Use of standardized body composition measurements and malnutrition screening tools to detect malnutrition risk and predict clinical outcomes in children with chronic conditions

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Short running head. Malnutrition risk and body composition in children

Abbreviations

BC, body composition

BMC, bone mineral density

BMI, Body Mass Index

CI, confidence interval

DXA, Dual Energy X-ray absorptiometry

EN, enteral nutrition

FM, fat mass

ICU, Intensive care unit

IQR, interquartile range

k, Cohen's kappa

LM, lean mass

LOS, length of stay

LTM, non-bone lean mass

MST, Malnutrition screening tool

OR, odds ratio

PN, parenteral nutrition

PYMS, Pediatric Yorkhill Malnutrition Score

SD, standard deviation

SDS, standard deviation score

SE, standard error

STAMP, Screening Tool for the Assessment of Malnutrition in Pediatrics

STRONGkids, Screening Tool for Risk of Impaired Nutritional Status and Growth

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ABSTRACT

Background: Better tools are needed to diagnose and identify children at risk of clinical malnutrition.

Objectives: To compare body composition (BC) and malnutrition screening tools (MSTs) for detecting malnutrition on admission; and examine their ability to predict adverse clinical outcomes (increased length of stay (LOS) and complications) in complex pediatric patients.

Design: Prospective study in children 5-18yrs admitted to a tertiary pediatric hospital (*n*=152). MSTs (Pediatric Yorkhill Malnutrition Score (PYMS), Screening Tool for the Assessment of Malnutrition in Pediatrics (STAMP) and Screening Tool for Risk of Impaired Nutritional Status and Growth (STRONGkids)) were completed on admission. Weight, height and BC (fat mass (FM) and lean mass (LM) by Dual Energy X-ray absorptiometry) were measured (*n*=118). Anthropometry/BC and MSTs were compared to each other and to clinical outcomes.

Results: Subjects were significantly shorter with low LM compared to reference data. 3-17% were classified as malnourished, depending on diagnostic criteria used. Agreement between BC/anthropometric parameters and MSTs was poor. STAMP and STRONGkids identified children with low weight, LM and height. PYMS and, to a lesser degree STRONGkids, identified children with increased LOS, as did LM compared to weight or height. Patients with complications had lower mean LM standard deviation scores (-1.38 (1.03) vs -0.74 (1.04), $p<0.05$). In multivariable models, PYMS high-risk and low LM were independent predictors of increased LOS (odds ratio (*OR*) 3.76, 95% Confidence

Interval (*CI):* 1.36,10.35; *OR* 3.69, *CI:* 1.24,10.98 respectively). Body Mass Index (BMI) did not predict increased LOS or complications.

Conclusions: LM appears better than weight and height for predicting adverse clinical outcomes in this population. BMI was a poor diagnostic parameter. MSTs performed differently in associations to BC/anthropometry and clinical outcomes. PYMS and LM provided complementary information regarding LOS. Studies on specific patient populations may further clarify the use of these tools and measurements.

Keywords: malnutrition, nutritional risk, screening, body composition, pediatric patients, clinical outcomes.

INTRODUCTION

Malnutrition affects around 1 in 3 hospitalized children (1–5) and is associated with adverse clinical outcomes and detrimental long-term effects on growth and development (4–7). Children with moderate and severe clinical malnutrition stay in hospital around 1.3 and 1.6 days longer, respectively, than well-nourished children (3), and have higher rates of infection, poor wound healing, immune dysfunction and higher mortality (8–10). This translates into a substantial financial healthcare burden (11–13). Despite awareness of these issues, malnutrition is often unrecognized (3,7,14), and its prevalence has not decreased over time, leading to a renewed interest in improving identification and management (4,15,16).

Both nutritional assessment and malnutrition screening have been proposed as complementary methods to reduce the prevalence of clinical malnutrition (17). Nutritional assessment is aimed at diagnosing patients with malnutrition, whereas screening additionally aims to identify children who may develop malnutrition during their hospital stay and who might benefit from early nutritional intervention (18,19). Guidelines in several countries suggest that children should be screened for malnutrition on admission (4,20,21), thus facilitating timely referral for nutritional assessment and intervention (3,17). However, whilst nutrition screening has been shown to prevent deterioration in nutritional status and improve the health and clinical outcomes of adult patients (22,23), this is not the case in children. Although there are now pediatric malnutrition screening tools, there is currently no consensus on which tool should be used to screen children on admission (19,21,24). This is compounded by the fact that, in the absence of an agreed gold standard to define malnutrition or malnutrition risk in

pediatric patients (4,16,21,25), different approaches have been used to ‘validate’ pediatric screening tools (23,26,27). Furthermore, whilst children classified as high risk by screening tools have been shown to have a longer hospital stay (28,29), there are no data on the predictive value of screening tools for other clinical outcomes.

Recent statements have also advocated the use of body composition (BC; fat mass (FM) and lean mass (LM) measurements) in addition to traditional anthropometric measurements of weight and height as diagnostic parameters for malnutrition (16,30). FM and LM might also contribute to clinical management, since they may differentially influence body function, nutritional requirements, response to treatment, and recovery (30–34). Preliminary results in adults (35) support the use of LM for predicting clinical outcomes. However, there is currently limited evidence that these measurements have an advantage over simple anthropometry, or that they can predict clinical outcomes in children (36–38). The aims of this study were therefore (i) to evaluate and compare BC measurements and malnutrition screening tools for the detection of clinical malnutrition and risk on admission; and (ii) to examine the predictive value of these measurements for adverse clinical outcomes in children with a range of chronic and complex underlying conditions.

SUBJECTS AND METHODS

Study design and subjects

This prospective cohort study enrolled patients admitted to Great Ormond Street Hospital for children NHS Foundation Trust, a tertiary children’s hospital in London, United Kingdom (UK) from September 2013 to March 2015. Children aged 5-18 yrs newly admitted to any medical or surgical ward with an expected length of stay of ≥3

days were eligible. The target age range reflected that of the UK BC reference data (39). Anthropometry and BC measurements were obtained at baseline, within 48hr of admission, and before any major medical or surgical procedure had taken place. Patients attending outpatient clinics, day-care units, or hospital transfers to intensive care units (ICU) were excluded. By design, the study recruited children with a wide range of diagnoses, given the limited evidence available on the use of these measurements in different patient populations.

