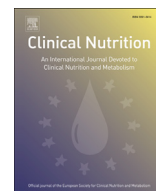




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Original article

Evaluation of the nutrition screening tool for childhood cancer (SCAN)

Alexia J. Murphy^{a,*}, Melinda White^b, Karina Viani^c, Terezia T. Mosby^d^a Children's Nutrition Research Centre, Queensland Children's Medical Research Institute, The University of Queensland, Brisbane, Australia^b Department of Nutrition and Dietetics, Royal Children's Hospital, Brisbane, Australia^c Hematology-Oncology Department and Hematopoietic Stem Cell Transplant Unit, Institute for Treatment of Childhood Cancer – Hematology-Oncology Department of Instituto da Criança, Hospital das Clínicas, University of São Paulo's Medical School, São Paulo, Brazil^d Food, Nutrition & Dietetics, Didactic Program in Dietetics, Tennessee Technological University College of Agriculture and Human Ecology, Cookeville, TN, USA

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SUMMARY

Background & aims: Malnutrition is a serious concern for children with cancer and nutrition screening may offer a simple alternative to nutrition assessment for identifying children with cancer who are at risk of malnutrition. The present paper aimed to evaluate the nutrition screening tool for childhood cancer (SCAN).

Methods: SCAN was developed after an extensive review of currently available tools and published screening recommendation, consideration of pediatric oncology nutrition guidelines, piloting questions, and consulting with members of International Pediatric Oncology Nutrition Group. In Study 1, the accuracy and validity of SCAN against pediatric subjective global nutrition assessment (pediatric SGNA) was determined. In Study 2, subjects were classified as 'at risk of malnutrition' and 'not at risk of malnutrition' according to SCAN and measures of height, weight, body mass index (BMI) and body composition were compared between the groups.

Results: The validation of SCAN against pediatric SGNA showed SCAN had 'excellent' accuracy (0.90, 95% CI 0.78–1.00; $p < 0.001$), 100% sensitivity, 39% specificity, 56% positive predictive value and 100% negative predictive value. When subjects in Study 2 were classified into 'at risk of malnutrition' and 'not at risk of malnutrition' according to SCAN, the 'at risk of malnutrition' group had significantly lower values for weight Z score ($p = 0.001$), BMI Z score ($p = 0.001$) and fat mass index (FMI) ($p = 0.04$), than the 'not at risk of malnutrition' group.

Conclusions: This study shows that SCAN is a simple, quick and valid tool which can be used to identify children with cancer who are at risk of malnutrition.

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1. Introduction

The problem of malnutrition in children with cancer is growing in awareness, with both under and over nutrition being reported in children undergoing treatment for cancer [1–3]. Malnutrition in children with cancer can significantly affect outcomes such as

decreased treatment tolerance, increased susceptibility to infections and reduced survival [4–7]. However, malnutrition continues to be largely unrecognized and unmonitored in many pediatric oncology hospitals [8–10]. To prevent malnutrition and its complications during cancer treatment, early identification is essential. Detailed nutrition assessment can be time consuming, expensive and impractical to complete on all children with cancer in often resource poor setting, and amongst the multitude of testing undertaken on patients, nutrition assessment is often overlooked.

Nutrition screening may offer an alternative to nutrition assessment for identifying children with cancer who are already malnourished or are at risk of malnutrition. The importance of early identification of nutrition risk and appropriate nutrition management is understood in hospitalized children at admission and numerous screening tools have been developed for this population

Abbreviations: SCAN, nutrition screening tool for childhood cancer; SGNA, subjective global nutrition assessment; HIC, high income country; LMIC, low middle income country; ROC, receiver-operator characteristic curve; AUC, area under the curve; BMI, body mass index; FM, fat mass; FFM, fat free mass; FMI, fat mass index; FFMI, fat free mass index.

* Corresponding author. Children's Nutrition Research Centre, The University of Queensland, Level 3 RCHF Building, Royal Children's Hospital, Herston, QLD 4029, Australia. Tel.: +61 7 33464994; fax: +61 7 33464684.

E-mail address: alexia.murphy@uq.edu.au (A.J. Murphy).

