



## ORIGINAL ARTICLE

# Assessment of nutritional status in paediatric outpatients using bioelectrical impedance analysis and anthropometric z-scores

Yuan Zhu,<sup>1</sup> Hong Ye,<sup>2</sup> Yi Feng,<sup>1</sup> Li-ya Pan ,<sup>1</sup> Huan-huan Fu,<sup>1</sup> Yun-man Liu,<sup>1</sup> Jun Fei<sup>1</sup> and Li Hong <sup>1</sup>

<sup>1</sup>Department of Clinical Nutrition, Shanghai Children's Medical Center, Shanghai Jiao Tong University School of Medicine, Shanghai and <sup>2</sup>Department of Paediatric, Fujian Province Children's Hospital, Fujian Provincial Maternity and Children's Hospital, Fujian Medical University, Fujian, China

**Aim:** To investigate paediatric outpatients' nutritional status using bioelectrical impedance analysis and anthropometric z-scores.

**Methods:** A retrospective data analysis of tertiary paediatric hospital outpatients from 2017 to 2019 was conducted. Patients were categorised into three groups (non-illness, illness and simple obesity) according to clinical diagnoses. The nutritional status was evaluated using anthropometric and bioelectrical impedance analysis. In addition, body composition measurements of patients in three subgroups of the illness group and age- and gender-matched healthy controls were compared.

**Results:** A total of 2015 paediatric outpatients were enrolled. According to body mass index z-scores, undernutrition prevalence among participants was 14.0% (non-illness group, 21.3%; illness group, 11.4%). Body composition measurements indicated that 41.6% of participants had a low fat-free mass index, and the proportions of participants with a low fat-free mass index in the non-illness, illness and simple obesity groups were 48.4, 47.0 and 10.7%, respectively. Compared with healthy controls, the haematology and oncology subgroup had a significantly lower fat-free mass index and fat mass index; the nephrology and rheumatology subgroup had significantly lower height-for-age z-scores but higher fat mass index; and the gastroenterology subgroups had lower fat mass index, fat-free mass index and body mass index z-scores.

**Conclusions:** The results suggested the low fat-free mass index prevalence was greater than the low body mass index z-score prevalence among paediatric outpatients, and body composition parameters varied across different illnesses. Body composition analysis is recommended in nutrition clinics for accurate paediatric outpatient nutritional assessment, thereby providing timely individualised nutritional interventions.

**Key words:** nutritional assessment; anthropometry; body composition; children; adolescent.

## What is already known on this topic

- 1 One of the main deficiencies of body mass index is that it does not differentiate between fat mass and fat-free mass.
- 2 Body composition is increasingly considered as an important aspect for the evaluation of nutritional status.

## What this paper adds

- 1 This study showed significantly higher prevalence of low fat free mass index than that of low body mass index z-score among pediatric outpatients.
- 2 Assessment of body composition, not just anthropometry, is vital to assess nutritional status in the pediatric outpatient setting.

Malnutrition is defined as a state of nutritional imbalance resulting from a deficiency or excess of energy, protein and other nutrients that leads to altered body composition and body functions and adverse effects on clinical outcome. Malnutrition can be classified into two types, nonillness-related malnutrition and illness-related malnutrition, based on aetiology-related definitions.<sup>1</sup> It is reported

that the published malnutrition prevalence in children ranges from 6 to 40%.<sup>2</sup> In addition to impeding growth and development, malnutrition may also undermine response to and tolerance of treatment, increase susceptibility to infections, prolong hospital length of stay and reduce survival rate.<sup>3</sup> In view of the relationship between malnutrition and adverse clinical outcomes, early diagnosis and timely intervention are of great significance. Body mass index (BMI) is currently one of the most commonly used indicators in the assessment of the nutritional status of children. However, BMI is inadequate for the proper determination of nutritional status in the paediatric population and may overlook the more clinically significant functional body components, including fat-free mass (FFM), fat mass (FM) and body cell mass (BCM). Previous research has shown that excess FM may conceal FFM deficits.<sup>4</sup> Moreover, recent studies have shown that the loss of FFM and BCM as well as FM accretion

**Correspondence:** Dr Li Hong, Department of Clinical Nutrition, Shanghai Children's Medical Center, Shanghai Jiao Tong University School of Medicine, 1678 Dong Fang Road, Shanghai 200127, China. Fax: +86 010 3862 6161; email: hongliscmc@163.com

Yuan Zhu and Hong Ye are co-first authors.

