Nutritional Screening and Assessment of Paediatric Cancer Patients: A Quality Improvement Project (Baseline results).

Authors: [1]Dominique Glatt, [1]Caoimhe Hughes, [1]Orlaith McCarthy, [1]Fiona O'Shea, [2]Mark Brougham, [3,4] David C Wilson, [1,4] Raquel Revuelta Iniesta.

[1]Dietetics, Nutrition and Biological Health Sciences, Queen Margaret University, EH21 6UU; [2]Department of Haematology and Oncology, Royal Hospital for Sick Children, EH9 1LF; [3]Department of Paediatric Gastroenterology and Nutrition, Royal Hospital for Sick Children, EH9 1LF; [4]Child Life and Health, University of Edinburgh, EH9 1UW.

Author Contributions (Author CRediT roles):

Dominique Glatt: Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Validation, Visualization, Roles/Writing – original draft, Writing – Review & Editing. **Caoimhe Hughes:** Conceptualisation, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Validation, Visualization, Writing – Review & Editing. **Orlaith McCarthy:** Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Validation, Visualization, Writing – Review & Editing. **Fiona O'Shea:** Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Validation, Visualization, Writing – Review & Editing. **Mark Brougham:** Conceptualisation, Data Curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Review & Editing. **David Wilson**: Conceptualisation, Data Curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Review & Editing. **Raquel Revuelta Iniesta**: Conceptualisation, Data Curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Roles/Writing – original draft, Writing – Review & Editing.

Correspondence: Raquel Revuelta Iniesta, Department of Dietetics, Nutrition and Biological Sciences, Queen Margaret University, Queen Margaret University Way, Musselburgh, EH21 6UU. rrevueltainiesta@qmu.ac.uk.

Key words: children, cancer, nutrition standards, quality improvement project, dietetics, audit

Research Location: Edinburgh, Scotland, United Kingdom.

Abstract

Background: The department of Haematology and Oncology at the Royal Hospital for Sick Children (RHSC) in Edinburgh have developed their own nutritional standards specific to paediatric cancer. We aimed to audit the current nutritional practice in anthropometry, nutritional biochemistry and malnutrition screening for paediatric cancer patients against nutritional standards to identify areas for nutritional-practice improvement and progress nutrition-related clinical outcomes.

Methods: A Clinical audit was conducted >20 weeks between 2015 and 2017 in three data collection locations (inpatient (IP), day-care (DC), or outpatient (OP)) at the RHSC. We included patients aged 0-18 years and undergoing treatment for diagnosed malignant childhood cancer (ICCC-3 or Langerhans cell histiocytosis). Data were collected by analysing documentation and observing clinical practice for frequency and mode of administration of anthropometry, malnutrition screening, nutritional biochemistry and resulting documentation completion. Results were presented as descriptive statistics and stratified by percentage of standard met (100%, 99-70%, <70%).

Results: 185 audited patient records (22 IP, 54 DC and 109 OP) were analysed. The areas which were <70% of the standard were: height and weight documentation for DC; head-circumference for IP; arm anthropometry assessment for all locations; initial PYMS screening and re-screening in IP; malnutrition screening in DC and OP; and initial assessment and re-assessment for serum vitamins D, A, E, B_{12} and parathyroid hormone levels.

Conclusion: Baseline nutritional practice was successfully established, identifying areas for practice improvement in the RHSC paediatric Oncology and Haematology Department to be implemented in the next step of the audit to optimise patients care.

Introduction

Paediatric cancer remains the most common cause of disease-related childhood mortality in industrialised societies(1); however, due to advances in diagnosis and treatment, the overall cure rate has risen to 70-82%, with 76% of patients surviving for 10 years or more(2). The improvement in survival rates has highlighted the long-term side effects of treatment, particularly in paediatrics when the child is still growing and developing(3), and emphasising the importance of improving care to minimise long-term health consequences(4).

Malnutrition, defined as "a state of nutrition in which a deficiency, excess, or imbalance of energy, protein, and other nutrients causing measurable adverse effects on tissue/body shape, size, composition and function, and clinical outcome"(5), is multifactorial within paediatric oncology(6). Sufficient nutritional status at diagnosis and during treatment has been shown to a have significant positive effect on treatment-response and survivorship(7).