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[11–16]. These screening tools have been developed for a variety of goals, applications and processes; however, none of these tools meet the specific requirements of children with cancer.

Screening tools should assess the current level of nutritional status, the stability of the nutritional status, and the effect the disease will have on accelerating nutritional deterioration [17]. Specifically, in children with cancer a tool needs to consider cancer type, treatment stages and nutrition related clinical symptoms that may occur throughout treatment as an inpatient or outpatient; none of the currently available nutrition screening tools addresses all the needs of a cancer specific tool. An ideal screening tool will be one that includes all these factors and can reliably triage the nutritional status of children with cancer, so as to identify children who are malnourished or at risk of malnutrition and need further assessment. With these guidelines in mind, the nutrition screening tool for childhood cancer (SCAN) has been developed to be a quick and simple process to identify childhood cancer patients who are at risk of developing malnutrition. The present study aimed to evaluate SCAN for use in children with cancer by testing the accuracy and validity of SCAN against pediatric SGNA and exploring differences in body composition between the SCAN malnutrition risk groups.

2. Research design and methods

2.1. Development of SCAN

The questions included in SCAN were selected after an extensive review of currently available nutrition screening tools for children and adults [11–16,18–20] and published screening recommendation [17,21], consideration of pediatric oncology nutrition guidelines, piloting questions, and consulting with members of the International Pediatric Oncology Nutrition Group who had extensive practical nutrition experience in treating pediatric oncology patients. Primary contributing factors for the choice of questions were that they 1) met nutrition screening tool principles [17], 2) were specific to identified pediatric oncology nutrition needs, 3) used routinely available data and required no measurements, 4) were quick and simple, and 5) were suitable and adaptable for both high income countries (HIC) and low middle income countries (LMIC). Several versions of SCAN were trialed in inpatient and outpatient settings to refine the practicality of the tool for both HIC and LMIC and to ensure the tool was rapid, simple and purposeful. The final version of SCAN (Fig. 1) consists of 6 questions with each question allocated a score of 1–2, with scoring determined by clinical evaluation of each questions contribution to nutrition risk.

1. Does the patient have a high risk cancer?

This should be based on the hospitals criteria and include patients on high risk treatment protocols, infants and patients with co-morbidities.

2. Is the patient currently undergoing intensive treatment?

Criteria for intensive treatment includes first block of chemotherapy, radiation therapy, bone marrow transplant or upcoming gastrointestinal surgery.

3. Does the patient have any symptoms relating to the gastrointestinal tract?

This question includes any gastrointestinal symptoms from mouth to anus; for example nausea, vomiting, diarrhea,

constipation, dysphagia, mucositis, typhilitis, ileus or radiation enteritis.

4. Has the patient had poor oral intake over the past week?

According to self-report, parent report or hospital chart, has the patient been eating less over the past week.

5. Has the patient had any weight loss over the past month?

This question asks according to weight records has the patient lost any weight over the previous month.

6. Does the patient show signs of under nutrition?

This question asks does the patient have any observable physical signs of under nutrition such as: visible muscle wasting, edema, bilateral pedal edema, dry, thin, shiny or wrinkled skin, thin, sparse and easily pulled out hair, or evidence of micronutrient deficiencies.

2.2. Study 1 – evaluation of SCAN against pediatric SGNA

2.2.1. Subjects

A convenient sample of children who were inpatients being treated for cancer at the Queensland Children's Cancer Centre, Royal Children's Hospital, were included in the validity analysis. Patients were excluded if they could not be weighed, were admitted for <24 h, had conditions that markedly affected hydration, were clinically unstable, or had non-English-speaking parents or caregivers. Ethical approval was obtained from the Children's Health Services Human Research Ethics Committee.

2.2.2. Measurements

2.2.2.1. International pediatric oncology nutrition screening tool. The information required to complete the six questions of SCAN was collected for each subject by a dietician in consultation with the parents or caregiver on the same day that the pediatric SGNA was completed. The SCAN was retrospectively completed for each subject using the information collected on the study day.