Conflict of interest: None declared.

Accepted for publication 8 March 2021.

were all associated with adverse clinical outcomes.<sup>5</sup> Therefore, nutritional status monitoring should involve not only BMI but also body composition for accurate nutritional diagnoses and aids in early individualised nutritional intervention, improving clinical outcomes and long-term health. The non-invasive, safe and inexpensive characteristics of bioelectrical impedance analysis (BIA) make this method applicable in paediatric populations.<sup>6</sup>

The purpose of this study was to assess the nutritional status of paediatric outpatients reflected by anthropometric and body composition parameters and to compare body composition measurements of illness subgroups with that of healthy controls.

## Methods

### Study design

The subjects in this study included paediatric patients who went to the nutrition outpatient clinic at Shanghai Children's Medical Center (SCMC), a national children's medical centre in China. The study comprised subjects who were 3 years of age or older with complete clinical information and BIA measurements. Children under 3 years old were excluded from the study due to the lack of reference data on body composition from BIA for this age group. From January 2017 to December 2019, a total of 10 101 patients went to the nutrition clinics of SCMC. Initially, 2421 subjects underwent body composition measurements. Among them, 406 subjects under the age of three were excluded. The remaining 2015 subjects were included in this study.

General demographics and clinical information, such as age, gender, clinical diagnosis and nutritional diagnosis, were

collected. According to the clinical diagnosis, the enrolled subjects were divided into non-illness, illness and simple obesity groups. The criteria of the illness group refer to the subjects with a clear history of specific disease or trauma, and the criteria of the non-illness group refer to those without a history of underlying pathological or physical disorders. Among the non-illness group, the criteria of healthy children refer to those whose nutritional assessment results (including anthropometric and body composition data) were within the normal range. Subjects in our simple obesity group were children suffering from overnutrition, who had simple obesity caused by poor lifestyles (such as excessive energy intake and decreased activity levels). Subgroup analysis was performed on three subgroups: the haematology and oncology (HO); nephrology and rheumatology (NR); and gastroenterology (GI) subgroups. Age- and gender-matched healthy subjects were selected from the non-illness group as controls. The body composition measurements of patients in the three subgroups and their controls were compared.

This research was approved by the SCMC ethics committee (SCMCIRB-K2017015); the requirement of informed consent was waived due to retrospective use of electronic record data.

### Anthropometric and body composition measurements

All measurements, including standing height, weight and BIA data were retrospectively obtained from electronic medical records and databases. Weight and body composition were measured by BIA using an Inbody 720 (Inbody Co. Ltd., Seoul, South Korea). The BIA data included weight, FM, FFM and BCM. BMI was calculated

**Table 1** Demographic and clinical characteristics of the study population

Variables	Total (n = 2015)	Non-illness (n = 929)	Illness (n = 760)	Simple obesity (n = 326)
Age, years	7.2 (5.6–10.4)	6.3 (5.2–9.2)	7.4 (5.3–11.2)	9.3 (7.3–11.4)
Age category				
3.0–5.9	589 (29.2)	320 (34.4)	235 (30.9)	34 (10.4)
6.0–8.9	694 (34.4)	361 (38.9)	225 (29.6)	108 (33.1)
9.0–11.9	453 (22.5)	167 (18.0)	157 (20.7)	129 (39.6)
12.0–18.0	279 (13.8)	81 (8.7)	143 (18.8)	55 (16.9)
Gender				
Boys	1217 (60.4)	539 (58.0)	440 (57.9)	238 (73.0)
Girls	798 (39.6)	390 (42.0)	320 (42.1)	88 (27.0)
BMIZ	−0.3 (−1.3, 1.4)	−1.0 (−1.7, −0.2)	−0.1 (−1.3, 0.9)	3.0 (2.5–3.6)
BMIZ category				
$-2 \leq Z \leq 2$	1347 (66.5)	733 (78.7)	614 (80.8)	NA
$Z < -2$	283 (14.0)	196 (21.3)	87 (11.4)	NA
$Z > 2$	385 (19.5)	NA	59 (7.8)	326 (100.0)
FM, kg	3.8 (2.3–9.3)	2.8 (1.8–4.1)	4.3 (2.7–8.2)	17.2 (12.2–24.5)
FMI, kg/m <sup>2</sup>	2.6 (1.6–5.3)	1.9 (1.3–2.7)	3.0 (1.9–4.8)	9.1 (6.9–11.5)
FFM, kg	19.6 (15.2–27.0)	17.9 (14.5–22.1)	19.8 (14.4–26.4)	29.2 (23.2–37.5)
FFMI, kg/m <sup>2</sup>	12.7 (11.9–13.9)	12.4 (11.8–13.1)	12.6 (11.7–13.7)	14.8 (13.9–16.5)
FFMI category				
Normal	1176 (58.4)	482 (51.9)	403 (53.0)	291 (89.3)
Low	839 (41.6)	447 (48.4)	357 (47.0)	35 (10.7)

