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A simple nutrition screening tool to identify nutritional deterioration in long stay paediatric inpatients: The paediatric nutrition rescreening tool (PNRT)

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SUMMARY

Background and aims: Children with extended hospital stays are at risk of nutritional deterioration making regular nutrition screening throughout their admission an integral part of the nutrition care pathway. The purpose of this study was to design and validate a simple, quick and universal weekly rescreening tool to identify hospital acquired nutritional deterioration during a child's hospital stay.

Methods: A prospective, longitudinal sample of children aged 0–16 years admitted to a paediatric tertiary hospital with a length of stay ≥7 days were included in the study. Agreement between nutritional deterioration markers of reduction in weight (kg), body mass index (kg/m^2), energy intake (kcal/day) and protein intake (g/day) over a 7-day period and two proposed rescreening questions was determined using sensitivity, specificity, area under the curve and positive and negative predictive values.

Results: Sixty-one children were included in the study with 224 full 7-day datasets. The sensitivity and specificity of the rescreening question 'Has the child had reduced nutritional intake in the last 7 days' for identifying children with a ≥25% reduction in energy intake over the previous 7-day period were 61.9% (95% CI 41.1–82.7) and 82.2% (95% CI 76.9–87.5) respectively. The sensitivity of 'Has the child lost weight or had poor weight gain' at detecting weight loss was 71.4% (95% CI 54.7–88.2) and specificity 87.8% (95% CI 83.1–92.5).

Conclusion: The paediatric nutrition rescreening questions provide a valid and simple tool to detect nutritional deterioration in long stay paediatric patients and should be an integral part of the nutrition care process.

1. Introduction

Hospital acquired malnutrition due to nutritional deterioration during extended hospital stay is defined as an aetiology of paediatric malnutrition [1]. The clinical and financial impact of poor nutritional status in hospitalised children is well established with malnourished children staying up to 2.5 times longer than children without malnutrition [2–5]. Despite this growing body of evidence, the prevalence rate of malnutrition in this population is approximately 11–15% [4,6]. Prevention of hospital acquired or worsening malnutrition should be a priority of paediatric inpatient nutrition care and facilitated via nutrition screening and surveillance in long stay patients.

Several nutrition screening tools exist for use in paediatric inpatient populations to identify children who are at risk of developing malnutrition and direct nutrition intervention [7,8]. The

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screening tools STRONGkids, PYMS (Paediatric Yorkhill Malnutrition Score), PeDiSMART, STAMP (Screening Tool for the Assessment for Malnutrition in Paediatrics) and the PNST (Paediatric Nutrition Screening Tool) are designed to be used on admission to hospital [9–13]. For children identified at risk of malnutrition, the same screening tool is repeated at predetermined intervals with exception of the PNST which is designed to be used on only admission [9–13]. These screening tools have been validated to identify nutritional risk for patients with a mean length of stay of 2 days [11,13] and 4–7 days [12]. They have not been validated for repeated screening to detect nutritional deterioration over an extended period of hospital stay. The existing initial nutrition risk criteria of diagnosis and anthropometric categorisation against standards do not measure nutritional deterioration and are unlikely to change significantly over a 7 day period meaning repetition of these questions will only add to work load in a health economics conscious environment.

The PNST is the simplest nutrition screening tool designed for screening on admission to hospital [7,13]. The questions ask about nutrition and weight history over multiple weeks and therefore are not appropriate for repeated weekly screening to detect recent nutritional deterioration. The PNST has been embedded into the electronic admissions process with the corresponding nutrition care pathway in multiple hospitals, globally. The progression of care via digital platforms created an opportunity for refinement of the screening process with the introduction of regular 'rescreening' as a weekly nursing order or task using a simplified tool specifically designed to detect nutritional deterioration.

The purpose of this study was to design and validate a simple, quick and easy nutrition screening tool that can be repeated to detect recent nutritional deterioration in long stay paediatric patients.