2.2.2.2. Pediatric subjective global nutrition assessment. Pediatric SGNA was chosen as a standard for defining malnutrition [22,23]. Pediatric SGNA is a method for evaluating nutritional status and is a comprehensive approach to nutrition assessment that uses clinical judgment to combine medical history, symptomatic and physical examination. The features involved in the pediatric SGNA were combined subjectively into a global assessment and subjects were rated as well nourished, moderately malnourished or severely malnourished. All pediatric SGNA were undertaken by a dietician. Subjects rated as moderately or severely malnourished according to pediatric SGNA were considered as malnourished for this study.

2.2.3. Statistical analysis

Descriptive statistics were used for the presentation of demographic data. To measure the validity of SCAN, a receiver-operator characteristic (ROC) curve was used to demonstrate the relationship of the SCAN score with the pediatric SGNA definition of malnutrition. The area under the curve (AUC) represents the validity of the SCAN, and is indexed from 0 to 1 where 1 indicates a faultless test and ≤ 0.5 a useless test. An SCAN cutoff value of 3 or 4 was considered to be clinically applicable and the sensitivity and specificity of both cutoffs was examined from the ROC curve to determine the ideal cutoff. The validity of SCAN determined cutoff

Nutrition screening tool for childhood cancer (SCAN)	
Does the patient have a high risk cancer ?	1
Is the patient currently undergoing intensive treatment?	1
Does the patient have any symptoms relating to the GI tract?	2
Has the patient had poor intake over the past week?	2
Has the patient had any weight loss over the past month?	2
Does the patient show signs of under nutrition?	2
Total	
<u>Score indication</u>	
≥3 At risk of malnutrition – Refer to dietician for further assessment	

Fig. 1. Nutrition screening tool for childhood cancer.

score was expressed in the sensitivity, specificity, negative predictive value and positive predictive value against the pediatric SGNA.

2.3. Study 2 – evaluation of SCAN against nutrition parameters

2.3.1. Subjects

A convenient sample of children from 5 to 18 years who were being treated for cancer at the Queensland Children's Cancer Centre, Royal Children's Hospital, were included in the analysis. Exclusion criteria included being unable to undertake the testing protocol due to age (<5 years) or clinical condition. Ethical approval was obtained from the University of Queensland Medical Research Committee and the Children's Health Services Human Research Ethics Committee. The two groups of subjects involved in Study 1 and Study 2 were distinct from each other.

2.3.2. Measurements

2.3.2.1. Pediatric oncology nutrition screening tool. The information required to complete SCAN was collected for each subject by a dietician or nutritionist in consultation with the parents or caregiver on the same day of the nutrition measurements and before any measurements were taken. The SCAN was retrospectively completed for each subject using the information collected on the study day.

2.3.2.2. Nutrition assessment. All measurements were carried out in the Children's Nutrition Research Centre Body Composition Laboratory at the Royal Children's Hospital. Body weight was measured to the nearest 0.05 kg using calibrated digital scales (Tanita BWB-600, Wedderburn Scales, Australia) and height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (Holtain Instruments Ltd, Crymch, UK). Body mass index (BMI) was calculated as weight divided by height squared. Height, weight and BMI Z-scores were calculated using data published by the Centers for Disease Control and Prevention [24]. According to BMI cut offs, underweight was defined as BMI < −1.65 (equivalent to 95th and 5th percentile) [25].

Air displacement plethysmography was used to measure body volume and estimate percent fat, fat mass (FM) and fat free mass

(FFM) using the Bod Pod® Body Composition System, adhering to the manufacturer's instructions (Cosmed, USA; software version 1.91) and described previously [1]. Fat mass index (FMI) was calculated as FM/height² and fat free mass index (FFMI) was calculated as FFM/height².

2.3.3. Statistical analysis

Descriptive statistics were used for the presentation of demographic data. Subjects were divided based on the SCAN cutoff score determine in Study 1. A Shapiro–Wilk's test and a visual inspection of histograms, normal Q–Q plots and box plots were performed to explore the distribution of the data. Comparison of variables between groups was carried out using Chi-squared, independent t-test or Mann–U Whitney test. Significance was set at $p < 0.05$. The statistical package for social sciences for window software (IBM SPSS Statistics 22) was used for all analyses.