For planned admissions, study information leaflets were sent in advance or the family was met in pre-assessment clinics. The family was then approached following admission to confirm if they wished to participate. Eligible children with unplanned admissions were identified from medical handover meetings and daily ward visits and given the study information leaflet. Parents and patients >16yrs provided written informed consent, and verbal assent was taken from children <12yrs, while children 12-16yrs signed an assent form. Ethical approval was granted by the National Research Ethics Service Committee London-Central.

Sample size calculation was not possible due to the lack of previous data on the associations between baseline BC and clinical outcomes in pediatric patients. Previous data on the number of hospital admissions and nutritional status in the patient population (41) suggested approximately 30% would be classified as high-risk by the screening tools. We set a target of 150 patients to be recruited in the available 18-month study period.

Data collection

Data were collected by three trained researchers (NL-P, JW, SM) using standard protocols. Hospital scales and stadiometers were audited to ensure adequate maintenance and calibration.

Dual-energy X-ray absorptiometry (DXA) was used as the clinical reference method to assess BC, based on previous studies comparing this to the 'gold-standard' in vivo 4-compartment model, which is unfeasible in routine clinical practice (42). Bone mineral content (BMC), FM and lean tissue mass (LTM; non-bone lean mass) were determined using a Lunar Prodigy DXA scanner (GE Medical Systems, USA; Lunar encore software version 6.7) on admission. Patients wore light indoor clothing with no removable metal objects. Scans were performed with the patient lying supine and took approximately 5 minutes, depending on the patient's height. Scans were only performed if the child could attend the Radiology department, lie still for the required amount of time and had no metal implants. LM was calculated as LTM + BMC. Age- and sex-specific standard deviation scores (SDS) for LM and FM were calculated using UK BC reference data (39).

Weight was measured to the nearest 0.01 kg using a standing, sitting or hoist electronic scale (Seca, Germany). Children were measured in light clothes whenever possible and asked to remove their shoes. Height was measured to the nearest 0.1 cm using a wall-mounted digital display stadiometer (Seca, Germany), Harpenden wall-mounted stadiometer (Holtain, UK) or a portable mechanical stadiometer (Seca, Germany). Children removed their shoes and stood with their back to the stadiometer, with their head in the Frankfurt horizontal plane. Children unable to stand for measurement of height were excluded from this analysis. Weight and height measurements were taken

in duplicate, and the mean used in the data analysis. Body Mass Index (BMI) was calculated from mean weight and height measurements for each subject. SDS for weight, height and BMI were calculated using UK 1990 reference data (43,44).

SDS for BC and anthropometric variables were calculated in Microsoft Excel, using the LMS Growth add-in (LMS Chart Maker, Medical Research Council, UK). BC values were analyzed both as continuous variables and as categorical variables using cut-offs of ≥2SDS and ≤-2SDS to indicate 'abnormal' BC as with weight and height, since these are commonly used in clinical practice. Thus, weight, height, LM and FM of ≤-2SDS were defined in this study as diagnostic parameters for 'malnutrition'.

Three malnutrition screening tools were applied on admission by the same investigator in the same order: 1) Pediatric Yorkhill Malnutrition Score (PYMS) (40); 2) Screening Tool for the Assessment of Malnutrition in Pediatrics (STAMP) (45); 3) Screening Tool for Risk of Impaired Nutritional Status and Growth (STRONGkids) (29). These tools included questions related to the child's nutritional intake, current nutritional status, increased losses and/or requirements, and risk associated with the underlying disease. Scores were used to categorize patients as low, medium or high-risk.

Data from the screening tools were analyzed as categorical variables (low-risk, medium-risk and high-risk) and as binary outcomes (high-risk and low-risk/medium-risk) which compares those children who in clinical practice would be referred for dietetic assessment with those who would not.

Baseline data on demographic factors, clinical condition and nutrition were collected, including information on age, sex, reason for admission and diagnoses. Considering the

heterogeneity of patient diagnoses, patients were re-categorized into ‘medical or surgical’ groups and this variable was used in the statistical analysis. The patients and/or parents were also asked about steroid medication prescription (not including inhaled or topical steroids) in the last 6 months, whether they had fluid or dietetic intake restrictions due to an underlying medical condition, whether a dietitian had been involved in their care, if they were receiving any form of artificial feeding (full or partial enteral nutrition (EN)/parenteral nutrition (PN)), and whether they were ambulatory or non-ambulatory/predominant wheelchair users.

Clinical outcomes

Clinical outcome variables were length of stay and in-patient complications. These were chosen, rather than more disease-specific clinical outcomes, because of the heterogeneity of study participants, as they could be obtained from all patients. Absolute length of stay was expected to be highly variable, so the actual number of days spent in hospital was compared to the predicted length of stay on admission, based on the judgement of the clinical team. This allowed length of stay to be analyzed as a binary variable, ‘Increased length of stay’ (yes/no), where those classified as ‘yes’ had a longer length of stay than predicted but also greater than the median (9 days), to ensure the identification of children who stayed longer for medical rather than administrative reasons which typically resulted in a delay of 1-2 days.

A patient was considered to have experienced ‘complications’ during their stay if they had any of the following: 1) transfer to the ICU or to their local hospital rather than discharge home; 2) unplanned increased reliance on artificial nutrition (enteral and/or

parenteral nutrition) during their stay; 3) reported periods of fever or infection treated with antibiotics.

Statistical analysis

Statistical analysis was performed using SPSS v21.0 (SPSS Inc., US).

Agreement between the different diagnostic parameters and between the different screening tools was assessed using Cohen's kappa (*k).* The association between nutrition risk categories and diagnostic parameters SDS was determined using one-way ANOVAs and Bonferroni post-hoc testing. The agreement between low SDS for the diagnostic parameters and high risk classification was assessed using *k*, % sensitivity and specificity (46).The associations between baseline anthropometry, BC and screening tools and later clinical outcomes were assessed using univariate analysis (independent samples t-tests and chi-squared tests) and logistic regression models. These parameters were entered in the models both independently and in combination; adjusting for sex ('male' or 'female'), age, admission group ('medical' or 'surgical') and other confounding variables related to the clinical condition and nutrition of the patients: steroid medication use, fluid restrictions, dietary restrictions, prior dietetic advice/management, on EN/PN feeds, non-ambulatory/predominantly wheelchair users ('yes' or 'no').

RESULTS

Patient characteristics

Two hundred and fifty-seven patients were given study information leaflets, of which 58 declined to take part, and 47 agreed but could not be measured due to lack of time or

scheduling of surgical procedures (**Figure 1**). A total of 152 patients (50% male) aged 5 to 18 years (mean 10.7 ± 3.6) were enrolled (48.7% medical, 51.3% surgical). **Figure 2** shows the main diagnoses and the reason for admission of recruited patients; 50% had more than one diagnosis, with 26 patients classified as having 3 or more underlying diagnoses.