2. Methods

2.1. Participant recruitment

This prospective, longitudinal study was conducted at Queensland Children's Hospital, a large 330 bed tertiary paediatric hospital in Queensland, Australia. Children who stay for more than 7 days range from 15% to 21% of the inpatient population. A convenience sample of children aged from birth to 17 years were recruited over a 9-month period from July 2017 to March 2018. Age corrected for gestational age was used for infants born ≤37 weeks, until the child was 2 years chronological age. Children from all inpatient wards including the paediatric intensive care unit were eligible for inclusion. Exclusion criteria included those children admitted to the mental health ward, patients whose primary language was not English (due to limited access to interpreters) and those children who were medically unstable and unable to have their weight measured.

Potential participants were identified through review of inpatient long stay reports, ward lists, medical records and discussion with nursing staff. Written informed consent was obtained from parents/legal guardians and or children after they had received a verbal explanation of the study and written information. Full ethical approvals were obtained from the Children's Health Queensland Hospital and Health Service Human Research Ethics Committee (HREC/16/QRCH/419) and The University of Queensland Human Research Ethics Committee (HREC/16/QRCH/419).

2.2. Study design

Selection and development of the nutrition rescreening questions was undertaken with consultation from dietitians and nurses who worked in paediatric tertiary hospitals in Australia. The rescreening questions were designed to be completed weekly after the initial screen by the PNST on admission. The wording of the rescreening questions is similar to those in the PNST. Three questions were initially considered including the repeat PNST question 'Does the child look significantly underweight'. Despite being validated against anthropometric measures of malnutrition this question was not incorporated into the rescreening tool as it is already asked on admission to hospital and was not considered a marker of nutritional deterioration. Two remaining questions were identified to undergo validation to determine if they can detect nutritional deterioration over a 7 day period: (1) 'Has the child had reduced nutritional intake in the last 7 days?' and (2) 'Has the child lost weight or had poor weight gain in the last 7 days?'

2.3. Data collection

Data collection was repeated every 7 days throughout the child's hospital admission. Nutritional deterioration markers were collected by trained paediatric dietitians. A second blinded investigator collected responses to the rescreening questions. Nutritional deterioration was defined as a reduction in anthropometric parameters and/or reduction in energy and/or protein intake during the previous 7 days.

Anthropometric measures of weight, height and/or length were taken using methods previously described by the World Health Organisation [14]. Calibration of scales and stadiometers occurred before the study commenced. Hoist scales or bed scales were used to measure weights for children unable to sit or stand. Knee heights were used to predict height for non-ambulatory children >24 months of age [15]. Body mass index (BMI) was calculated as weight(kg)/height squared (m) [2]. Mid upper arm circumference (MUAC) was measured in children older than 2 months using a flexible tape measure at the mid-point between the acromion and olecranon process. Anthropometric data were converted to Z scores using reference data for the general population [16,17]. Poor weight gain was defined in infants under 12 months as not meeting identified weekly weight gain goals [18]. Energy (kcal/day) and protein (g/day) intakes were calculated from diet history recall data of actual intake from parents/carers or intake charts over the past week collected by paediatric dietitians. Energy and protein requirements for each child were calculated using disease specific clinical guidelines and published predictive equations and then compared to intake [19]. A reduction of ≥25% in energy and protein intake was criteria for nutritional deterioration as recommended by a consensus statement on paediatric malnutrition [20].

2.4. Statistical analysis

Descriptive statistics were reported for continuous data using median and inter-quartile range (IQR) as normality of data was not met. Normality was assessed using Shapiro–Wilk test. Categorical data were presented using frequencies and percentages.

Sensitivity, specificity, Area Under the Curve (AUC) and positive and negative predicted values (PPV and NPV) were calculated and reported along with 95% Confidence Interval (CI), to evaluate the performance of the question 'Has the child had reduced nutritional intake in the last 7 days' in detecting reduction in intake compared to the gold standard clinical measures (energy and protein intake) and the question 'Has the child lost weight or had poor weight gain in the last 7 days?' against gold standard anthropometric measures (weight and BMI Z score). The combination of two positive responses to both rescreening questions was then compared to clinical or anthropometric measures using the same approach. All analyses were two-tailed and $p < 0.05$ was considered as

significant. All analyses were performed using the R statistical software [21].