Paediatric oncology patients are at risk of malnutrition due to a range of multifactorial elements including cancer type, treatment side-effects, and nutritional status at diagnosis(6). For all ICCC-3(8) paediatric cancer patients, roughly 10-20% of patient are under-nourished(7,9,10) and 7-57% are over-nourished(7) at time of diagnosis. Both forms of malnutrition have been shown to increase in prevalence during treatment(7,10). Waning nutritional status contributes to impaired immune function, delayed wound healing, altered drug metabolism and response(11,12), and increases the risk of morbidity and mortality(6,7,13). Overnutrition may disguise lean mass weight, sarcopenic obesity, and micronutrient depletion(6); and incorrect lean mass weight may impact drug response and compound treatment side-effects(14). Long-term side effects of treatment (as seen in survivors of childhood cancer) include metabolic syndrome, cardiac complications, reduced bone mass density, secondary cancers(15,16), and premature death in adulthood(3). Nevertheless, some of the observed health consequences in survivors may be modifiable (i.e. metabolic syndrome)(17) highlighting a need for nutritional care and monitoring. When patients receive adequate nutritional

care, clinical outcomes such as treatment response, quality of life and cost of care improve(9). Appropriate nutritional screening, dietetic assessment and implementation of nutritional care plans can aid in the timely identification and therapy of nutritionally at-risk patients(6,7,14).

Currently, there are no paediatric oncology-specific nutrition guidelines, nor standardised nutritional practice(6,7,9,13). And while the scientific literature is relatively consistent with their nutritional care recommendations, these are not yet expressed in clinical practice(18,19). As a result, best practice is currently relied upon(6,7,12), highlighting the need to establish evidence-based childhood cancer-specific nutritional guidelines(20). The Oncology and Haematology department at the Royal Hospital for Sick Children (RHSC) in Edinburgh (Scotland), is currently conducting an ongoing quality improvement project (QIP) to develop and implement standardised nutritional guidelines to maximise their provision of effective and safe nutritional patient care. A pilot study established local nutritional practice in the Oncology and Haematology Department at the RHSC(21) and these results were used to develop department-agreed evidence-based nutritional standards.

The aim of this audit was to identify and assess the current baseline nutritional practice in anthropometry, nutritional screening and nutritional biochemistry of paediatric oncology and haematology patients at the RHSC and compare the observed practice to the nutritional standards(21); thereby aiding in the development of nutritional guidelines and improving clinical nutritional practice in this patient group.

Methods

The audit was a cross-sectional study conducted in the paediatric Oncology/Haematology department at the RHSC (NHS South East Scotland service covering NHS Lothian/NHS Borders/NHS Fife). The audit followed the clinical audit cycle by Healthcare Quality Improvement Partnership(22).

Four researchers (DG, OM, FO, RRI) collected data by analysing patient documentation and by observing clinical practice pertaining to the nutritional care of all eligible patient records seen in the inpatient (IP) ward (Ward 2, RHSC Edinburgh), day-care (DC) unit and outpatient (OP) clinic. The audit was performed over 20 weeks from May 2015-August 2017.

Inclusion criteria were records from children aged >0 to <18 years diagnosed and treated for cancer (diagnosis via ICCC-3, OR Langerhans Cell Histiocytosis(8)). Exclusion criteria were records of palliative patients, patients with non-malignant haematological conditions and those diagnosed with brain tumours (treated with surgery alone).

To establish current nutritional practice, frequency and mode of administration of nutritional parameters and completion of documentation was gathered in the three settings (IP, DC and OP). Each patient record was only represented once within each location; patient readmissions were not added as new patient records. However, a patient record pertaining to one patient could be analysed separately in each location if the patient was using each clinical service.