Table 1 details subject characteristics at baseline. At the time of admission, 56% of patients had received prior dietetic advice, 34% were following dietary restrictions (limiting food groups due to allergy or other medical conditions), and 19% were receiving some form of EN/PN feeding. Additionally, 11% of study participants were wheelchair-users (82% completely non-ambulatory), 9% of patients were receiving oral steroid medication, and 13% were fluid restricted.

The median length of stay was 9 days (Inter-quartile range (*IQR*) 4-15 days), compared to a median predicted length of stay of 8 days (*IQR* 5-14 days), with 35 patients (23%) classified as having an 'increased length of stay'. 'Complications' occurred in 21.7% of patients. These included increased and/or unplanned use of artificial nutrition during hospitalization in 20 (9 temporary, 11 ongoing at the time of discharge), transfer to another ward or discharge to their local hospital for ongoing management in 13, and 'other complications' including periods of infection requiring antibiotic use, poor wound healing, and the need for reoperation due to wound infection in 9.

Anthropometry and body composition on admission

118 children had a complete set of measurements for weight, height, and BC using DXA. In the remaining 34 patients, one or more of the measurements were either not

obtained or were considered to be of sub-optimal quality. The reasons were scheduling issues, or the patient's underlying medical condition precluding the measurements. Three of 17 predominantly wheelchair-users were able to stand long enough to take height measurements.

Participants were on average significantly shorter and had lower LM SDS than the population reference, with SDS≤-2 for height in 13.6% and for LM in 16.9% (Table 1). Mean weight, BMI and FM SDS were not significantly different from zero, but 8.5% were underweight (≤-2SDS) and 6.8% overweight (≥2SDS), whilst 5.9% had low FM SDS and 5.1% high FM SDS. 4.2% of patients had low BMI SDS, and 11.8% had high BMI SDS. Thus, using a cut-off of ≤-2SDS, between 4.2-16.9% of patients were classified as having 'malnutrition' on admission depending on the parameter used.

Agreement between parameters was poor (**Supplementary Table 1**), with the best (moderate, k=0.61) agreement between height and LM. Using low height as a diagnostic parameter for malnutrition missed around 40% of patients with low LM. Conversely, low weight missed 55% of patients with low LM, showing a weak agreement (k=0.55). Agreement between BMI and other parameters was poor (k=0.26 to 0.40, compared to height and weight respectively). Most children were classified with a 'normal' BMI, explained by the fact that 90% of patients with low weight also had low height. Using low BMI as a diagnostic parameter missed 81.3% of children with low height, 70% with low weight, 80% with low LM, and 71.4% with low FM.

Multivariable analysis of the factors predicting the baseline diagnostic parameters indicated patients who were on a restricted diet due to an underlying condition, had

lower height, weight and FM SDS (**Supplementary Table 2**). Artificial feeding (EN/PN) predicted lower LM SDS.

Malnutrition risk scores on admission

The percentage of patients classified as high-risk was 25.0% using PYMS, 35.5% with STAMP, and 18.4% with STRONGkids (Table 1). The distribution of risk also differed, with most patients being classified as low-risk using PYMS, but medium-risk using STAMP and STRONGkids. Only 10.5% of patients were classified as high-risk by all tools, and only 1 in 3 patients were classified in the same risk category by all three screening tools, increasing to 2 in 3 patients when low-risk and medium-risk were combined. The best absolute agreement was found between STRONGkids and PYMS (82.9%), followed by STAMP with PYMS (73.7%) and STRONGkids (73.7%) (**Supplementary Table 3**), but agreement was overall weak to minimal. Further details of the differences between screening tools are given in **Supplementary Table 4**, which shows the scoring per assessment item in each tool. Most differences were observed in Item 1 (assessment of current nutritional status) and Item 4 (underlying disease).

Relationship of anthropometry and body composition to malnutrition risk scores

Mean height SDS was significantly different between risk categories using both STAMP and STRONGkids (**Figure 3A**), with lower height SDS in the high-risk group compared to low-risk and medium-risk groups. Conversely, there was no significant difference in height SDS between PYMS risk groups.

The mean LM SDS for high-risk groups from all three screening tools was lower than for low-risk and medium-risk groups (**Figure 3C**). For STRONGkids, there was furthermore a

significant difference in the mean LM SDS between all three risk categories. For weight, the STRONGkids high-risk category had significantly lower mean SDS compared to medium-risk and low-risk categories (**Figure 3B**). PYMS high-risk patients also had significantly lower weight SDS compared to medium-risk patients but not significantly different to low-risk patients. Mean FM SDS (**Figure 3D**) showed a similar distribution to that observed for mean weight SDS, but STRONGkids was the only tool to show significant differences between groups.

Agreement was further assessed by comparing the proportion of patients classified as high-risk and low/medium-risk by each tool and the proportion with low weight, height, LM and FM (≤-2SDS) (**Supplementary Table 5**). All screening tools showed better agreement with LM, height, and weight than with FM. The results suggested that STAMP, followed by STRONGkids, was better able to identify children with low weight, height, and LM SDS on admission (70%, 75%, 70% respectively for STAMP; 50%, 37.5%, 35% respectively for STRONGkids); whilst all tools displayed a low sensitivity for identifying children with low FM SDS.

Prediction of clinical outcomes by baseline anthropometry and body composition

Mean SDS for height, LM, and to a lesser extent weight, were significantly lower in patients who had an increased length of stay compared to those who did not (**Table 2**). Patients who had low height, LM and weight (≤-2SDS) were 4-4.5 times more likely to have an increased length of stay, even after adjusting for age, sex, admission group and other confounding variables (**Table 3**), whilst those with low FM SDS were 6 times more likely to have an increased length of stay but with a wider confidence interval (odds ratio

(*OR*) 6.07 *95% Confidence Interval (CI):* 1.26, 29.2). The most significant associations were observed for LM and height, followed by weight and FM. BMI was not a significant predictor of length of stay.

Including 'Low LM SDS' and 'Low FM SDS' together in the model increased the R^2, with the model now explaining 13% of the variance in the outcome of increased length of stay (10% and 6% for LM and FM respectively when entered as individual predictor variables). However, 'Low FM SDS' was no longer significant in the model. Weight was not a significant predictor after including any of the other parameters in the model, and height was also non-significant when LM was included.