3. Results

One hundred and fifty patients were approached to participate in this study, 88 (59%) of these consented to participate. A total of 224 full 7 day datasets where collected from 61 patients, the remainder of patients (n = 27) stayed for less than the required 7 days or had a missing weight at baseline. Tables 1 and 2 describe the baseline demographics, primary diagnosis, reason for admission and the anthropometric variables of those patients with a minimum of 7 days of data. Nine patients were in the intensive care unit at the time of the study.

Due to large variability in LOS for individuals, nutritional deterioration measures were collected over a range of 1–20 weeks, with a median of 6 weeks (IQR 2–12 weeks). Figure 1 presents the number and proportion of patients who experienced a weight loss or poor gain and/or any energy and protein intake reduction from the previous week. The information is presented by week for a total of 10 weeks, 6 patients were followed for more than 10 weeks but there were too few to present graphically.

The overall median percentage difference in energy intake of patients compared to predicted requirements was 0% (IQR −8.84 to 13.85) The median percentage difference in protein intake versus estimated protein requirements was also 0% (IQR −21.31 to 26.14).

Over the 20 week periods, 'Has the child lost weight or had poor weight gain?' was answered 'yes' 44 times out of 224 (19.6%) and there were 49 (21.8%) 'yes' answers to 'Has the child had reduced nutritional intake in the last 7 days?' For weekly clinical patient measures 13.3% had a reduction in weight and 9.82% had a ≥25% reduction in energy intake during at least one week of data collection (Tables 3 and 4).

Agreement measures between the rescreening question 'Has the child had reduced nutritional intake in the last 7 days?' and reduction in protein and energy intake over the last week are presented in Table 3. The highest agreement with this rescreening question was seen with ≥25% reduction in both energy and protein intakes with AUC of 0.72 and 0.69 respectively. Specificity for energy (82%) was higher than sensitivity (61.9%) indicating that the rescreening questions did not over identify false positives. Table 4 shows the agreement between the rescreening question 'Has the child lost weight or has poor weight gain in the last 7 days?' and reduction in anthropometric measures. The highest agreement was with any reduction in weekly weight measures with a AUC of 0.8.

Table 1
Descriptive statistics of categorical data for patients with at least 7 days of data (N = 61).

Variable	N (%)
Gender	
Female	27 (44.26%)
Male	34 (55.74%)
Primary diagnosis	
Cardiac	18 (29.51%)
Cystic fibrosis	7 (11.48%)
Gastroenterology	3 (4.92%)
Oncology	9 (14.75%)
Other	20 (32.79%)
Surgical	4 (6.56%)
Reasons for admission	
Gastroenterology	1 (1.64%)
Infection	5 (8.20%)
Other	25 (40.98%)
Respiratory infection	12 (19.67%)
Surgery	18 (29.51%)

Table 5 shows that utilising both rescreening questions with the requirement of having two positive answers improves specificity at the expense of sensitivity and overall does not enhance the agreement with the nutritional deterioration measures with a reduction in AUC.

4. Discussion

This study identified two viable questions that can be utilised weekly to detect nutritional deterioration in long stay paediatric patients. The study found the sensitivity and specificity of the rescreening question 'Has the child had reduced nutritional intake in the last 7 days' for identifying children with a ≥25% reduction in energy intake over the previous 7-day period were 61.9% (95% CI 41.1–82.7) and 82.2% (95% CI 76.9–87.5) respectively. The sensitivity of 'Has the child lost weight or had poor weight gain' at detecting weight loss was 71.4% (95% CI 54.7–88.2) and specificity 87.8% (95% CI 83.1–92.5).