The following nutritional parameters were assessed:

(i) anthropometry; weight (kg), height/body length (m)(23), head circumference (cm)(24), upper arm anthropometry (mid-arm upper circumference (MUAC, cm) and tricep skinfold thickness (TSF; mm)(25)(26), and plotted growth charts (written and electronic) with body mass index (BMI; kg/m2^2) centiles(24)(27);

(ii) malnutritional screening by Paediatric Yorkhill Malnutrition Score (PYMS)(28) and appropriate referral to and follow-up by the dietitian;

(iii) assessment and management of nutritional bloods for all patients; plasma statuses were assessed for: vitamin D, vitamin E, vitamin A, vitamin B12, potassium, magnesium, phosphate, calcium, and albumin. Reference ranges for vitamin D(29) and remaining nutritional biochemistry(30) assessed by the used by the Royal Infirmary Laboratory of Glasgow.

These were then compared to RHSC nutritional standards (table 1) (**see supplementary material**).

In total, there are 50 different audit criteria discussed in this report (anthropometry: six criteria per location; malnutrition screening: 11 criteria for IP and one criterion for DC and OP each; nutritional bloods: 19 criteria in total (locations are grouped together)). Data was obtained from nursing notes, medical notes, and the online patient data system *Trak Care* (TrakCare). The researchers observed the weighing and measuring of patients in each location as able.

All data was recorded on one of three data-collection location specific audit. RHSC nutritional standards were to be met 100% of the time, except for upper arm anthropometry (50% standard set), as this was not part of regular clinical practice.

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) Statistics Inc. (IMB 2012), Chicago, USA. All continuous variables were tested for normality (Shapiro-Wilk ($n<50$) and Kolmogorov-Smirnov ($n>50$)); all data was normally distributed and presented as mean (+SD)(31). All remaining statistical analysis was descriptive. Results have been presented as percentage of RHSC nutritional standard met and colour coded accordingly (100% met: green; 99-70% met: amber; ≤69% met: red) to aid in highlighting areas requiring the greatest improvement. Ethical approval for the ongoing QIP was granted from NHS Scotland on the 1st of June 2007 (NHS REC 06-51104-52).

Table 1 Audit: Summary of Audit Sections Represented in the Audit Tool

Section	Criteria	Assessment Details	Applicable Data Collection Locations			RHSC Standard
			IP	DC	OP	
1	**Anthropometry**	Completion and Documentation of Height, Weight, and Head Circumference	✓	✓	✓	100%
		Completion and Documentation of Mid Upper Arm Circumference and Tricep Skinfold Thickness	✓	✓	✓	50%
		PYMS Completion and Documentation, Documentation of Nutritional Status by BMI centile	✓	✓	✓	100%
2	**Paediatric Yorkhill Malnutrition Score** (PYMS)	Paediatric Yorkhill Malnutrition Score (PYMS) Completion and Documentation	✓	✓	✓	100%
3	**Documented Clinical Notes**	Completion of Documented Clinical Notes including Anthropometry Documentation	✓	✓	✓	100%
4	**Nutritional Review Documentation**	Completion of Nutritional Review Documentation in Dietetic Notes	×	✓	✓	100%
5	**Nutritional Support at Home**	Completion of Documentation of Nutritional Support at Home	×	✓	✓	100%

6	**Physical Activity Advice**	Completion of Verbal and Documented Physical Activity Advice	✓	✓	✓	100%
7	**Nutritional Bloods**	Documentation and Follow-up of Nutritional Bloods	✓	✓	✓	100%
8	**Refeeding Syndrome Risk**	Documentation of Refeeding Syndrome Risk Assessment	✓	✓	✓	100%
9	**Supplementation**	Documentation of Vitamin or Mineral Supplementation Prescriptions	✓	✓	✓	100%
10	**Mealtimes**	Observation of Ward Meal-Time Practices	✓	×	×	100%
11	**Nutritional Advice for Neutropenic Patients**	Completion of Documentation of Nutritional Advice for Neutropenia given to Neutropenic Patients	✓	×	×	100%
12	**Nutritional Support on the Ward**	Completion of Documentation of Nutritional Support on the Ward	✓	×	×	100%
13	**Food and Fluid Record Charts**	Completion of Food and Fluid Record Chart Documentation	✓	×	×	100%
14	**RD Referral Process**	Completion of Verbal and Documented RD Referrals and RD follow-up	✓	×	×	100%

