Baracos V, Barthelemy N, Bertz H, Bozzetti F, et al. ESPEN guidelines on nutrition in cancer patients. Clin Nutr 2017;36(1):11–48.

[2] Garla P, Waitzberg DL, Tesser A. Nutritional therapy in gastrointestinal cancers. Gastroenterol Clin N Am 2017;47(1):231–42.

[3] Joffe L, Dwyer S, Glade Bender JL, Frazier AL, Ladas EJ. Nutritional status and clinical outcomes in pediatric patients with solid tumors: a systematic review of the literature. Semin Oncol 2018;46(1):48–56.

[4] Co-Reyes E, Li R, Huh W, Chandra J. Malnutrition and obesity in pediatric oncology patients: causes, consequences, and interventions. Pediatr Blood Canc 2012;59(7):1160–7.

[5] Howlader N, Noone A, Krapcho M, Miller D, Bishop K, Altekruse S, et al. Cancer statistics review, 1975-2013 - previous version. SEER Cancer Statistics Review 2016. https://seer.cancer.gov/archive/csr/1975_2013/index.html. [Accessed 11 October 2019].

[6] Ries L, Smith M, Gurney J, Linet M, Tamra T, Young J, et al. Cancer incidence and survival among children and adolescents. United states SEER program 1975-1995. American Psychological Association; 1999. http://www.crossref.org/deleted_DOI.html. [Accessed 11 October 2019].

[7] Steliarova-Foucher E, Colombet M, Ries LAG, Moreno F, Dolya A, Bray F, et al. International incidence of childhood cancer, 2001–10: a population-based registry study. Lancet Oncol 2017;18(6):719–31.

[8] Estimativa 2020: incidência de câncer no Brasil | INCA - instituto Nacional de Câncer. Brasil: Instituto Nacional de Câncer José Alencar Gomes da Silva I, Coordenação de prevenção e vigilância, Ministério da Saúde; 2019. https://www.inca.gov.br/publicacoes/livros/estimativa-2020-incidencia-de-cancer-no-brasil. [Accessed 20 February 2020].

[9] Alexandre T da S, Duarte YA de O, Santos JLF, Lebrão ML, Alexandre T da S, Duarte YA de O, et al. Prevalence and associated factors of sarcopenia, dynapenia, and sarcodynapenia in community-dwelling elderly in São Paulo - SABE Study. Rev Bras Epidemiol 2018;21.

[10] Bouma S, Peterson M, Gatza E, Choi SW. Nutritional status and weakness following pediatric hematopoietic cell transplantation. Pediatr Transplant 2016;20(8):1125–31.

[11] Jensen KC, Bellini SG, Derrick JW, Fullmer S, Eggett D. Handgrip strength and malnutrition (undernutrition) in hospitalized versus nonhospitalized children aged 6–14 years. Nutr Clin Pract 2017;32(5):687–93.

[12] Marrodán Serrano MD, Romero Collazos JF, Moreno Romero S, Mesa Santurino MS, Cabañas Armesilla MD, Pacheco del Cerro JL, et al. Dinamometría en niños y jóvenes de entre 6 y 18 años: valores de referencia, asociación con tamaño y composición corporal. An Pediatr 2009;70(4):340–8.

[13] Ploegmakers JJW, Hepping AM, Geertzen JHB, Bulstra SK, Stevens M. Grip strength is strongly associated with height, weight and gender in childhood: a cross sectional study of 2241 children and adolescents providing reference values. J Physiother 2013;59(4):255–61.

[14] Gómez-Campos R, Andruske CL, Arruda M de, Sulla-Torres J, Pacheco-Carrillo J, Urra-Albornoz C, et al. Normative data for handgrip strength in children and adolescents in the Maule Region, Chile: evaluation based on chronological and biological age. PloS One 2018;13(8):e0201033.

[15] López JJ, Cooper JN, Albert B, Adler B, King D, Minneci PC. Sarcopenia in children with perforated appendicitis. J Surg Res 2017;220:1–5.

[16] Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019;48(1):16–31.

[17] Ooi PH, Thompson-Hodgetts S, Pritchard-Wiart L, Gilmour SM, Mager DR. Pediatric sarcopenia: a paradigm in the overall definition of malnutrition in children? J Parenter Enteral Nutr 2019:1681. jpen.

[18] Figueiredo IM, Sampaio RF, Mancini MC, Silva FCM, Souza MAP. Test of grip strength using the Jamar dynamometer. Acta Fisiátrica 2007;14(2). Disponível em: http://www.gnresearch.org/doi/10.5935/0104-7795.20070002.

[19] WHO child growth standards: methods and development. WORLD HEALTH ORGANIZATION. WHO; 2006. https://www.who.int/childgrowth/standards/technical_report/en/. [Accessed 16 October 2019].

[20] Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. Anesth Analg 2018;126(5):1763–8.

[21] Moreira KA, Carvalho ALM de, Schramm MT, Martucci RB, Murad LB, Saraiva D da CA. Estado Nutricional de Pacientes Pediátricos Recém-Diagnosticados com Leucemia Linfoblástica Aguda em um Instituto de Referência em Oncologia do Rio de Janeiro. Rev Bras Cancerol 2019;64(3):349–55.

[22] Lifson LF, Hadley GP, Wiles NL, Pillay K. Nutritional status of children with Wilms' tumour on admission to a South African hospital and its influence on outcome. Pediatr Blood Canc 2017;64(7):e26382.

[23] Dodds RM, Syddall HE, Cooper R, Benzeval M, Deary IJ, Dennison EM, et al. Grip strength across the life course: normative data from twelve British studies. PloS One 2014;9(12):e113637.

[24] de Souza MA, de Jesus Alves de Baptista CR, Baranauskas Benedicto MM, Pizzato TM, Mattiello-Sverzut AC. Normative data for hand grip strength in healthy children measured with a bulb dynamometer: a cross-sectional study. Physiotherapy 2014;100(4):313–8.

[25] Cole TJ, Green PJ. Smoothing reference centile curves: the lms method and penalized likelihood. Stat Med 1992;11(10):1305–19.

[26] Steffl M, Chrudimsky J, Tufano JJ. Using relative handgrip strength to identify children at risk of sarcopenic obesity. PloS One 2017;12(5):e0177006.