Non-normally distributed data are expressed as medians (IQRs), and categorical data are presented as numbers and percentages, n (%). BMIZ, body mass index z-score; FFM, fat-free mass; FFMI, fat-free mass index; FM, fat mass; FMI, fat mass index; IQR, interquartile range.

as weight (kg) divided by height squared (m<sup>2</sup>). Anthropometric z-scores were calculated using WHO Anthro (version 3.2.2) software (Geneva, Switzerland) for subjects younger than 5 years old and WHO AnthroPlus (version 1.0.4) software (Geneva, Switzerland) for subjects 5 years of age or older. The subjects were categorised according to their BMI z-score (BMIZ) as follows: undernutrition (BMIZ <-2), normal nutritional status (-2 ≤ BMIZ ≤ 2) and obesity (BMIZ >2).<sup>7,8</sup> Similar to the BMI, FM and FFM were adjusted for height by calculating the FM index (FMI) and FFM index (FFMI), respectively. According to the reference values given in the study by Nakao *et al.*<sup>9</sup> for children over 3 years of age, a low FFMI for boys was defined as less than 12.7 kg/m<sup>2</sup> and for girls was less than 12.0 kg/m<sup>2</sup>.

**Statistics**

All data analyses were conducted using SPSS version 26 (IBM, SPSS Inc., Armonk, NY, USA). The continuous variables are shown as the median interquartile range, and the classification variables are shown as frequencies and percentages. Categorical data were analysed by the χ<sup>2</sup> test. Mann–Whitney *U*-tests were applied to compare continuous variables between illness subgroups with those of controls after data had been tested for normal distribution, based on the Shapiro–Wilk’s test. *P* value <0.05 were considered statistically significant.

**Table 2** Diagnosis information of the illness group (*n* = 760)

Diagnosis	<i>n</i> (%)
Gastroenterology	32
Crohn’s disease	12 (37.5)
Hirschsprung’s disease	3 (9.4)
Necrotising enterocolitis	3 (9.4)
Short-bowel syndrome	3 (9.4)
Intestinal obstruction	2 (6.3)
Pancreatitis	7 (21.9)
Gastrointestinal fistula	2 (6.3)
Haematology and oncology	209
Leukaemia	52 (24.9)
Lymphoma	10 (4.8)
Solid tumour	59 (28.2)
Brain tumour	6 (2.9)
Aplastic anaemia	57 (27.3)
Thalassaemia	6 (2.9)
Myelodysplastic syndrome	14 (6.7)
Others	5 (2.4)
Nephropathology and rheumatology	84
Systemic lupus erythematosus	36 (42.9)
Juvenile idiopathic arthritis	11 (13.1)
Nephritis/Nephrotic syndrome	20 (23.8)
Chronic kidney disease	5 (6.0)
Others	12 (14.3)
Congenital heart disease	185
Allergy	61
Asthma	134
Others	55

