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Original Article

Comparison of two bioelectrical impedance analyzers for estimating body composition in a cohort of pediatric oncology patients

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SUMMARY

Background and Aims: Unfavourable changes in body composition are frequently reported in children with cancer. An easy and affordable method to measure body composition is bioelectrical impedance analysis (BIA). In this study, we compared the Tanita MC780-MA Body Composition Analyzer (Tanita) versus the Bodystat Quadscan 4000 analyzer (Bodystat) to determine whether the Tanita is a suitable analyzer for pediatric oncology patients.
Methods: In this study, 84 childhood cancer patients/survivors were included. Per patient 1, 2 or 3 visits were planned during or after treatment. During each visit, BIA measurements were performed first with the Tanita analyzer followed by the Bodystat analyzer. In total, 131 measurements were included. Spearman correlation and concordance correlation coefficients of Lin (CCC) were calculated for fat percentage (Fat%), fat mass (FM) and fat free mass (FFM). Bland-Altman plots were constructed to assess the agreement between both analyzers.
Results: Fat%, FM and FFM values differed statistically significantly when comparing the BIA devices (Wilcoxon signed rank test, $P<0.001$), but absolute differences between medians were small. Spearman correlations and CCC's were high for FM (0.94 and 0.92, respectively) and FFM (0.99 and 0.99, respectively), but moderate

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for Fat% (0.70 and 0.65, respectively). Bland-Altman plots did not show low differences of means (biases; for Fat%, FM and FFM 2,6%, 0,6 kg and -0,6 kg respectively), but relatively large limits of agreement (-9.77%–15.89%, -5.6 kg–7.2 kg and -5.9 kg–4.6 kg respectively).
Conclusions: Based on the good agreement between the Tanita and Bodystat on group level, and the fact that the Tanita is a more patient-friendly device, the Tanita can be used to measure body composition instead of the Bodystat in pediatric oncology patients, making it easier and faster to gain information about body composition.

Introduction

Malnutrition is frequently reported in childhood cancer patients [1] and is classified by the World Health Organization as undernutrition, micronutrient-related malnutrition or overnutrition [2]. Both undernutrition and overnutrition are associated with lower survival rates [3,4] and an increased risk of treatment-related toxicities in children with cancer [5,6]. Furthermore, childhood obesity is linked to obesity at older age in the general population, leading to enhanced health risks including diabetes mellitus and cardiovascular diseases [7]. Body composition is one of the measures used to define nutritional status and specifically under- and overnutrition [8]. To be able to prevent and potentially reverse malnutrition in children with cancer, it is important to monitor body composition before, during and after cancer treatment [9]. Several body composition analyzers are currently available for clinical use in adults, however, little is known about the performance of these analyzers in children with cancer.

There are several methods to measure body composition. Dual-energy X-ray absorptiometry (DXA) is considered to be the reference method for measuring body composition in clinical care [10,11]. However, specific DXA equipment is expensive, not everywhere available and the procedure is time consuming, thereby limiting feasibility in clinical practice. Furthermore, a DXA scan can be frightening for younger children because of the sounds and size of equipment, making it a stressful experience [12]. Bioelectrical impedance analysis (BIA) is an easy and affordable alternative to measure body composition [10]. This method defines body composition by measuring the resistance and reactance of a small electrical current through the body. By using standard equations as defined by the manufacturers, information about fat percentage (Fat%), fat mass (FM), and fat free mass (FFM) is given [13]. BIA devices come in different types and sizes, ranging from a small portable device to a well-equipped scale. In our facility, the Bodystat Quadscan 4000 analyzer (Bodystat) is used to perform BIA in children with cancer. This device is small and portable, but patients have to be in supine position for at least five minutes before a measurement can be done. The Tanita MC780-MA Body Composition Analyzer (Tanita) is a transportable scale that gives results within one minute, which would be more practical in the pediatric outpatient clinic. Multiple studies among adults and children have shown that the Bodystat gives reliable results for FM and FFM [14–16]. The performance of the Tanita has also been evaluated in obese children [17], but, to the best of our knowledge, not in children with undernutrition or normal weight yet.

The objective for this study was to compare body composition measurements collected with the Tanita MC780-MA Body Composition Analyzer versus the Bodystat Quadscan 4000 analyzer and determine if the Tanita is a suitable BIA device for the pediatric oncology patient. We hypothesized that measurements of both device would be comparable.