Paediatric inpatients are at risk of experiencing illness related malnutrition, classified by a nutrient imbalance resulting from one or more of the following conditions: decreased intake, increased requirement, increased losses, and altered utilization of nutrients [1]. Nutrition surveillance is an essential part of the nutrition care process for paediatric inpatients. An international consensus statement identified a basic set of indicators for diagnosing malnutrition using 2 data points which included reduction in weight gain velocity, weight, weight for height/length z scores and intake [20]. However, the purpose of the statement was not to use the criteria as screening for nutrition risk due to the relative complexity of identifying and interpreting the criteria [20]. Nutrition screening should be simple, quick and easy so it can be routinely incorporated into nursing care plans. The investigators of this study have had experience in developing and implementing the PNST into clinical practice and adopted the same design principles of simplicity and useability, to develop a paediatric nutrition rescreening tool (PNRT) [13].

This study validated two simple nutrition rescreening questions that can identify children whose nutritional status has deteriorated over the previous week of their hospital stay and therefore, can be included as an essential part of the nutrition surveillance process for paediatric inpatients. The questions are designed to be repeated weekly for the duration of a child's hospital stay.

The study population was reflective of long stay patients in a tertiary paediatric hospital. Study participation commenced at a median of day 16 of hospital stay and participation in the study continued for a further median of six weeks. The low Z scores for BMI, MUAC and weight for length/height at study commencement (Table 2) and diagnoses associated with a high risk of malnutrition such as cardiac, cystic fibrosis, gastroenterology and oncology (Table 1) indicate that children who stay longer in hospital are more at risk of malnutrition, muscle wasting and nutritional deterioration supporting the need for screening to prevent further nutritional deterioration. Since nutrition screening on admission is part of routine practice in the hospital where the study took place a proportion of these children would have already been identified as at nutritional risk on admission and subsequently have a nutrition care plan in place. However, a proportion of these children would not have met the nutrition risk criteria of nutrition screening tools on admission such as weight loss, poor nutritional intake or already established malnutrition and nutritional deterioration would have remained undetected until it was severe and difficult to treat. This is demonstrated in Fig. 1 by the significant portion of children who did experience nutritional deterioration of weight loss or poor weight gain and reduced protein and energy intake over the hospital stay.

Table 2
Descriptive statistics of continuous data for patients at baseline of the study with at least 7 days of data (N = 61).

Variable	N	Median (IQR)	Min	Max
Age (months)	61	53.1 (2.51–144.89)	0.7	204.73
Weight (kg)	61	16.7 (4.22–37.5)	2.52	76.5
Length or height (cm)	55	111 (55–145.85)	47.1	178.2
BMI (kg/m2)	55	15.5 (13.9–16.9)	11.35	30.7
Mid upper arm circumference (MUAC) (cm).	58	16.75 (12.19–22.1)	8.8	35.3
MUAC z score	46	−0.66 (−1.38–0.16)	−3.49	1.84
Weight for age z score	61	−0.83 (−1.84–0.02)	−4.61	2.4
BMI z score	55	−0.65 (−1.7–0.05)	−3.67	2.27
Length of stay on day 1 of study (days)	61	16 (7–31)	1	138