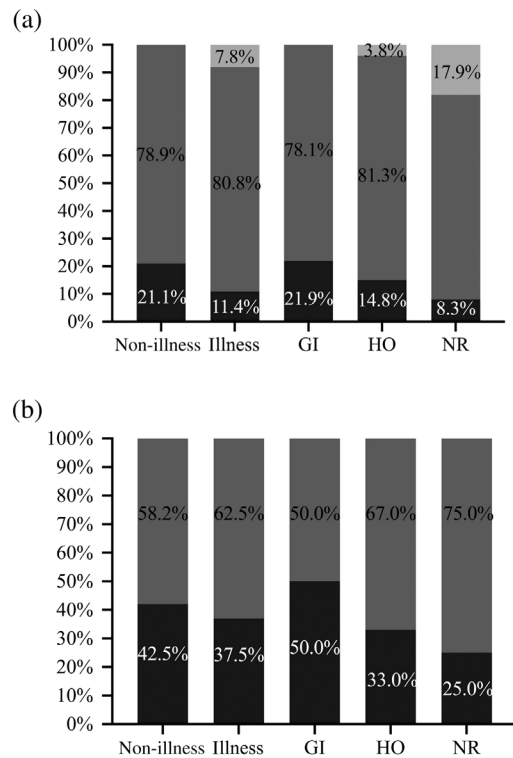
**Results**

**Patients characteristics**

Demographic, anthropometric and body composition data for each group were reported in Table 1. The detailed diagnosis information of illness group patients was presented in Table 2. A total of 2015 paediatric outpatients were enrolled. Their median age was 7.2 years (5.6, 10.4), and 60.4% of them were boys. As defined by BMIZ, 283 subjects (14.0%) fell in the category of BMIZ <-2, 385 subjects (19.5%) fell in the category of BMIZ >2 and 1347 subjects (66.5%) fell in the category of -2 ≤ BMIZ ≤ 2. Among all the study subjects, 839 (41.6%) had low FFMI values. The percentages of individuals with low FFMI in the non-illness group, illness group and simple obesity group were 48.4, 47.0 and 10.7%, respectively.

**Distributions of categories of BMIZ and FFMI of the non-illness group, illness group and three illness subgroups (HO, GI and NR)**

Whether in the non-illness group or illness group, the proportion of patients with low FFMI was greater than that of patients with



**Fig 1** Distributions of categories of body mass index z-score (BMIZ) and fat-free mass index (FFMI) of the non-illness group, illness group, and three illness subgroups (HO, GI, and NR). (a) Distributions of BMIZ; (b) Distributions of FFMI. GI, gastroenterology; HO, haematology and oncology; NR, nephrology and rheumatology. In each group and subgroup, the prevalence of low FFMI was higher than the prevalence of BMIZ <-2. (a) (■), BMIZ >2; (▒), -2 ≤ BMIZ ≤ 2; (□), BMIZ <-2. (b) (■), Normal FFMI; (□), low FFMI.



low BMIZ. The subgroup distributions of FFMI and BMIZ by illness category are shown in Figure 1. In the GI, HO and NR subgroups, the proportions of patients with  $BMIZ < -2$  were 21.9, 14.8 and 8.3%, respectively, and the proportions of patients with low FFMI were 50.0, 33.0 and 25.0%, respectively.

### Distribution of BMIZ and FFMI of the study population stratified by gender

Table 3 and Figure 2 show the overall distribution of BMIZ and FFMI by gender. Among patients with BMIZ between  $-2$  and  $2$ , the proportions of boys and girls with low FFMI were 28.1 and 13.1%, respectively. Among patients with BMIZ, over  $2$ , 2.6% of the girls and 9.7% of the boys had low FFMI. In addition, among patients with BMIZ was less than  $-2$ , 6.4% of boys and 9.2% of girls had normal FFMI. In general, compared to girls, a higher proportion of boys had low FFMI.

### Comparison of the nutrition status of three illness subgroups with that of healthy controls

The statistical details of the body composition comparisons between the three main subgroups and age- and gender-matched healthy controls are given in Table 4. Compared with healthy controls, HO subgroup showed significantly lower FFMI ( $P < 0.001$ ) and FMI ( $P = 0.003$ ). The NR subgroup had significantly lower height-for-age z-scores (HAZ) but higher BMIZ and FMI (all  $P$  values  $< 0.001$ ). The GI subgroup had significantly lower BMIZ ( $P < 0.001$ ), FMI ( $P < 0.001$ ) and FFMI ( $P = 0.002$ ).