For the outcome of in-patient complications, the mean LM SDS was significantly lower (p=0.021) in those who presented with complications (-1.38 mean SDS, 0.23 standard error, SE) compared to those who did not (-0.74 mean SDS, 0.14 SE), but other diagnostic baseline parameters were not significantly different (Table 2). In logistic regression analyses, none of the baseline anthropometric or BC measurements expressed as 'low' versus 'normal', entered individually or in combination, significantly predicted this outcome (**Table 4**).

Prediction of clinical outcomes by baseline malnutrition risk scores

Table 5 summarizes the associations between screening tool risk categories and 'increased length of stay' before and after adjusting for confounding variables. PYMS and STRONGkids were significant predictors, with PYMS showing the best predictive validity and explaining 9% (19% after adjustment for 'prior dietetic advice') of the variance in the outcome. PYMS and STRONGkids high-risk patients were 3.6 times

(*95% CI:* 1.6, 8.2) and 3.3 times (*95% CI:* 1.4, 8.0) more likely, respectively, to have an increased length of stay compared to low-risk/medium-risk patients. STAMP was not a significant predictor of increased length of stay.

PYMS also showed the most significant association with the outcome of 'complications' (**Table 6**). PYMS high-risk patients were 5.9 times more likely (*95% CI:* 2.6, 13.7) to experience complications during their stay, while STRONGkids and STAMP high-risk patients were 3.0 (*95% CI:* 1.2, 7.3) and 2.4 (*95% CI:* 1.1, 5.2) times more likely, respectively.

PYMS had the best sensitivity and specificity (49% and 81% respectively) for an increased length of stay. STRONGkids and STAMP had a sensitivity of 46% and 34%, and specificity of 68% and 86%, respectively. For the outcome of 'complications', PYMS had a sensitivity of 55% and a specificity of 83%, while sensitivity and specificity for STRONGkids was 52% and 69% and for STAMP 33% and 86%.

Prediction of increased length of stay using a combination of physical variables and malnutrition risk scores

A model including both PYMS (high-risk vs medium-risk/low-risk) and LM (low SDS yes/no) explained 17.7% of the variance in the outcome. Patients categorized as high-risk using PYMS were 3.76 times more likely (p=0.011, *95% CI:* 1.36, 10.35) to have an increased length of stay whilst, independently, those with a low LM SDS were 3.69 times more likely (p=0.019, *95% CI:* 1.24, 10.98) to present with this negative clinical outcome.

DISCUSSION

The estimated prevalence of clinical malnutrition in children varies widely, depending on patient population and diagnostic criteria (2). However, it has not decreased over time, prompting renewed discussion over better ways to diagnose, treat and prevent it (47). Diagnostic criteria for malnutrition in the community, based on weight and height measurements, are well-established. However, clinical malnutrition involves different factors and pathological mechanisms (48–50) and the optimal diagnostic parameters for detection and prevention remain subject to debate (4,16).

Although recent international diagnostic guidelines suggest the potential use of BC measurements in clinical settings (4,16), there is no clear evidence that these have an advantage over weight and height measurements. Previous studies on BC in hospitalized children have mostly focused on specific patient groups, using different BC techniques, but were limited by a lack of reference data (51). However, reference data for pediatric BC measured using several techniques are now available (39), so it is possible to generate measurements of FM and LM standardized for age and sex, which can be compared with standardized weight and height.

Using these measures, children in our study had significantly low mean height and LM, with 13.6% and 16.9% respectively ≤-2SDS. The mean weight, BMI and FM in the study sample was normal, but there was a large inter-individual variation, with both low and high values observed. Overall, abnormal BC (low LM +/- low FM) was present in 20% of our patients. These findings are not surprising given the heterogeneous population with complex and often chronic conditions, and cannot be directly compared to other studies of patients with a single disease, or from a general pediatric hospital setting. A previous study in the same hospital population (41) reported a similar prevalence of

undernutrition on admission (using weight-for-age) of 27%. It also highlighted the complexity of these patients, with 25.4% having more than 6 medical diagnoses.

There was generally poor agreement between the different diagnostic parameters. Using simple weight and height measurements would miss 40% and 55%, respectively, of children with abnormal BC. BMI performed poorly, showing weak agreement with other parameters and missing 70 to 81.3% of children classified with low weight, height or abnormal BC. Weight was generally in agreement with FM, but did not always reflect LM, as 50% of children with low LM would be missed using weight measurements alone.

Whilst anthropometry and BC measurements might detect current malnutrition, it is also important to consider the risk of a child becoming malnourished as a result of their disease or treatment (27). Paediatric screening tools are relatively new compared to those for adults (22,29,40,45). Studies have typically compared them to each other, or to various diagnostic criteria for malnutrition (27). Few studies have related them to clinical outcomes (28,29,43,52). Similar to previous studies (27,28), the three screening tools evaluated in our study differed significantly in the percentage of patients classified as high-risk and in the distribution of low-risk/medium-risk, with only 10.5% of patients being classified high-risk by all three. These findings are most likely explained by differences in the criteria used by the tools, particularly how they assess current nutritional status: BMI is used in PYMS, weight and height in STAMP, and subjective assessment in STRONGkids. A large proportion of children with low weight in our study also had low height, translating into a ‘normal’ BMI score which probably explains why PYMS classified most patients as low-risk.

There was weak agreement between patients classified as high-risk by all the screening tools and those with a low weight, height, LM or FM. The strongest agreement and best sensitivity for anthropometric and BC parameters was found for STAMP, followed by STRONGkids then PYMS. However, it is important to recognize that perfect agreement would not be expected, since screening tools are designed to identify children who may be currently well-nourished but who are at risk of developing malnutrition during their hospital stay, and not just those who are currently malnourished.

In order to determine the most appropriate parameter for diagnosing clinical malnutrition, it is important to consider the extent to which each predicts clinical outcomes. We found that low LM, height and weight on admission were associated with a 4-fold increase in length of stay, even after adjusting for several confounding variables. The most significant predictor of increased length of stay was LM, followed by height, weight and finally FM. Importantly, BMI was not a significant predictor for clinical outcomes in our study. When LM was combined in a model together with weight or height, the latter became non-significant, suggesting LM may have an advantage over weight and height for this outcome. However, none of the baseline measurements predicted complications in our cohort, possibly due to the broad definition used for this outcome given the heterogeneous population.