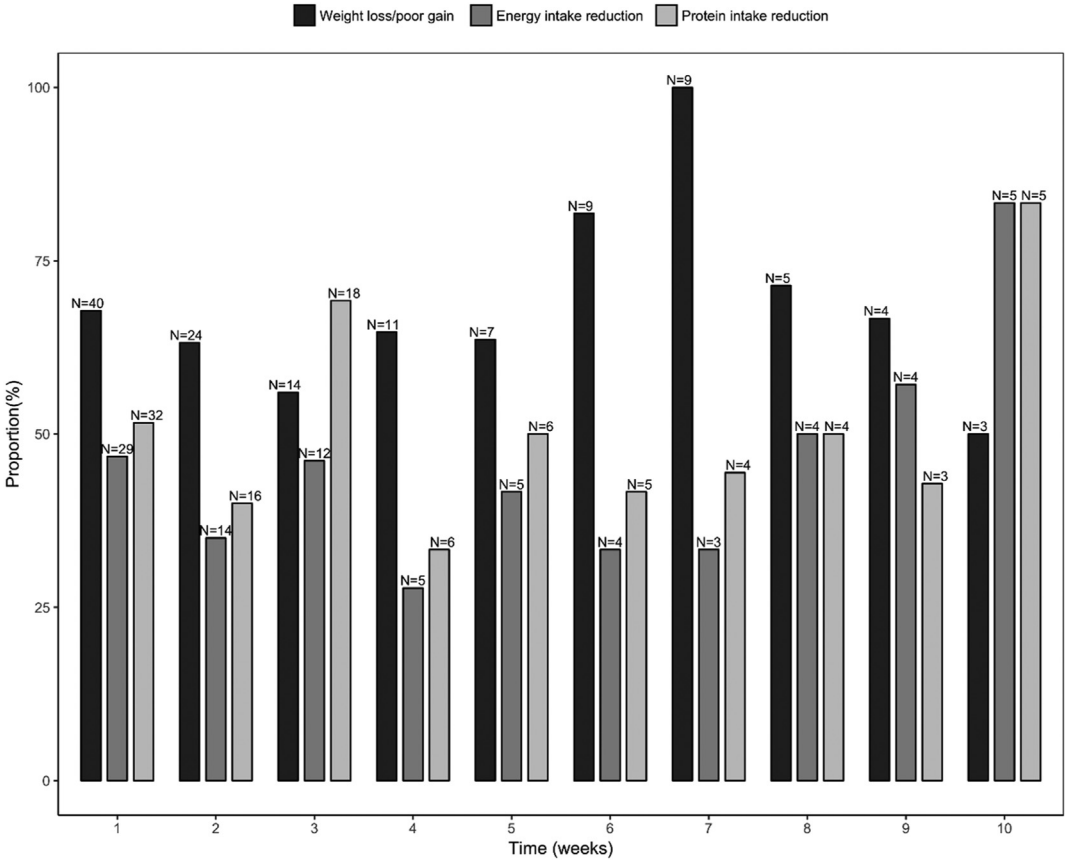

Fig. 1. The number and proportion (%) of patients who experienced a weight loss or poor gain and/or any energy and protein intake reduction from the previous week up to 10 weeks of hospital stay.

Table 3
Agreement between 'Has the child had reduced nutritional intake in the last 7 days' and clinical measures of a reduction in energy and protein intakes.

Clinical measure	N (%)[a]	Sensitivity (95%CI)	Specificity (95%CI)	AUC (95%CI)	PPV (95%CI)	NPV (95%CI)
Any reduction in energy intake	102 (45.54%)	28.7 (19.9,37.5)	83.6 (77,90.2)	0.56 (0.48,0.64)	59.2 (45.4,72.9)	58.6 (51.3,65.9)
≥25% reduction in energy intake	22 (9.82%)	61.9 (41.1,82.7)	82.2 (76.9,87.5)	0.72 (0.59,0.85)	26.5 (14.2,38.9)	95.4 (92.3,98.5)
Any reduction in protein intake	113 (50.45%)	28.6 (20.2,36.9)	84.7 (78,91.4)	0.57 (0.49,0.64)	65.3 (52,78.6)	54 (46.6,61.4)
≥25% reduction in protein intake	28 (12.5%)	55.6 (36.8,74.3)	82.7 (77.4,88)	0.69 (0.57,0.81)	30.6 (17.7,43.5)	93.1 (89.3,96.9)

*Area Under the Curve (AUC).
*Positive Predictive Value (PPV).
*Negative Predictive Value (NPV).
[a] Percentages calculated out of non-missing values.

The rescreening question 'Has the child had reduced nutritional intake in the last 7 days' was validated against measures of reduction in energy and protein intake from one week to the next. If a child already had poor intake, nutritional deterioration was taken as a further reduction in intake from this baseline. There was zero median difference between actual protein and energy intake and estimated requirements but a greater proportion of children had protein intake less than estimated requirements which reflect consumption of foods higher in carbohydrate and fat and possibly of lower nutritional value.