## Discussion

In recent years, accurate evaluation of the nutritional status of children and adolescents has drawn much attention.<sup>3</sup> Based on the 2016 Paediatric Malnutrition Diagnosis guidelines, in addition to anthropometric parameters, underlying diseases were also incorporated into the diagnosis of malnutrition to determine the aetiology of malnutrition and to provide aetiology-related individualised nutritional interventions.<sup>1</sup> At present, body composition parameters are considered as a more appropriate anthropometric measurement to understand children's nutritional status. In comparison with conventional anthropometric measurements such as body weight and BMI, body composition reflects changes in FM and FFM, which improves the accuracy of nutritional assessment.<sup>10</sup> The Global Leadership Initiative on Malnutrition Criteria for the Diagnosis of Malnutrition included the FFMI as a diagnostic parameter for adult malnutrition.<sup>11</sup> However, to date, there is no well-recognised age- and gender-specific reference standard for the FFMI in paediatric populations. Therefore, the FFMI has not yet been recognised as an indicator for the diagnosis of malnutrition in paediatric populations, but it is advantageous in optimising catch-up growth, predicting prognosis and promoting individualised nutritional intervention.<sup>12</sup> Previous studies have also shown the importance of the body composition parameters of FM and FFM in nutritional assessment and prediction of clinical outcome and prognosis. To the best of our knowledge, the USA, the UK and Europe have previously reported the FFMI reference standard retrieved from the reference method in their paediatric populations.<sup>13–15</sup> So far, in the

Asian population, only one study published by Nakao *et al.*<sup>9</sup> has used the BIA method to calculate the reference standard of FFMI for children aged three or above. Both Japanese children and our study populations belonged to the East Asian population, where their growth and nutritional status were relatively close compared to those of children of other ethnic groups. We, therefore, chose the reference data by Nakao *et al.*<sup>9</sup> in this study.

Body composition analysis has become a useful tool in clinical practice in paediatric populations. Commonly used methods include isotope dilution, air displacement plethysmography, dual-energy X-ray absorptiometry, computerised tomography, magnetic resonance imaging and BIA. Although techniques such as air displacement plethysmography, dual-energy X-ray absorptiometry, computerised tomography and magnetic resonance imaging have high precision and accuracy, they are not practical and perfect for routinely use in the clinical setting because of the need for costly equipment, well-trained technicians and has potential radiation exposure. Recently, BIA has become a valid alternative for body composition evaluation and has been validated against existing reference methods, and it is a more practical, inexpensive, nonradioactive and well-tolerated method that can be finished in a short operating time. However, the lack of reference standards, the low applicability to children with altered hydration, and the need for population-specific equations are the three main limitations of this method.<sup>16</sup> Despite these limitations, in contrast to other methods, BIA is suitable and convenient for nutritional status monitoring and follow-up in paediatric clinical practice, especially in outpatient clinics.

In this retrospective study, we noticed a higher prevalence of low FFMI than that of low BMIZ in both the non-illness group and the illness group. In addition, nearly 10% of subjects in the simple obesity group had a low FFMI. A study carried out to assess the nutritional status of Crohn's disease outpatients and healthy control pairs reported a higher prevalence of low FFMI than that of low BMI in patients with Crohn's disease.<sup>17</sup> Similar results have also been reported in other studies.<sup>18</sup>

Among the subjects with normal BMIZ values, 13.1% of girls and 28.1% of boys had low FFMI, indicating that these children may have a potential risk of malnutrition. A study found that the BMIZ of patients with ulcerative colitis were normal, and the metabolically active component of FFM decreased significantly. In addition, among subjects with a BMIZ greater than  $2$ , 2.6% of girls and 9.7% of boys had low FFMI, known as sarcopenic obesity. In a recent review, Buch *et al.*<sup>19</sup> suggested that a higher risk of metabolic complications may be associated with sarcopenic obesity. According to a previous report of long-term survivors of childhood allogeneic haematopoietic stem-cell transplantation, sarcopenic obesity is prevalent and adversely affects the overall quality of life.<sup>20</sup>