Regarding screening tools, our findings suggest that, at least in this population, it is not possible to select a single screening tool which is both a good marker of current malnutrition (criterion validity) and a predictor of clinical outcome (predictive validity). STAMP seems best for the former, and PYMS for the latter. In our combined model, PYMS high-risk and low LM were independent predictors of length of stay, suggesting

these measures provide complementary information. In contrast, only PYMS high-risk remained a significant predictor of complications, suggesting no additional advantage of using BC measurements.

Strengths and limitations

Our study was the first to evaluate and compare both BC and screening tools for the detection of clinical malnutrition in children with a range of chronic and complex diseases. This was facilitated by the availability of UK BC reference data (39), allowing us to generate standardized values for FM and LM analogous to those for weight and height. Most importantly, we examined the predictive value of these measures for clinical outcomes including complications which, to our knowledge, is novel. We almost certainly did not include the sickest children since it would not have been possible to obtain the measurements. We also had to exclude children under 5 years; the group who have been shown to be at greatest risk of undernutrition (5,41). We cannot assume that our findings could be generalized to other groups of patients who may be less sick. Although we aimed to investigate different measurements as parameters for malnutrition, it is likely at least in some patients that a low LM, FM and/or weight might be primarily due to their underlying disease – for example, the presence of inflammation - rather than due to poor nutrition. In this situation, it cannot be assumed that providing additional or better nutrition would necessarily be beneficial (children might just increase their FM without an improvement in LM), and a key priority for future research is to investigate, preferably in a randomized trial, whether interventions based on baseline measurements are able to improve clinical outcome in different patient groups.

Reflecting the heterogeneous population, our chosen clinical outcomes were generic enough to allow their measurement in all patients, and this limited our ability to identify predictors. This applied particularly to our composite outcome of ‘complications’ which required a number of assumptions and did not include potentially important parameters such as readmissions to hospital. More research is necessary to investigate the predictive value of BC and screening tools for more specific clinical outcomes in different patient groups.

It is also important to consider that, whilst our analyses suggested a potential additive benefit for LM and screening tools, this must be weighed against the practical and logistical issues related to obtaining BC measurements, which will vary depending on setting and resources. In this context, it is also important to note that we were only able to obtain a full set of BC measurements in 78% of these complex patients. The most common reason for failing to obtain a measurement was the child’s limited ability to stand, and thus consideration should be given to proxy measures of height. This is particularly important as it is possible that height standardized BC measures could have an advantage over unadjusted values. The BC reference data available for our study started at age 5 years. However, we have recently published reference data for infants and children aged 6 weeks to 5 years based on measurement of total body water using isotope dilution (53). This will allow future studies to include this population, who make up a substantial proportion of hospital patients.

Conclusion

In children with complex conditions, BC measurements – particularly LM – had an advantage over weight, height or BMI for identifying children with worse clinical

outcomes. The screening tools identified different children as high risk. STAMP and STRONGkids were best at detecting malnutrition on admission while PYMS was best able to identify children with adverse clinical outcomes. LM and PYMS provided complementary information for the risk of an increased length of stay. Ultimately, in order to justify the routine use of screening tools or BC measurements, it is important to establish that the results can be used to alter management and improve clinical outcomes. Ideally such research should be conducted in specific patient groups with relevant clinical outcomes, and the selection of the most appropriate screening tool and/or BC parameter should be guided by the characteristics of the patient population.

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Conflict of Interest (COI) Statement

The authors declare no conflict of interest to disclose.

Authors' contributions

MF, SH, JCW, JW, VS, KK, JV and NEL designed research; NEL, JW, SM and KF conducted research; NEL analyzed data and performed statistical analysis; NEL and MF wrote the paper; MF had primary responsibility for final content. All authors read and approved the final version of the manuscript.

REFERENCES

1. Hendrikse WH, Reilly JJ, Weaver LT. Malnutrition in a children's hospital. Clin Nutr. 1997 Feb;16(1):13–8.

2. Joosten KFM, Hulst JM. Prevalence of malnutrition in pediatric hospital patients. Curr Opin Pediatr. 2008 Oct;20(5):590–6.

3. Beer SS, Juarez MD, Vega MW, Canada NL. Pediatric Malnutrition: Putting the New Definition and Standards Into Practice. Nutr Clin Pract. 2015;30(5):609–24.

4. Becker P, Carney LN, Corkins MR, Monczka J, Smith E, Smith SE, et al. Consensus Statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: Indicators Recommended for the Identification and Documentation of Pediatric Malnutrition (Undernutrition). J Acad Nutr Diet. 2014 Dec 24;114(12):1988–2000.

5. Aurangzeb B, Whitten KE, Harrison B, Mitchell M, Kepreotes H, Sidler M, et al. Prevalence of malnutrition and risk of under-nutrition in hospitalized children. Clin Nutr. 2012 Feb;31(1):35–40.

6. Hecht C, Weber M, Grote V, Daskalou E, Dell'Era L, Flynn D, et al. Disease associated malnutrition correlates with length of hospital stay in children. Clin Nutr. 2014 Jan 11;34(1):53–9.

7. Huysentruyt K, Alliet P, Muyshont L, Devreker T, Bontems P, Vandenplas Y. Hospital-related undernutrition in children: still an often unrecognized and undertreated problem. Acta Paediatr. 2013 Oct;102(10):e460-6.

8. de Souza Menezes F, Leite HP, Koch Nogueira PC. Malnutrition as an independent predictor of clinical outcome in critically ill children. Nutrition. 2012 Mar;28(3):267–70.

9. Hill R, Paulus S, Dey P, Hurley MA, Carter B. Is undernutrition prognostic of infection complications in children undergoing surgery? A systematic review. J Hosp Infect. 2016;44.

10. Bechard LJ, Duggan C, Touger-Decker R, Parrott JS, Rothpletz-Puglia P, Byham-Gray L, et al. Nutritional Status Based on Body Mass Index Is Associated With Morbidity and Mortality in Mechanically Ventilated Critically Ill Children in the PICU. Crit Care Med. 2016;44(6):1.

11. Amaral TF, Matos LC, Tavares MM, Subtil A, Martins R, Nazaré M, et al. The economic impact of disease-related malnutrition at hospital admission. Clin Nutr. 2007 Dec;26(6):778–84.

12. Burgos R, Sarto B, Elío I, Planas M, Forga M, Cantón A, et al. Prevalence of malnutrition and its etiological factors in hospitals. Nutr Hosp. 2012;27(2):469–76.

13. Lennard J. A positive approach to nutrition as treatment; Report of a working party on the role of enteral and parenteral feeding in hospital and at home. London; 1992.