Table 4
Agreement between 'Has the child lost weight or had poor weight gain in the last 7 days?' and anthropometric measures.

Anthropometric Measure	N (%)[a]	Sensitivity (95%CI)	Specificity (95%CI)	AUC (95%CI)	PPV (95%CI)	NPV (95%CI)
Weight loss or poor weight gain	72 (33.64%)	42.3 (30.8,53.7)	90.8 (86,95.6)	0.66 (0.58,0.75)	69.8 (56,83.5)	75.7 (69.3,82.2)
Any reduction in weight	29 (13.3%)	71.4 (54.7,88.2)	87.8 (83.1,92.5)	0.8 (0.69,0.9)	46.5 (31.6,61.4)	95.4 (92.2,98.5)
Any BMI z score reduction	67 (31.6%)	40.9 (29,52.8)	89.6 (84.6,94.6)	0.65 (0.57,0.74)	64.3 (49.8,78.8)	76.8 (70.4,83.2)
>/ = 5% BMI z sore reduction	61 (28.77%)	39.3 (27.1,51.6)	87.9 (82.7,93.2)	0.64 (0.55,0.72)	57.1 (42.2,72.1)	78 (71.7,84.2)

*Area Under the Curve (AUC).
*Positive Predictive Value (PPV).
*Negative Predictive Value (NPV).
[a] Percentages calculated out of non-missing values.

Table 5
Agreement between two positive response to both rescreening questions and nutritional deterioration measures.

Clinical or Anthropometric Measure	N (%)[a]	Sensitivity (95%CI)	Specificity (95%CI)	AUC (95%CI)	PPV (95%CI)	NPV (95%CI)
Any reduction in energy intake	102 (45.54%)	13.9 (7.1,20.6)	93.4 (89.1,97.8)	0.54 (0.48,0.59)	63.6 (43.5,83.7)	56.7 (49.9,63.6)
>/ = 25% reduction in energy intake	22 (9.82%)	42.9 (21.7,64)	93.6 (90.2,96.9)	0.68 (0.56,0.8)	40.9 (20.4,61.5)	94 (90.8,97.3)
Any reduction in protein intake	113 (50.45%)	15.2 (8.5,21.8)	95.5 (91.6,99.4)	0.55 (0.5,0.61)	77.3 (59.8,94.8)	52.7 (45.8,59.6)
>/ = 25% reduction in protein intake	28 (12.50%)	33.3 (15.6,51.1)	93.4 (89.9,96.9)	0.63 (0.53,0.74)	40.9 (20.4,61.5)	91 (87.1,95)
Weight loss or poor weight gain	72 (33.64%)	22.5 (12.8,32.3)	96.5 (93.4,99.5)	0.6 (0.53,0.66)	76.2 (58,94.4)	71.2 (64.8,77.6)
Any reduction in weight	29 (13.3%)	42.9 (24.5,61.2)	95.2 (92.2,98.3)	0.69 (0.58,0.8)	57.1 (36,78.3)	91.8 (87.9,95.6)
Any reduction in BMI z score	67 (31.6%)	21.2 (11.3,31.1)	95.8 (92.6,99.1)	0.58 (0.52,0.65)	70 (49.9,90.1)	72.6 (66.3,79)
>/ = 5% BMI z score reduction	61 (28.77%)	19.7 (9.7,29.6)	94.6 (91,98.3)	0.57 (0.5,0.64)	60 (38.5,81.5)	74.2 (68,80.4)

*Area Under the Curve (AUC).
*Positive Predictive Value (PPV).
*Negative Predictive Value (NPV).
[a] Percentages calculated out of non-missing values.

Table 3 shows the rescreening question had a poor sensitivity of 28.7% with any reduction in intake for both protein and energy however there was a significant improvement in the sensitivity 61.9% when a ≥25% reduction in energy intake cut off was introduced. There is consensus that intake needs to be reduced by more than 25% of estimated requirement for inadequate nutrient intake to define malnutrition and effect clinical outcome [20]. This study demonstrated that nutrition screening cannot detect small changes in nutritional intake however is able to identify a clinically significant reduction in intake. The sensitivity to reduced energy intake was higher (82.2%) than specificity (61.5%), a higher sensitivity is more desirable in clinical practice as it reduces the risk of children with nutritional deterioration not being detected.