As we described in the study, the changes of body composition in different illness subgroups have different characteristics. FM, FMI and FFMI in the HO subgroups were significantly lower than those in healthy controls. The findings of this study are consistent with those of other studies, which found lower FFM in patients with leukaemia or solid tumours.<sup>21,22</sup> Our previous study also indicated that children with acute graft-versus-host disease experienced FFM reduction in the early stage of the post-transplantation period.<sup>23</sup> Similar studies have also found that cancer patients have persistently low FFM and high FM during

and after intensive treatment, which might be associated with multimodal cancer therapy. Based on previous findings, alterations in body composition, such as the loss of FFM in paediatric patients with oncology conditions, may lead to a deterioration of the quality of life, physical dysfunction and shortened survival time.<sup>3</sup> Our study found that the FM was higher in NR subgroup than in the healthy controls; in contrast, the HAZ was significantly lower. Similar findings were also documented in systemic lupus erythematosus patients by Mok *et al.*<sup>4</sup> and in juvenile idiopathic arthritis patients by Więch *et al.*<sup>24</sup> These changes might be related to the accumulation of adipose tissue induced by treatment with glucocorticoids such as prednisone, which may hinder growth and interfere with endogenous growth hormone and osteogenesis. In the present study, FMI, FFMI and BMIZ were significantly lower in the GI subgroup than in healthy controls. The findings were consistent with Selbuz's research.<sup>25</sup> According to these limited study results, it is recommended to carry out a comprehensive nutritional assessment by integrating body composition analysis with anthropometry for malnutrition management, early detection and timely treatment.

To the best of our knowledge, this is the first study focused on the application of body composition analysis among paediatric nutrition outpatients in China. There are some limitations to the study as well. First, despite our large sample size, data regarding grades of severity of illness, and clinical outcome of the subjects have not been collected completely, owing to the nature of the retrospective design of the present study. We did not stratify the illness according to grades of severity, and the associations between body composition parameters and clinical outcome were not analysed. Second, due to the lack of reference norm of FFMI using the BIA method applied to 3–18 years children in China, we used the data of Nakao *et al.*<sup>9</sup> as our reference value.

## Conclusions

The prevalence of low FFMI is much higher than that of BMIZ < -2 in paediatric outpatients and the changes in body composition may vary across the illness. Given the relationship between abnormal body composition changes and adverse clinical outcomes, we strongly recommend body composition analysis as part of the routine nutritional assessment in paediatric outpatient nutrition clinic, as it is helpful in early detection of the adverse changes in body composition and may also provide a guideline for clinicians to adjust appropriate nutrition regimens for individualised treatment in paediatric outpatients and consequently improve nutritional status and long-term health. To date, there is no age- and gender-specific reference norm of FFMI using the BIA method in the Chinese paediatric population; therefore, future studies to develop the appropriate reference norm of FFMI is needed, which could aid in accurate nutrition diagnosis and early nutritional intervention.

## Acknowledgements

We wish to express our gratitude to all participants in this study for their dedication. This work was supported by the Key Subject Program for Clinical Nutrition from Shanghai Municipal Health Commission for L Hong (No. 2019ZB0103). The funders had no