Materials and methods

Subjects

In this cohort study, patients were recruited between April 2021 and December 2022 at the national pediatric oncology center (Princess Máxima Center for pediatric oncology in Utrecht) in the Netherlands, where all children with cancer are diagnosed and treated. Eligible patients were between 2 and 18 years old, were able to comprehend Dutch or English, and were treated for a malignancy and/or hypothalamic dysfunction after an earlier malignancy. Exclusion criteria were wearing biosensors or having electrical implants, having oxygen delivery, inability to lie still for 10 minutes, inability to fast, pregnancy, burn wounds and having an abnormal hydration status such as edema. All eligible consecutive patients diagnosed in our center were asked to participate. As part of a larger longitudinal study on resting energy expenditure in childhood cancer patients, body composition was measured at 6 weeks, 3 months and 6 months after diagnosis. The patients with hypothalamic dysfunction were measured for patient care, in case of (severe) obesity.

Ethics

The study was approved by the Medical Ethics Review Committee of the University Medical Center Utrecht (METC 19/348, NL69551.041.19) and all children and/or parents provided written informed consent.

Measurements

Both BIA measurements were conducted for research purposes during a visit to the outpatient clinic of the Princess Máxima Center for pediatric oncology. After a fasting period of at least 8 hours (not because of the BIA measurement, but for other study measurements (resting energy expenditure), body weight and height were measured. Measurements were performed between 08:00 AM and 12:00 PM. Before the measurements started, patients were asked to urinate and to remove their shoes, socks and heavy clothing like sweaters. Patients were allowed to wear other clothing. Electrical devices were removed from their pockets. Standing height was measured with shoes and caps off. Weight was measured using the Tanita simultaneously with the body composition measurement. Lastly, body composition was measured with the Bodystat. Thus, a single measurement was performed with both BIA devices, always in the same order. BMI was calculated and patients were divided into four different BMI categories; underweight, normal weight, overweight and severe overweight. Reference values per age and sex category were obtained from the BMI index tables from the Dutch Nutrition Center [18].

Bioelectrical impedance analysis (BIA)

Resistance and reactance of the body were measured using the Tanita MC-780MA Body Composition Analyzer (TANITA, Japan). Patients were instructed to stand on the scale with bare feet and keep their arms separated from their legs while holding the grips. For the measurement, both hands and feet needed to be placed on the right place of the instrument. Fat%, FM, and FFM were estimated using the manufacturers' equations and registered.

Secondly, resistance and reactance were measured using the Bodystat Quadscan 4000 (Bodystat Ltd., Isle of Man), followed by an estimation of Fat%, FM, and FFM from the manufacturers' equations. Patients were instructed to lie down in supine position for at least five minutes before BIA was performed [19]. Patient's right hand and foot were cleaned with alcohol before the electrodes were placed (2 on the right hand and 2 on the right foot). During the measurement, patients were instructed to lay still with legs and arms separated.

For both measurements, no specific body segments were measured and the standard analysis methods were used. Maintenance and yearly calibration of both devices was conducted by our in-house medical technical department. For both devices, the standard equations per device were used to calculate the Fat%, FM and FFM.

Data analysis

Endpoints for the study were Fat%, FM and FFM. For data analyses, we used IBM SPSS (version 26) and R studio (version 1.3.1093). Given that this was an exploratory study, no power calculation has been performed. Based on the distribution of the data, population characteristics are presented as mean and standard deviation (SD), or as median and interquartile range (IQR). Dichotomous or categorical variables are presented as numbers and percentages. Because the body composition data was not normally distributed, Wilcoxon signed rank tests were performed to evaluate differences between the two analyzers. Spearman correlations were calculated for Fat%, FM, and FFM to determine the correlation between the two analyzers. In addition, the concordance correlation coefficient of Lin (CCC) was calculated and Bland-Altman plots were constructed to visualize the agreement between both analyzers. In these plots the difference between the two measurements is plotted against the mean of the two measurements. Limits of agreement (LOA) are calculated by mean of the difference +/- (standard deviation x 1.96).