Table 1 presents the RHSC nutritional standards

*Full nutritional bloods only recorded for "on treatment" patients. Any patient in survivorship or late effects will only be audited on vitamin D testing. *Abbreviations: registered Dietitian, RD; Royal Hospital for Sick Children in Edinburgh, Scotland, RHSC.*

This report only covers sections 1, 2, 3, 7, and 14 of the wider audit and QIP

Results

Population Demographics: The Audited Patient Records

Over half of patient records stemmed from OP and were on treatment at time of the audit (62%, *n*=114). The researchers recorded all documented RD input from all patient records (current care for IP and DC, and current and past care for OP) and found that 57% (*n*=84) of all audited patient records had documented RD input.

Table 2 Population Demographics

	Data Collection Location *n* **(%)**			
	Inpatient	Day-Care	Outpatient	**Total**
	22 (12)	54 (29)	109 (59)	**185 (100)**
On treatment	22 (100)	54 (100)	38 (35)	**114 (62)**
Survivorship (<5years)	-	-	61 (56)	**61 (33)**
Late effects (>5years)	-	-	10 (9)	**10 (5)**
Documented RD input	10 (46)	13 (76)*	61 (56)	**84 (57)°**

Table 2 presents the location of data collection, patient stage of treatment, and documented RD input.

*37 DC records had missing data on RD input and were excluded from the percentage of documented RD input (n=17); °therefore impacting the final total (n=148) instead of n=185. *Abbreviations: RD, registered dietitian*

Anthropometry

Table 3 Anthropometry Results by Data Collection Location

Location of Data Collection: **Inpatient**							*RHSC Anthropometry Standards*
Anthropometry Criteria	*n*	yes *n* (%)	no *n* (%)	other *n* (%)	n/a *n* (%)	**Total •**	
Weight	22	20 (91)	0 (0)	2 (9)	-	**22 (100)**	*100%*
Height	22	15 (68)	4 (18)	3 (10)	-	**18 (81)**	*100%*
HC	22	0 (0)	4 (10)	-	18 (90)	**0 (0)**	*100%*
MUAC	22	0 (0)	22 (100)	-	0 (0)	**0 (0)**	*50%*
TSF	22	0 (0)	22 (100)	-	0 (0)	**0 (0)**	*50%*
Location of Data Collection: **Day-Care**							*RHSC Anthropometry Standards*
Anthropometry Criteria	*n*	yes *n* (%)	no *n* (%)	other *n* (%)	n/a *n* (%)	**Total •**	
Weight	54	28 (52)	25 (46)	-	1 (2)	**28 (52)**	*100%*
Height	54	11 (20)	42 (78)	-	1 (2)	**11 (20)**	*100%*
HC	54	0 (0)	0 (0)	-	54 (100)	-	*100%*
MUAC	54	0 (0)	54 (100)	-	0 (0)	**0 (0)**	*50%*
TSF	54	0 (0)	54 (100)	-	0 (0)	**0 (0)**	*50%*
Location of Data Collection: **Outpatient**							*RHSC Anthropometry Standards*
Anthropometry Criteria	*n*	yes *n* (%)	no *n* (%)	other *n* (%)	n/a *n* (%)	**Total •**	
Weight	109	96 (88)	1 (1)	12 (11)	-	**108 (99)**	*100%*
Height	109	94 (86)	3 (3)	12 (11)	-	**106 (97)**	*100%*
HC	109	1 (1)	0 (0)	-	108 (99)	**1 (100)**	*100%*
MUAC	109	0 (0)	109 (100)	-	0 (0)	**0 (0)**	*50%*
TSF	109	0 (0)	109 (100)	-	0 (0)	**0 (0)**	*50%*

Table 3 presents the Anthropometry results by data collection location.

•Total n is all "yes" and "other" answers; Total % = (Total n / all "no")*100; "n/a" answers have been excluded from the total n and total %; "n/a" answers have been excluded from the total n and total %.