role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

## References

- 1 Bouma S. Diagnosing pediatric malnutrition: Paradigm shifts of etiology-related definitions and appraisal of the indicators. *Nutr. Clin. Pract.* 2017; **32**: 52–67.
- 2 Joosten KF, Hulst JM. Prevalence of malnutrition in pediatric hospital patients. *Curr. Opin. Pediatr.* 2008; **20**: 590–6.
- 3 Murphy AJ, Hill RJ, Buntain H, White M, Brookes D, Davies PSW. Nutritional status of children with clinical conditions. *Clin. Nutr.* 2017; **36**: 788–92.
- 4 Mok C, To C, Ma K. Changes in body composition after glucocorticoid therapy in patients with systemic lupus erythematosus. *Lupus* 2008; **17**: 1018–22.
- 5 Wells JCK. Body composition of children with moderate and severe undernutrition and after treatment: A narrative review. *BMC Med.* 2019; **17**: 215.
- 6 Kyle UG, Earthman CP, Pichard C, Coss-Bu JA. Body composition during growth in children: Limitations and perspectives of bioelectrical impedance analysis. *Eur. J. Clin. Nutr.* 2015; **69**: 1298–305.
- 7 Green Corkins K, Teague EE. Pediatric nutrition assessment: Anthropometrics to zinc. *Nutr. Clin. Pract.* 2017; **32**: 40–51.
- 8 Ou Y-L, Lai Y-R, Jiang C-N, Zhang J, Ding Z. Diagnostic performance of individual characteristics and anthropometric measurements in detecting elevated serum alanine aminotransferase among children and adolescents. *BMC Pediatr.* 2020; **20**: 131.
- 9 Nakao T, Komiya S. Reference norms for a fat-free mass index and fat mass index in the Japanese child population. *J. Physiol. Anthropol.* 2003; **22**: 293–8.
- 10 Mogensen KM, Malone A, Becker P *et al.* Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition consensus malnutrition characteristics: Usability and association with outcomes. *Nutr. Clin. Pract.* 2019; **34**: 657–65.
- 11 Cederholm T, Jensen GL, Correia MITD *et al.* GLIM criteria for the diagnosis of malnutrition – A consensus report from the global clinical nutrition community. *Clin. Nutr.* 2019; **38**: 1–9.
- 12 Chung S. Body composition analysis and references in children: Clinical usefulness and limitations. *Eur. J. Clin. Nutr.* 2019; **73**: 236–42.
- 13 Wells JCK, Williams JE, Chomtho S *et al.* Body-composition reference data for simple and reference techniques and a 4-component model: A new UK reference child. *Am. J. Clin. Nutr.* 2012; **96**: 1316–26.
- 14 Shypailo RJ, Wong WW. Fat and fat-free mass index references in children and young adults: Assessments along racial and ethnic lines. *Am. J. Clin. Nutr.* 2020; **112**: 566–75.
- 15 Kudsk KA, Munoz-del-Rio A, Busch RA, Kight CE, Schoeller DA. Stratification of fat-free mass index percentiles for body composition based on National Health and Nutrition Examination Survey III bioelectric impedance data. *JPEN. J. Parenter. Enteral Nutr.* 2017; **41**: 249–57.
- 16 Talma H, Chinapaw MJM, Bakker B, HiraSing RA, Terwee CB, Altenburg TM. Bioelectrical impedance analysis to estimate body composition in children and adolescents: A systematic review and evidence appraisal of validity, responsiveness, reliability and measurement error. *Obes. Rev.* 2013; **14**: 895–905.
- 17 Molnár A, Csontos ÁA, Kovács I, Anton ÁD, Pálfi E, Miheller P. Body composition assessment of Crohn's outpatients and comparison with gender- and age-specific multiple matched control pairs. *Eur. J. Clin. Nutr.* 2017; **71**: 1246–50.
- 18 Lara-Pompa NE, Hill S, Williams J *et al.* Use of standardized body composition measurements and malnutrition screening

- tools to detect malnutrition risk and predict clinical outcomes in children with chronic conditions. *Am. J. Clin. Nutr.* 2020; **112**: 1456–67.
- 19 Buch A, Carmeli E, Boker LK et al. Muscle function and fat content in relation to sarcopenia, obesity and frailty of old age – an overview. *Exp. Gerontol.* 2016; **76**: 25–32.
- 20 Mostoufi-Moab S, Ginsberg JP, Bunin N et al. Body composition abnormalities in long-term survivors of pediatric hematopoietic stem cell transplantation. *J. Pediatr.* 2012; **160**: 122–8.
- 21 Joffe L, Schadler KL, Shen W, Ladas EJ. Body composition in pediatric solid tumors: State of the science and future directions. *JNCI Monographs* 2019; **2019**: 144–8.
- 22 Revuelta Iniesta R, Paciarotti I, Davidson I, McKenzie JM, Brougham MFH, Wilson DC. Nutritional status of children and adolescents with cancer in Scotland: A prospective cohort study. *Clin. Nutr. ESPEN* 2019; **32**: 96–106.
- 23 Feng Y, Pan L, Shen L, Chang P, Zhang B, Hong L. Changes in body composition in children with acute graft-versus-host disease within the first 100 days after hematopoietic stem cell transplantation. *Eur. J. Clin. Nutr.* 2018; **72**: 1167–75.
- 24 Więch P, Sałacińska I, Bazaliński D, Dąbrowski M. Body composition and phase angle as an indicator of nutritional status in children with juvenile idiopathic arthritis. *Pediatr. Rheumatol. Online J.* 2018; **16**: 82.
- 25 Selbuz S, Kansu A, Berberoğlu M, Şklar Z, Kuloğlu Z. Nutritional status and body composition in children with inflammatory bowel disease: A prospective, controlled, and longitudinal study. *Eur. J. Clin. Nutr.* 2020; **74**: 1173–80.



Organ by Morgan Du (12) from WOW Art Competition