Results

Demographics

A total of 84 childhood cancer patients/survivors were included, from whom 19 children diagnosed with hypothalamic dysfunction. Per patient 1, 2 or 3 measurements were performed at different days. In total, 131 different measurements from 84 children were available and considered in the analysis. The median age of the children was 10 years (IQR 7–13). Overall demographics of the included patients are shown in Table 1. There were slightly more boys (55%) than girls (45%). Patients with a hematological malignancy represented the largest group (59%). The distribution of BMI categories shows a relative high percentage of severe overweight patients (14%), which can be explained by the inclusion of hypothalamic dysfunction patients.

Comparison of the Bodystat and Tanita BIA devices

Table 2 shows the difference in body composition measured by the two BIA devices. All parameters measured using the two analyzers were significantly different ($P<0.001$; Table 2). Median differences

Table 1
Demographic and clinical characteristics.

Sex and diagnosis of 84 patients		
	n	%
Sex		
Male	46	55%
Diagnosis		
Hematological malignancy	50	59%
Solid tumor	14	17%
Brain tumor	1	1%
Hypothalamic dysfunction	19	23%
BMI category in 131 measurements		
	n	%
BMI category[a]		
Underweight	3	2%
Normal weight	86	66%
Overweight	23	18%
Severe overweight	19	14%

[a] Based on the age- and sex-specific reference values from the BMI index tables from the Dutch Nutrition Center [17].

Table 2
Correlation between results of the Bodystat and Tanita BIA devices.

	Bodystat[a]	Tanita[a]	p-value[b]	Correlation (Spearman's rho)	CCC of Lin
Fat percentage (%)	28.2 (23.7–34.0)	24.3 (20.4–29.6)	<0.001	0.70	0.65
Fat Mass (kg)	10.7 (7.5–18.0)	9.6 (6.3–16.5)	<0.001	0.94	0.92
Fat Free Mass (kg)	31.7 (19.0–44.2)	32.0 (20.3–45.6)	<0.001	0.99	0.99

[a] Values are expressed as median (IQR).
[b] Based on Wilcoxon Signed Rank test.

in individual measurements (Bodystat − Tanita) for Fat%, FM and FMM were respectively 3.4% (IQR -0.4 − 6.2), 1.2 kg (IQR -0.3 − 2.5) and -1.1 kg (IQR -2.3 − 0.3). Despite these differences, measurements from the two analyzers were strongly correlated for FM and FFM (rho 0.94 and 0.99, respectively; Table 2, Figure 1) with high values of CCC (0.92 and 0.99, respectively; Table 2). Fat% results of the two analyzers were moderately correlated (rho 0.70, CCC 0.65; Table 2, Figure 1). When identifying outliers, there were four measurements that were logically not possible, for example a higher dry lean weight value then the measured body weight. All these four measurements were performed with the Bodystat in children between 4-6 years old. These measurements were kept in the data analysis because the results were considered relevant. When these four measurements were removed from data analysis, Spearman's rho and CCC increased for Fat% (to respectively 0.83 and 0.73), but remained more or less the same for FM (rho 0.95 and CCC 0.94) and FFM (rho 0.95 and CCC 0.94).

Bland-Altman plots presenting agreement in measurement of Fat%, FM and FFM obtained by the two BIA devices are shown in Figure 1. All three plots show that the differences between the means, the so called biases, are low; respectively 2,6%, 0,6 kg and -0,6 kg, but LOA are large; respectively -9.77%–15.89%, -5.6 kg–7.2 kg and -5.9 kg–4.6 kg. The difference in Fat% between the two analyzers is larger for the higher Fat% values. This pattern is even more clear in FM, particularly for the severe overweight patients, where the difference between measurements becomes larger (and more negative) when the mean FM value increases. The differences in FFM show that in patients with normal weight the Tanita showed higher FFM compared to the Bodystat, whereas in the patients with (severe) overweight, the Tanita showed lower FFM compared to the Bodystat. When excluding the hypothalamic dysfunction patients from analysis, LOA for Fat%, FM and FMM were respectively -8.2%–16.3%, -4.0 kg–6.7 kg and -5.3 kg–2.8 kg.

Discussion

In this study we found that the Tanita MC780 Body Composition Analyzer and the Bodystat Quadscan 4000 can both be used in clinical practice in pediatric oncology patients. Although the measurements from the Tanita and Bodystat differed in terms of statistical significance, there was only a small difference between the medians. Moreover, there was good agreement on group level and moderate agreement on individual level. However, in severe overweight patients, differences between the two analyzers are larger and results should be interpreted with caution.