Abbreviations: HC, head circumference; MUAC, mid-upper arm circumference; TSF, tricep skinfold thickness; n/a, not applicable; RHSC, Royal Hospital for Sick Children Edinburgh.

Weights and heights were measured on Mondays and Thursdays in inpatients, where patient weight and height was measured and documented in accordance with standards for 81% (*n*=18) of records.

Where staff were unable to take both weight and height (*n*=3) appropriate reasons were documented, and height was taken at the next suitable time.

For DC patients (*n*=54), only 11 patient records had a correctly documented height and weight. Documentation showed that patients could go months without height being documented; for one patient an updated height had not been recorded for seven months. At the time of the audit all recorded DC anthropometry was documented on weight and height lists; only two of the 43 records without height or weight had documented reasons for lack of recording. There were no TrakCare anthropometry entries made by DC although a computer was available in the DC assessment room. If patients did have TrakCare anthropometry entries it was due to them being documented in either IP or OP.

OP weight and height was recorded for 99% (*n*=108) and 97% (*n*=106) of patients respectively and almost meeting the 100% standard. When staff were unable to document weight or height ("other"), appropriate reasons were documented. All recorded OP anthropometry was documented directly onto TrakCare records.

HC is to be measured in centimetres for all patients ≤2 years of age; this only applied to five patient records (IP=4 and OP=1); IP measurements were not recorded; however, outpatient met the RHSC standard. No reasons were documented for the missing IP HC measurements.

TSF and MUAC measurements are currently not part of regular nutritional care in the Oncology and Haematology Department at the RHSC, and 0% of all IP, DC and OP patients were measured.

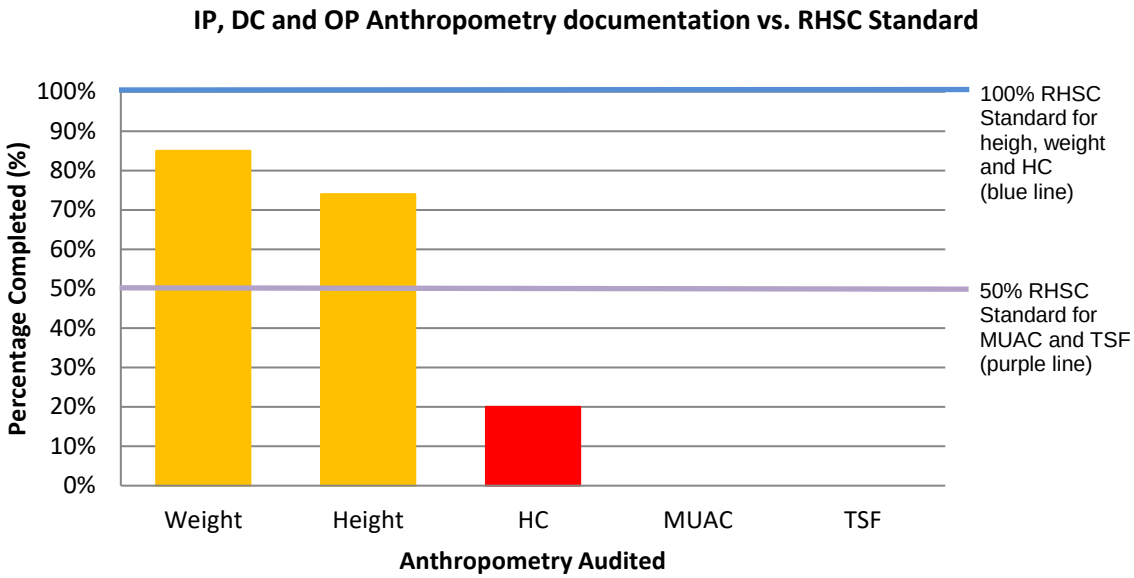

Figure 1: Bar-chart of the Anthropometry Results (all data collection locations combined) vs. expected RHSC Anthropometry Standards. Weight measurements were taken in 85% of patients (n=158), height measurements were taken in 74% of patients (n=136), and HC was recorded for 20% (n=1) of the applicable patients. *Abbreviations: HC, head circumference; MUAC, mid-upper arm circumference; TSF, tricep skinfold thickness; RHSC, Royal Hospital for Sick Children Edinburgh.*