14. Restier L, Duclos A, Jarri L, Touzet S, Denis A, Occelli P, et al. Incorrect evaluation of the frequency of malnutrition and of its screening in hospitalized children by health care professionals. J Eval Clin Pract. 2015;21(5):958–62.

15. Meijers JMM, van Bokhorst-de van der Schueren M a E, Schols JMG a, Soeters

PB, Halfens RJG. Defining malnutrition: mission or mission impossible? Nutrition. 2010 Apr;26(4):432–40.

16. Cederholm T, Bosaeus I, Barazzoni R, Bauer J, Van Gossum A, Klek S, et al. Diagnostic criteria for malnutrition - An ESPEN Consensus Statement. Clin Nutr. 2015;34(3):335–40.

17. Huysentruyt K, De Schepper J, Bontems P, Alliet P, Peeters E, Roelants M, et al. Proposal for An Algorithm for Screening for Under-Nutrition in Hospitalized Children. J Pediatr Gastroenterol Nutr. 2016;63(5):86–91.

18. Beck E, Patch C, Milosavljevic M, Mason S, White C, Carrie M, et al. Implementation of malnutrition screening and assessment by dietitians: malnutrition exists in acute and rehabilitation settings. Aust J Nutr Diet. 2001;58(2):92–7.

19. Joosten K, Hulst J. Nutritional screening tools for hospitalized children: Methodological considerations. Clin Nutr. 2014 Feb;33(1):1–5.

20. Agostoni C, Axelson I, Colomb V, Goulet O, Koletzko B, Michaelsen KF, et al. The need for nutrition support teams in pediatric units: a commentary by the ESPGHAN committee on nutrition. J Pediatr Gastroenterol Nutr. 2005 Jul;41(1):8–11.

21. Huysentruyt K, Devreker T, Dejonckheere J, De Schepper J, Vandenplas Y, Cools F. Accuracy of Nutritional Screening Tools in Assessing the Risk of Undernutrition in Hospitalized Children. J Pediatr Gastroenterol Nutr. 2015;61(2):159–66.

22. White M, Lawson K, Ramsey R, Dennis N, Hutchinson Z, Soh XY, et al. A Simple

Nutrition Screening Tool for Pediatric Inpatients. JPEN J Parenter Enteral Nutr. 2014;40(3):392–8.

23. Joosten KFM, Hulst JM. Malnutrition in pediatric hospital patients: current issues. Nutrition. 2011 Feb;27(2):133–7.

24. van den Berg A, Rasmussen E, Wanten G. Paediatric screening for malnutrition still in its infancy. Ned Tijdschr Geneeskd. 2010 Jan;154:A1825.

25. Hartman C, Shamir R, Hecht C, Koletzko B. Malnutrition screening tools for hospitalized children. Curr Opin Clin Nutr Metab Care. 2012 May;15(3):303–9.

26. Chourdakis M. Malnutrition screening tools in the pediatric setting. In: DIETS-EFAD conference. 2014.

27. Huysentruyt K, Vandenplas Y, De Schepper J. Screening and assessment tools for pediatric malnutrition. Curr Opin Clin Nutr Metab Care. 2016;19(5):336–40.

28. Chourdakis M, Hecht C, Gerasimidis K, Joosten KFM, Shamir R, Szajewska H, et al. Malnutrition risk in hospitalized children: use of 3 screening tools in a large Eurpoean population. Am J Clin Nutr. 2016;103:1301–10.

29. Hulst JM, Zwart H, Hop WC, Joosten KFM. Dutch national survey to test the STRONGkids nutritional risk screening tool in hospitalized children. Clin Nutr. 2010 Feb;29(1):106–11.

30. Wells JCK, Fewtrell MS. Is body composition important for paediatricians? Arch Dis Child. 2008 Feb 1;93(2):168–72.

31. Halpern-Silveira D, Susin LRO, Borges LR, Paiva SI, Assunção MCF, Gonzalez

MC. Body weight and fat-free mass changes in a cohort of patients receiving chemotherapy. Support care cancer. 2010 May;18(5):617–25.

32. King SJ, Nyulasi IB, Strauss BJG, Kotsimbos T, Bailey M, Wilson JW. Fat-free mass depletion in cystic fibrosis: associated with lung disease severity but poorly detected by body mass index. Nutrition. 2010;26(7–8):753–9.

33. Müller MJ, Bosy-Westphal A, Kutzner D, Heller M. Metabolically active components of fat-free mass and resting energy expenditure in humans: recent lessons from imaging technologies. Obes Rev. 2002 May;3(2):113–22.

34. McCarthy HD, Samani-Radia D, Jebb S a., Prentice AM. Skeletal muscle mass reference curves for children and adolescents. Pediatr Obes. 2014;9(4):249–59.

35. Rondel ALMA, Langius JAE, de van der Schueren MAE, Kruizenga HM. The new ESPEN diagnostic criteria for malnutrition predict overall survival in hospitalised patients. Clin Nutr. 2016;6–11.

36. Chaves CRM de M, Britto JAA de, Oliveira CQ de, Gomes MM, Cunha ALP da. Association between nutritional status measurements and pulmonary function in children and adolescents with cystic fibrosis. J Bras Pneumol. 2009 May;35(5):409–14.

37. Pedreira CC, Robert RGD, Dalton V, Oliver MR, Carlin JB, Robinson P, et al. Association of body composition and lung function in children with cystic fibrosis. Pediatr Pulmonol. 2005 Mar;39(3):276–80.

38. Radman M, Mack R, Barnoya J, Castañeda A, Rosales M, Azakie A, et al. The effect of preoperative nutritional status on postoperative outcomes in children

undergoing surgery for congenital heart defects in San Francisco (UCSF) and Guatemala City (UNICAR). J Thorac Cardiovasc Surg. 2014 Jan;147(1):442–50.

39. Wells JCK, Williams J, Chomtho S, Darch T, Grijalva-Eternod C, Kennedy K, 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 Dec;96(6):1316–26.

40. Gerasimidis K, Keane O, Macleod I, Flynn DM, Wright CM. A four-stage evaluation of the Paediatric Yorkhill Malnutrition Score in a tertiary paediatric hospital and a district general hospital. Br J Nutr. 2010 Sep;104(5):751–6.

41. Pichler J, Hill SM, Shaw V, Lucas A. Prevalence of undernutrition during hospitalisation in a children's hospital: what happens during admission? Eur J Clin Nutr. 2014 Mar 12;1–6.