3. Results

3.1. Study 1 – evaluation of SCAN against pediatric SGNA

Thirty-two children ($n = 16$ females, 50%) with cancer were involved in the analysis. All children were inpatients and 59% of subjects ($n = 19$) were diagnosed with a solid tumor. The subject characteristics are listed in Table 1. The AUC result from the ROC curve showed SCAN had 'excellent' accuracy (0.90, 95% CI 0.78–1.00; $p < 0.001$) compared to the pediatric SGNA. Cutoffs of ≥ 4 and ≥ 3 were examined to determine the clinically appropriate cutoff that should be applied to SCAN. When compared to pediatric

Table 1
Characteristics of the study subjects.

Subject characteristics	Study 1 ($n = 32$)	Study 2 ($n = 58$)
Age (years)	6.2 ± 4.1	11.0 ± 3.3
Time since diagnosis (years)	0.8 ± 1.1	1.0 ± 1.7
Weight Z score	-0.06 ± 1.20	0.23 ± 1.26
Height Z score	-0.11 ± 1.02	0.30 ± 1.04
BMI Z score	-0.01 ± 1.45	0.14 ± 1.44

Data presented as mean \pm s.d.

SGNA, SCAN score ≥ 3 had 100% sensitivity and 39% specificity for detecting chronically malnourished children with cancer. When compared to pediatric SGNA, SCAN score ≥ 4 had 85% sensitivity and 50% specificity for detecting chronically malnourished children with cancer. The SCAN cutoff of ≥ 3 was determined to be the ideal cutoff as no child with malnutrition would go unidentified as 'at risk of malnutrition', with the ideal sensitivity of 1.00 for a screening tool.

With a SCAN cutoff of ≥ 3 , 14 subjects were correctly classified by SCAN as being malnourished, while 7 subjects were correctly classified as being well nourished. No malnourished subjects were misclassified as being well nourished and 11 subjects were classified by SCAN as 'at risk of malnutrition' when they were assessed as well nourished by pediatric SGNA. In this cohort, against pediatric SGNA, this gave SCAN a sensitivity of 100% (95% CI = 76–100%), a specificity of 39% (95% CI = 17–64%), a positive predictive value of 56% (95% CI = 35–76%), and a negative predictive value of 100% (95% CI = 59–100%).

3.2. Study 2 – evaluation of SCAN against nutrition parameters

Fifty-eight children with cancer ($n = 30$ females, 52%) were involved in the analysis, only 42 performed a Bod Pod[®] measurement. Fifty-two percent were diagnosed with a solid tumor. The subject characteristics are listed in Table 1. The SCAN cutoff of a score ≥ 3 to identify subject 'at risk of malnutrition' was applied. Subjects with a SCAN score < 3 were considered 'not at risk of malnutrition'. When SCAN was undertaken, 49% of the subjects were classified as 'at risk of malnutrition'. There were no subjects in the 'not at risk of malnutrition' group that had a BMI Z score ≤ -2 , however 28% of subjects in the 'at risk of malnutrition' group were considered underweight. The percentage of subjects with affirmative answers to each SCAN question is presented in Fig. 2, categorized by SCAN malnutrition risk.

A Shapiro–Wilk's test and a visual inspection of histograms, normal Q–Q plots and box plots showed the data for age, height Z score, weight Z score, BMI Z score, percent fat and FFMI were normally distributed for both groups; however the data for FMI was not normally distributed. Comparisons between the variables for the 'at risk of malnutrition' group and the 'not at risk of malnutrition' is shown in Table 2. Subjects who were identified as 'at risk of

Table 2
Differences between SCAN defined malnutrition risk groups.

	Not at risk of malnutrition ($n = 32$)	At risk of malnutrition ($n = 26$)	P-value
Sex			
Male	16	12	0.98
Female	16	14	
Age (years)	10.2 \pm 3.2	11.9 \pm 3.2	0.05
Cancer type			
Hematological cancer	20	8	0.03
Solid tumor	12	18	
Time since diagnosis (years)	0.99 \pm 1.14	1.07 \pm 2.34	0.87
Weight Z score	0.72 \pm 0.96	−0.38 \pm 1.33	0.001
Height Z score	0.35 \pm 1.04	0.26 \pm 1.06	0.75
BMI Z score	0.78 \pm 0.96	−0.65 \pm 1.55	<0.001
%Fat ^a	31.5 \pm 9.6	27.3 \pm 10.3	0.18
FMI ^a	5.3 (11.4)	4.0 (10.1)	0.04
FFMI ^a	13.2 \pm 2.3	12.3 \pm 1.5	0.14