Table 4 Nutritional Status according to Body Mass Index Results

Nutritional Status classified by BMI centile•	Data collection Location *n* (%)			
	Inpatient	Day-Care	Outpatient	**Total**
	9 (100)*	17 (100)	105 (100)	**131 (100)***
Under-nourished	0 (0)	0 (0)	5 (4)	**5 (4)**
Well-nourished	5 (56)	6 (35)	53 (58)	**64 (49)**
Over-nourished	0 (0)	3 (18)	20 (18)	**23 (17)**
Obese	0 (0)	0 (0)	21 (18)	**21 (16)**
Unknown *(due to lack of documentation)*	4 (44)	8 (47)	6 (2)	**18 (14)**

° Nutritional Status Assessed n=113 (86%)

RHSC Nutritional Status Completion Standard for 100% Completion (n=131 (100%)) including all under-nourished, well-nourished, over-nourished, and obese; with 0% Unknown (n=0 (0%)).

Table 4 presents the nutritional status of all audited patient records according to BMI centile across all data collection locations. 54 patient records were excluded due to missing data, they were not included in calculating the percentage standard met (IP=13, DC=37, and OP=4 excluded).

•BMI centile definitions: undernourished: <2nd centile, well-nourished: 2nd- 91st centile, over-nourished: >91st - 98Th centile, obese: >98th centile;*one patient record was not-applicable due to BMI centiles being not age appropriate for the patient (<2years); ° Total % (total number of patients with a nutritional status) to be compared to RHSC Standard (100%).

Abbreviations: HC, head circumference; BMI, Body Mass Index; RHSC, Royal Hospital for Sick Children Edinburgh

In regard to RD input in relation to BMI centile nutritional status, 100% of patients documented as underweight had RD input (*n*=5), 19% of well-nourished patients (*n*=12) had documented input, 26% of over-nourished (*n*=6) and 14% of obese patients (*n*=3) had documented RD input.

Paediatric Yorkhill Malnutrition Score (PYMS) and the RD Referral Process

Table 5 PYMS Results and RD referral

	Location of Data Collection *n* (%)			***RHSC Standard***
	Inpatient	**Day-Care**	**Outpatient**	
	19 (100)*	54 (100)	109 (100)	*(%)*
PYMS in Place•	yes	no	no	*yes*
PYMS screened	16 (84)	0 (0)	0 (0)	*100*
PYMS completed *(of those screened)*	16 (100)	0 (0)	0 (0)	*100*
Average PYMS score (μ (±SD))°	1.7 (1.1)°	-	-	-
PYMS of 0	2 (11)	-	-	-
PYMS of 1	6 (32)	-	-	-
PYMS of 2	4 (21)	-	-	-
PYMS of 3+	4 (21)	-	-	-
PYMS score unknown*	3 (15)	-	-	-
Following data for total number of PYMS screened patients (n=16)				
Weight recorded on PYMS	16 (100)	-	-	*100*
Height recorded on PYMS	15 (94)	-	-	*100*
If PYMS 0, appropriate re-screening	1 (50)	-	-	*100*
If PYMS 1, appropriate re-screening	4 (67)	-	-	*100*
If PYMS 2+, appropriate re-screening	4 (50)	-	-	*100*
PYMS Referral to RD (n=8 (100%))				
If PYMS 2+, RD referral (within 24 hr)	8 (100)	-	-	*100*
Patient seen by RD (within 72 hr)	6 (75)	-	-	*100*
If PYMS 3+, regular RD review	3 (75)	-	-	*100*

Table 5 presents the PYMS documentation and execution results by data collection location; none of the data collection locations fully met the PYMS standards.