42. Atherton RR, Williams JE, Wells JCK, Fewtrell MS. Use of fat mass and fat free mass standard deviation scores obtained using simple measurement methods in healthy children and patients: comparison with the reference 4-component model. PLoS One. 2013 Jan;8(5):e62139.

43. Freeman J V, Cole TJ, Chinn S, Jones PR, White EM, Preece M a. Cross sectional stature and weight reference curves for the UK, 1990. Arch Dis Child. 1995 Jul;73(1):17–24.

44. Cole TJ, Freeman J V, Preece M a. Body mass index reference curves for the UK, 1990. Arch Dis Child. 1995 Jul;73(1):25–9.

45. McCarthy H, Dixon M, Crabtree I, Eaton-Evans MJ, McNulty H. The development

and evaluation of the Screening Tool for the Assessment of Malnutrition in Paediatrics (STAMP©) for use by healthcare staff. J Hum Nutr Diet. 2012 Aug;25(4):311–8.

46. McHugh M. Interrater reliability: the kappa statistic. Biochem Medica. 2012;22(3):276–82.

47. Huysentruyt K, Hulst J, Bian F, Shamir R, White M, Galera-Martinez R, et al. Opinions and practices of healthcare professionals on assessment of disease associated malnutrition in children: Results from an international survey. Clin Nutr. 2018;1–7.

48. Mehta NM, Corkins MR, Lyman B, Malone A, Goday PS, Carney LN, et al. Defining Pediatric Malnutrition: A Paradigm Shift Toward Etiology-Related Definitions. J Parenter Enter Nutr. 2013 Mar 25;37(4):460–81.

49. Sullivan PB. Malnutrition in hospitalised children. Arch Dis Child. 2010 Jul;95(7):489–90.

50. Beer SS, Juarez MD, Vega MW, Canada NL. Pediatric Malnutrition. Nutr Clin Pract. 2015;30(5):609–24.

51. Elia M. Body composition by whole-body bioelectrical impedance and prediction of clinically relevant outcomes: overvalued or underused? Eur J Clin Nutr. 2013 Jan;67 Suppl 1(S1):S60-70.

52. Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. Clin Nutr. 2003 Aug;22(4):415–21.

53. Wells JCK, Davies PSW, Fewtrell MS, Cole TJ. Body composition reference charts for UK infants and children aged 6 weeks to 5 years based on measurement of total body water by isotope dilution. Eur J Clin Nutr. 2019;

TABLE 1

Subject characteristics, baseline and outcome data

n=152 unless stated	*Number*	*%*
Boys	76	50
Surgical patients	78	51.3
Steroid medication	14	9
Fluid restriction	20	13
Restricted diet	52	34
Prior dietetic advice	85	56
EN/PN feeding	29	19
Wheelchair user	17	11
Clinical outcomes		
Increased length of stay [4]	35	23.0
Complications	33	21.7
Increased use of EN/PN [5]	20	13.1
Transfer to another ward	13	8.6
Other complications	9	5.9

Anthropometry and BC on admission

(n=118)	*mean SDS* [1]	*≤-2 SDS* [2]	*≥2 SDS* [3]
Height	-0.55 (1.3) **	13.6	1.7
Weight	-0.07 (1.6)	8.5	6.8
BMI	0.33 (1.4)	4.2	11.8

LM	-0.85 (1.3) **	16.9	-
FM	0.08 (1.2)	5.9	5.1
Malnutrition risk on admission		*Number*	*%*
PYMS	low-risk	70	46.1
	medium-risk	44	28.9
	high-risk	38	25.0
STAMP	low-risk	24	15.8
	medium-risk	74	48.7
	high-risk	54	35.5
STRONGkids	low-risk	25	16.4
	medium-risk	99	65.1
	high-risk	28	18.4

(1) Mean standard deviation score (SDS) and standard deviation (SD) in parenthesis; (*) One-sample t-test for the mean SDS (H_0: mean SDS=0) significant ($p<0.05$) and (**) significant ($p<0.001$); (2) Percentage (%) of patients with ≤-2SDS; (3) % patients with ≥2SDS; (4) Increased length of stay defined as a longer hospital stay than predicted by the medical team on admission, but also greater than the median stay of 9 days; (5) Increased use of EN/PN defined as receiving any form of artificial feeding (full or partial enteral nutrition (EN)/parenteral nutrition (PN)). BMI=Body Mass Index; FM=fat mass; LM=lean mass; PYMS=Pediatric Yorkhill Malnutrition Score; STAMP=Screening Tool for the Assessment of Malnutrition in Pediatrics; STRONGkids=Screening Tool for Risk of Impaired Nutritional Status and Growth.

TABLE 2

Baseline anthropometric and body composition standard deviation scores in patients with or without adverse clinical outcomes

Parameter	Increased length of stay [1]		Complications [2]	
(n=118)	*No*	*Yes*	*No*	*Yes*
Height	-0.36 (1.15)	-1.30 (1.77) **	-0.51 (1.38)	-0.72 (1.16)
Weight	0.08 (1.48)	-0.68 (1.95) *	-0.01 (1.68)	-0.37 (1.19)
BMI	0.37 (1.37)	0.16 (1.55)	0.39 (1.45)	0.05 (1.19)
LM	-0.68 (1.25)	-1.54 (1.57) **	-0.74 (1.40)	-1.38 (1.03) *
FM	0.17 (1.11)	-0.27 (1.63)	0.10 (1.22)	-0.01 (1.31)

Table shows mean standard deviation scores (SDS) and standard deviation (SD) in parenthesis for each parameter; (1) Greater length of stay than predicted on admission together with an actual total length of stay ≥9 days; (2) Ward/hospital transfer, increased use of enteral/parenteral nutrition or other infectious complications during stay. Independent samples t-test for difference in mean SDS for each anthropometric and body composition parameter between groups, (*) significant ($p<0.05$), (**) significant ($p<0.01$). BMI=Body Mass Index; FM=fat mass; LM=lean mass.