Agreement in measuring body composition

Bland-Altman plots are often used to compare two measuring methods. It does not depict which method is better but rather how much the two methods differ. The LOA indicate the range in which 95% of the differences between the two measurements lie [20]. Which range of the LOA is acceptable, depends on the clinical application [21]. The LOA's in the present study are considered large because the differences between measurements of FM and FFM ranged from -5 to +7kg, which can be clinically relevant (or even unacceptable) depending on the patients weight. This indicates that, although results are comparable at group level, BIA results should be interpreted with caution on individual level as variation between measurements performed with the Bodystat and Tanita can be high. In our population, monitoring changes in body composition is more important than absolute FM and FMM values. Therefore, we are satisfied with the good agreement on group level and the presented LOA. Previous studies comparing two different BIA devices also describe large LOA [22,23], so this might be inherent to the method. Furthermore, in previous studies comparing BIA with DXA or dilution techniques in

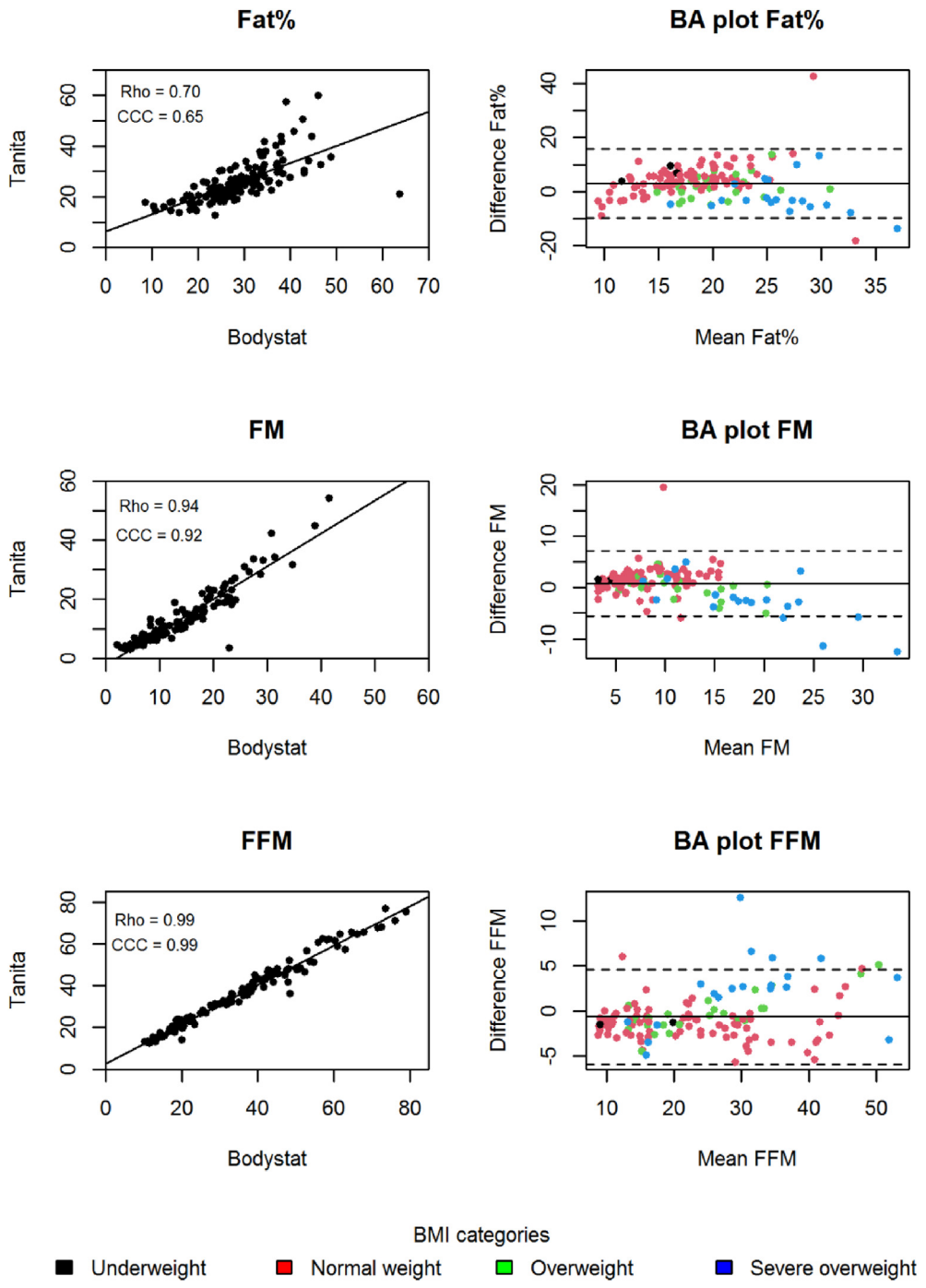

Figure 1. Comparison of Fat%, Fat Mass in kg (FM) and Fat Free Mass in kg (FFM) measurements by Bodystat and Tanita BIA devices. Bland-Altman (BA) plots with indicated BMI categories were created with mean of the differences (solid horizontal line) and limits of agreements (dashed lines) depicted.

children and adults, large LOA have also been described [14–16,24]. Relevant differences between different body composition measuring methods seem to be common and not specific for the present study. It raises questions about the underlying equations used to calculate body composition measures such as FM, FFM and the variability between analyzers.

Measuring body composition in patients with overweight

The Bland-Altman plots show that the differences for the two analyzers are randomly distributed, except for the patients with severe overweight. For these patients, the difference in Fat% and FM between the two methods appeared to be more extreme compared to patients with a normal weight. This phenomena has been well described in literature [25,26]. In agreement with our observations, the ESPEN (European Society for Clinical Nutrition and Metabolism) guideline about utilization of BIA in clinical practice [8] states that measuring body composition in morbid obesity gives unreliable results that are not reproducible within individual patients. This can be explained by a different distribution of Total Body Water (TBW) and Extracellular Water (ECW) compared to healthy individuals, resulting in an underestimation of FM and an overestimation of FFM [27]. For this reason, we also performed our data analysis in only the patients without hypothalamic dysfunction to eliminate the patients with severe obesity. LOA did not change for Fat%, but did decrease for FM and FMM. For patients with severe overweight, it is therefore recommended to use equations that are validated for this patient group. However, although studies have been performed to determine which equations give valid results in obese children [25], it remains difficult to determine which BIA device should be used in this population as most manufactures do not share the underlying equations of their devices.