^a $n = 20$ 'not at risk of malnutrition', $n = 22$ 'at risk of malnutrition'. Continuous variables presented as mean \pm s.d. for normally distributed variables, or median (range) for data that are not normally distributed. Comparisons between groups used an independent *t*-test for normally distributed variables or Mann–U Whitney for non-normally distributed variables. Chi-square test was used for categorical variables.

malnutrition' had significantly lower values for weight Z score ($p = 0.001$), BMI Z score ($p < 0.001$) and FMI ($p = 0.04$) than subjects who were 'not at risk of malnutrition'. The subjects who were classified as 'at risk of malnutrition' were significantly older ($p = 0.05$) and more likely to be diagnosed with a solid tumor ($p = 0.03$).

4. Discussion

Screening for malnutrition risk to ensure prompt identification and intervention may provide one part of a solution to the high prevalence of malnutrition evident in children with cancer. The screening tools currently available for children focus on nutrition risk in hospitalized children and there are no screening tools which address the nutrition issues that affect children with cancer throughout their treatment. In busy and poorly resourced oncology hospitals and outpatient clinics, dieticians will not see all subjects and in some LMIC there is no dietician available. Therefore, it is vital

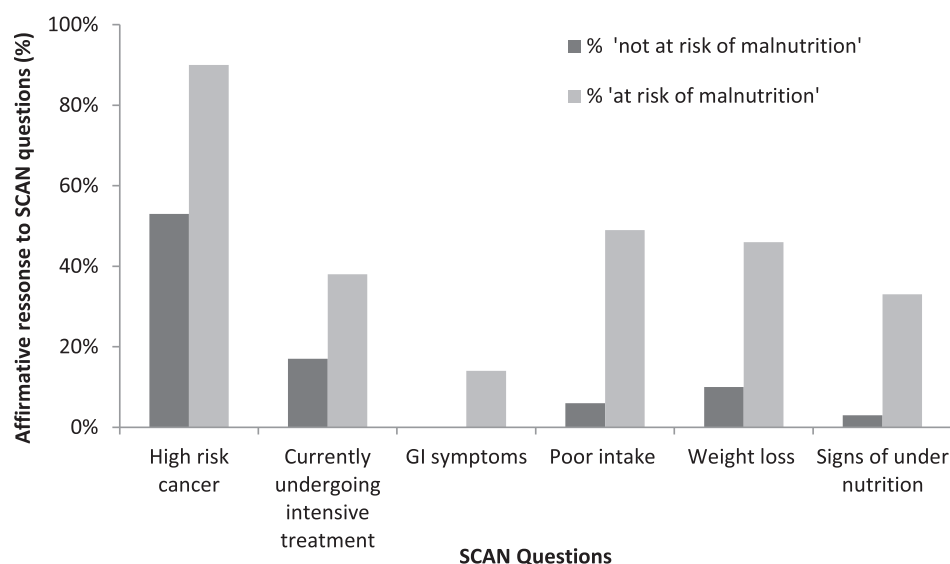


Fig. 2. Affirmative responses to SCAN screening questions in Study 2.

that there is a nutrition screening tool available that can be performed by any staff, at any stage of cancer treatment, and in any setting, that can triage the children that need to be referred on for further detailed nutrition assessment. This is the first study to present SCAN and validate the nutrition screening tool in children with cancer.

Considering the framework provided by Elia and Stratton [21], SCAN is explained. The *aim* of the tool is to overall identify the need for nutritional intervention by pinpointing patients that are currently undernourished or are at high risk of becoming malnourished due to their current symptoms and status. The *application* of the tool is for use in children up to 18 years being treated for cancer in either an inpatient or outpatient setting. The *processes* of the tool are that it should be able to be completed by a nurse and at risk patients will be referred on to a dietician or clinician for further assessment. All subjects should be screened at each outpatient appointment, hospital admission or weekly as an inpatient as children with cancer may be at high risk for malnutrition at diagnosis or the treatment may increase nutrition related symptoms at any stage.