Table 4 shows the agreement between the question 'Has the child lost weight or had poor weight gain in the last 7 days' and anthropometric measures. Nutritional deterioration was measured as a reduction in anthropometric indices or if the child was less than 12 months of age failure to meet weekly weight gain goals. This question was poor at predicting whether a child had a reduction in weight and/or poor weight gain (AUC 0.66) or a reduction in BMI Z score (AUC 0.65) however predictive ability improved when the question was only required to detect weight loss only (i.e. not poor weight gain) with an AUC of 0.8. This indicates that carers or health professionals who responded to the rescreening questions are better at identifying weight loss rather than poor weight gain in infants, possibly attributed to the specialist knowledge and skills in paediatric nutrition required to interpret growth standards demonstrating that screening tools should not carry this level of complexity. The authors therefore recommend that the question be reworded and simplified to 'Has the child lost weight in the last 7 days'.

A requirement for a positive response to both rescreening questions did not enhance the agreement with any of the nutritional deterioration measures. Instead, there was a substantial decrease in sensitivity across all nutritional deterioration parameters increasing the number of false positives which would result in an increase in redundant nutrition assessments being performed. Consequently, there was a small increase in specificity which was already high when a single question was compared to the nutritional deterioration markers. In practice each question is specific for detecting weight loss or reduction in nutritional intake therefore both questions should be used and only one positive answer required to trigger a referral for a nutritional assessment.

This study did not collect interrater reliability or reproducibility data which is part of the validation process of a nutrition screening tool. However, given the PNRT questions are simple with a yes or no response required and do not require specialist skills to ask it is highly likely that interrater reliability would have been acceptable. It would have been ideal to have commenced data collection for patients on day 1 of admission however recruitment for the study was challenging with 59% of approached patients consenting to the study. Recruiting patients in the dynamic and challenging environment on the first day of hospital admission would have resulted in a further reduction in recruitment rates. The study design was not reliant on collecting data from admission as the validation methodology was based on 7 day datasets from a variety of patients whose nutritional status was either stable, improving or deteriorating over a 7 day period. The use of the same subjects for multiple data sets could result in test repetition bias and needs to be considered when interpreting the results.

A source of potential bias is the study design of a convenience sample where participants were identified by a health care professional for inclusion in the study and not randomly selected. There is a possibility of potential bias with staff being familiar with the screening process completing the PNRT. This was reduced by asking nursing staff when available to complete the screening tool. However the nurses worked in the same hospital where the PNST is used in routine practice so they would have been familiar with nutrition screening methodology. Patients who were positively identified was being at risk of nutritional deterioration and would have had nutrition intervention were not removed from the study as the PNRT can also be used to monitor for further nutritional deterioration if the nutrition intervention is unsuccessful.

In conclusion, this study presents two rescreening questions that make up the paediatric nutrition rescreening tool (PNRT). The questions are 'Has the child had reduced nutritional intake in the last 7 days?' and 'Has the child lost weight in the last 7 days?' a positive answer to either question indicates the need for a full nutrition assessment. The PNRT is a nutrition screening tool targeted at detecting nutritional deterioration in paediatric patients that stay seven days or more in hospital. The PNRT is designed to be repeated every 7 days and in conjunction with the PNST which is used for nutrition screening on admission. The PNRT adds to the treatment and prevention of further nutritional deterioration in hospitalised children and should be an integral part of the nutrition care process.

Statement of authorship

M.S. White and A. Doolan equally contributed to the conception and design of the research; M.S. White contributed to the design of the research; M. S. White, M. Ziemann, A. Bernard, A. Doolan and S. Q. Song contributed to the acquisition and analysis of the data; M.S. White, A Bernard and M. Ziemann contributed to the interpretation of the data; and M.S. White drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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Competing interests statement

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