TABLE 3

Associations between baseline diagnostic parameters and increased length of stay

n =118	Predictors	*B* [1]	*95% CI* [2]	*p* [3]	Nagelkerke R^2
Height	Low height SDS	3.89	(1.27, 11.9)	0.017	0.07
Weight	Low weight SDS	4.68	(1.23, 17.8)	0.023	0.06
BMI	Low BMI SDS	2.64	(0.42, 16.7)	0.303	0.01
LM	Low LM SDS	4.53	(1.60, 12.7)	0.004	0.10
FM	Low FM SDS	6.07	(1.26, 29.2)	0.025	0.06
Combined	Low LM SDS	3.70	(1.25, 10.95)	0.018	0.13
model	Low FM SDS	3.80	(0.71, 20.50)	0.120	

(1) Coefficients (odds ratios) for the predictors in the logistic regression model (Dependent variable: increased length of stay (1=yes). Models adjusted step-wise using the variables: age, sex (1=female), admission group (1=surgical), steroid use (1=yes), enteral/parenteral nutrition (1=yes), restricted diet (1=yes), fluid restriction (1=yes), wheelchair user (1=yes) and prior dietetic advice (1=yes) – none significant so not shown; (2) 95% Confidence Interval for the coefficients; (3) p-value of the coefficients. Low standard deviation score (SDS)= ≤-2SDS (1=yes). BMI=Body Mass Index; FM=fat mass; LM=lean mass.

TABLE 4

Associations between baseline diagnostic parameters and complications

n =118	Predictors	*B* [1]	*95% CI* [2]	*p* [3]	Nagelkerke R^2
Height	Low Height SDS	0.62	(0.13, 2.98)	0.554	0.00
Weight	Low Weight SDS	1.17	(0.23, 5.96)	0.849	0.00
BMI	Low BMI SDS	0.00	(0.00, -)	0.999	0.03
LM	Low LM SDS	1.71	(0.54, 5.37)	0.359	0.01
FM	Low FM SDS	3.88	(0.80, 18.81)	0.093	0.04

(1) Coefficients (odds ratios) for the predictors in the logistic regression model (Dependent variable: Complications (1=yes). Models adjusted step-wise using the variables: age, sex (1=female), admission group (1=surgical), steroid use (1=yes), enteral/parenteral nutrition (1=yes), restricted diet (1=yes), fluid restriction (1=yes), wheelchair user (1=yes) and prior dietetic advice (1=yes) – none significant so not shown (2) 95% Confidence Interval for the coefficients; (3) p-value of the coefficients. Low standard deviation score (SDS)= ≤-2SDS (1=yes). BMI=Body Mass Index; FM=fat mass; LM=lean mass.

TABLE 5

Predictive validity of screening tools for increased length of stay

n=152		Predictors	*B* [1]	*95% CI* [2]	*p* [3]	Nagelkerke R^2
PYMS	Model 1	PYMS high-risk	3.6	(1.6, 8.2)	0.002	0.09
	Model 2	PYMS high-risk	3.5	(1.3, 9.2)	0.011	0.19
		Prior dietetic advice	3.5	(1.2, 10.0)	0.018	
STAMP	Model 1	STAMP high-risk	2.0	(0.9, 4.4)	0.069	0.03
STRONGkids	Model 1	STRONGkids high-risk	3.3	(1.4, 8.0)	0.008	0.07
	Model 2	STRONGkids high-risk	2.7	(1.1, 6.7)	0.031	0.12
		Complications	2.9	(1.2, 6.9)	0.015	

(1) Coefficients (odds ratios) for the predictors in the logistic regression model (Dependent variable: increased length of stay (1=yes)). Models adjusted step-wise using the variables: age, sex (1=female), admission group (1=surgical), steroid use (1=yes), enteral/parenteral nutrition (1=yes), restricted diet (1=yes), fluid restriction (1=yes), wheelchair user (1=yes) and prior dietetic advice (1=yes) – only significant variables shown; (2) 95% Confidence Interval for the coefficients; (3) significance of the coefficients (p<0.05). PYMS high-risk=high risk groups using PYMS (1=yes); STAMP high-risk=high risk groups using STAMP (1=yes); STRONGkids high-risk=high risk groups using STRONGkids (1=yes). PYMS=Pediatric Yorkhill Malnutrition Score; STAMP=Screening Tool for the Assessment of Malnutrition in Pediatrics; STRONGkids=Screening Tool for Risk of Impaired Nutritional Status and Growth.

TABLE 6

Predictive validity of screening tools for complications

n=152		Predictors	*B* [1]	*95% CI* [2]	*p* [3]	Nagelkerke R^2
PYMS	Model 1	PYMS high-risk	5.9	(2.6, 13.7)	<0.001	0.17
STAMP	Model 1	STAMP high-risk	2.4	(1.1, 5.2)	0.033	0.05
	Model 2	STAMP high-risk	2.2	(0.9, 4.8)	0.058	0.09
		Admission group	2.5	(1.1, 5.8)	0.032	
STRONGkids	Model 1	STRONGkids high-risk	3.0	(1.2, 7.3)	0.015	0.06
	Model 2	STRONGkids high-risk	3.4	(1.4, 8.6)	0.009	0.12
		Admission group	3.0	(1.3, 7.0)	0.013	

(1) Coefficients (odds ratios) for the predictors in the logistic regression model (Dependent variable: Complications (1=yes). Models adjusted step-wise using the variables: age, sex (1=female), admission group (1=surgical), steroid use (1=yes), enteral/parenteral nutrition (1=yes), restricted diet (1=yes), fluid restriction (1=yes), wheelchair user (1=yes) and prior dietetic advice (1=yes) – only significant variables shown; (2) 95% Confidence Interval for the coefficients; (3) significance of the coefficients (p<0.05). PYMS high-risk=high risk groups using PYMS (1=yes); STAMP high-risk=high risk groups using STAMP (1=yes); STRONGkids high-risk=high risk groups using STRONGkids (1=yes). PYMS=Pediatric Yorkhill Malnutrition Score; STAMP=Screening Tool for the Assessment of Malnutrition in Pediatrics; STRONGkids=Screening Tool for Risk of Impaired Nutritional Status and Growth.

FIGURE 1 Subject flow through the study

FIGURE 2 Primary diagnosis and reason for admission of recruited patients. *n*=152.

FIGURE 3 Mean weight, height, LM and FM standard deviation score according to risk categories for each screening tool

Graphs show mean standard deviation scores (bar) for (A) height, (B) weight, (C) LM, (D) and FM for each risk category (low, medium and high) by each of the screening tools. (*) One-way ANOVA, significantly different ($p<0.05$) mean standard deviation score for the parameter between risk categories. Letters indicate significant differences between each category of risk (Bonferroni post-hoc testing). n=118. DXA= Dual Energy X-ray absorptiometry; FM=fat mass; LM=lean mass; PYMS=Pediatric Yorkhill Malnutrition Score; SDS=standard deviation score; STAMP=Screening Tool for the Assessment of Malnutrition in Pediatrics; STRONGkids=Screening Tool for Risk of Impaired Nutritional Status and Growth.