SCAN utilizes information that should be routinely available and simple to collect for all staff.

In the first piloting of the tool, completing SCAN required the knowledge of detailed measurement and calculations, such as eating less than 80% of recommended energy intake, BMI $Z < -2$, or losing 5% body weight. However, throughout the piloting of the tool, the detailed criteria were removed to ensure the tool was simple and easy in both LMIC and HIC by not being reliant on measures and calculations. SCAN is only a screening tool and detailed nutrition assessment should be undertaken in those subjects identified as at risk of malnutrition. The introduction of the tool should require minimal training on its use or interpretation, and not take a significant amount of time for the tool to be completed, which is important as these factors are commonly considered barriers to implementing screening procedures. The piloting of the tool has shown the final SCAN to be a simple process to be undertaken in oncology hospitals and the usability of the tool is being further explored across HIC and LMIC.

There is no universally accepted definition for malnutrition, so there is no gold standard method to validate a screening tool. In this study, dietetic assessment by pediatric SGNA [23] was used as the criterion to assess validity. Our study demonstrates the strong validity of SCAN, with the ROC analysis indicating the validity of SCAN to be excellent when assessed against pediatric SGNA. The high sensitivity of SCAN against pediatric SGNA in this study means every subject who was malnourished was identified 'at risk of malnutrition' by SCAN and the high NPV signifies that it is 100% likely that the subject would not be malnourished if the SCAN classified them as 'not at risk of malnutrition'.

A highly sensitive test is clinically important when identifying a serious but treatable condition like malnutrition, with the main purpose of a screening tool being to minimize subjects who are at risk of malnutrition being overlooked and not referred for nutritional assessment and intervention. To ensure the high sensitivity of SCAN with a cutoff of ≥ 3 , specificity and PPV was sacrificed. This may mean that some well-nourished subjects will be identified by SCAN as 'at risk of malnutrition' and will be unnecessarily referred on for further nutrition assessment. However, with minimal distress, further assessment with a dietician or clinician would determine these subjects were well nourished and in no need of nutritional support.

The SCAN aimed to be able to identify patients at risk of malnutrition, which includes patients with already reduced nutritional status. The subjects identified 'at high risk of malnutrition' by SCAN had significantly lower weight, BMI and fat than the subjects

identified as 'not at risk of malnutrition'. This suggests that children identified as 'at risk of malnutrition' were showing signs indicative of malnutrition, and that the SCAN classification had the ability to discriminate between subjects who were well nourished and malnourished according to nutritional measures. This study showed no significant difference in the FFMI between the two risk groups, which may be an indication of the early stage of the malnutrition of the subjects and that the tool represents patients 'at risk of malnutrition', with FM lost preferentially to FFM in malnutrition.

It is important to understand the limitation of simple nutrition screening tools and how to interpret them correctly in light of the goal of the tool. This study shows SCAN will accurately identify subjects who are at risk of malnutrition and should be followed up by a dietician or other trained healthcare provider. This tool has not been designed to identify subjects who are at risk of developing obesity during cancer treatment. Although the development of obesity is considered a concern for children undergoing treatment for cancer [1,3] and proper education should occur to prevent obesity from developing, it is not considered an acute nutrition priority requiring prompt nutrition intervention during cancer treatment in children.

The main limitation of this introductory study is the small subject numbers. Research is underway to assess the usability, inter-rater reliability, validity and effectiveness of SCAN in larger cohorts and age ranges from HIC and LMIC. The use of any screening tool to identify children at risk of malnutrition can only be effective if it results in improved nutritional status of the population and improved outcomes. Other recommendations for further research with SCAN include examining the prospective validity of SCAN against clinical outcomes, assessing the impact of screening on prevalence of malnutrition, and the effect of intervention on clinical outcomes in identified high risk subjects.

5. Conclusion

SCAN appears to be a simple, quick and valid tool which can be used to screen children with cancer for risk of malnutrition. The use of the tool will allow early identification and treatment of malnutrition, potentially improving clinical outcomes for children with cancer.

Conflict of interest

The authors declare that no conflicts of interest exist in this study.

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