Limitations and strengths

The main limitation of this study is that we were not able to compare the BIA results with the gold standard method for measuring body composition, a DXA scan. Performing a DXA scan in our patients would have been time consuming, expensive and primarily burdensome to the patients. Therefore, we were not able to determine whether either the Tanita or the Bodystat analyzer produced more valid results. However, previous research has already demonstrated that the Bodystat provides reliable results in different pediatric and adult populations [15,16,24], making the Bodystat a good reference analyzer in our study. A last limitation is the lack of the sample size calculation. Given that this was an exploratory study, we did not do a sample size calculation, but this would have make the results of the study stronger.

Strengths of the present study are the diversity within our study population, allowing comparison of the two BIA devices in individuals from different ages and with different diagnoses and BMI values. Measurements were performed in a well-controlled setting and according to standardized protocols. Furthermore, studies focusing on the agreement between two different BIA devices are scarce [22,23], making the present study novel and relevant.

Conclusion

Although measurements of both analyzers are highly correlated and the agreement is good on a group level but moderate on an individual level, we also took into account that the Tanita is a more patient-friendly device for our population since there is no use of electrodes and patients are not required to be in supine position for at least five minutes. Furthermore, the Tanita analyzer appears to be more reliable in children 4–6 years old, as all outliers and incorrect measurements in our study originated from the Bodystat measurements. Therefore, we conclude that the Tanita can be used in pediatric oncology patients, making it easier and more patient friendly to gain vital information about the body composition (changes) of the patient.

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Author contributions

Denise Froon: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Writing original draft and editing, Visualization, Project Administration. **Lisanne Renting**: Writing- Review, Investigation, Project Administration. **Dieuwertje Kok**: Writing- Review and Editing, Supervision. **Wilbert Vermeij**: Writing- Review and Editing, Supervision. **Wim Tissing**: Conceptualization, Methodology, Resources, Writing- Review and Editing, Supervision, Funding Acquisition.

Data availability statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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