*IP records (n=3) were excluded from the total because they were non-applicable (height was unavailable with a documented reason; therefore, the document was excluded; two other individuals were too unwell to be assessed). °PYMS Score results are normally distributed (n<50; Shapiro-Wilk test for normality, p=0.161). • PYMS was not available on Day-Care or in Outpatients. Therefore, it was not possible to audit its completion. *Abbreviations: RD, registered dietitian; PYMS, Paediatric Yorkhill Malnutrition Score; µ, mean; SD, Standard deviation; RHSC, Royal Hospital for Sick Children Edinburgh*

None of the data collection locations fully met the PYMS standards. The lowest IP standard compliance was in relation to appropriately re-screening a patient. In DC and OP, patients were not screened for malnutrition using PYMS and no alternative malnutrition screening tool was used in its place. When asked, staff explained that clinical judgement was used to refer to the RD. Of the 18 patient records who had an unknown nutritional status (table 4), only 11 were screened using PYMS, resulting in 7 patients with no manner of anthropometric assessment or malnutrition screening (data not shown). The IP ward staff met initial screening standards except for three PYMS re-screening criteria; one patient with a PYMS score of 2+ was not re-screened with no documented reason at the time of the audit. The other two audit criteria which did not meet the 100% standard involved RD care; one patient was not seen within 72 hours of a referral and one patient did not receive appropriate RD follow-up (there were no reasons documented for either of the criteria).

Nutritional Biochemistry

Table 6 The Assessment and Reassessment of Nutritional Bloods from audited patient records for all patients "on treatment".

Nutritional Blood		***RHSC Standard***	Assessed			Appropriately Reassessed			
			Yes	No	**Total**	Yes	No	n/a	**Total •**
	n	*%*	*n* (%)	*n* (%)	**n (%)**	*n* (%)	*n* (%)	*n* (%)	**n (%)**
Vitamin D	182	*100*	33 (18)	149 (82)	**33 (18)**	2 (6)	31 (94)	0 (0)	**2 (6)**
Vitamin A	185	*100*	11 (6)	174 (94)	**11 (6)**	1 (9)	10 (91)	0 (0)	**1 (9)**
Vitamin E	112	*100*	11 (10)	101 (90)	**11 (10)**	2 (18)	8 (73)	1 (9)	**2 (20)**
Vitamin B12	112	*100*	26 (23)	86 (77)	**26 (23)**	3 (11)	22 (85)	1 (4)	**3 (12)**
Potassium	112	*100*	112 (100)	0 (0)	**112 (100)**	104 (93)	7 (0)	1 (4)	**104 (94)**

Magnesium	112	*100*	110 (98)	2 (2)	**110 (98)**	101 (96)	5 (2)	1 (2)	**101 (93)**
Phosphate	112	*100*	111 (99)	1 (1)	**111 (99)**	100 (90)	11 (10)	0 (0)	**100 (90)**
Calcium	112	*100*	112 (100)	0 (0)	**112 (100)**	103 (92)	9 (8)	0 (0)	**103 (92)**
PTH	106	*100*	9 (8)	97 (92)	**9 (8)**	0 (0)	9 (100)	0 (0)	**0 (0)**
Albumin	112	*100*	112 (100)	0 (0)	**112 (100)**	-	-	-	-

Table 6 presents the assessment and reassessment results of all nutritional bloods (except vitamin D) from all "on treatment" audited patient records and vitamin D assessment and reassessment results for all patient records regardless of treatment stage.

• N/A removed from total; total taken from those who were assessed to the nutritional blood in question.

Abbreviations: N/A, not applicable; RHSC, Royal Hospital for Sick Children Edinburgh

Vitamin D, A, E, B_{12}, and PTH assessment did not meet the RHSC nutritional standard; and none of the nutritional bloods were reassessed according to the standards. Vitamin D status (29) of all assessed patients (*n*=33) were documented; 27% (*n*=9) of patients had optimal vitamin D levels (>75 µmol/L), 24.5% (*n*=8) had sub-optimal levels (50-75 µmol/L), 24.5% (*n*=8) had insufficient levels (25-50 µmol/L), and 15% (*n*=5) were vitamin D deficient (<25 µmol/L). Three patients (9%) had unknown levels as lab results were never obtained. 94% (*n*=31) of the patients had no follow-up regardless of vitamin D status or failed results; however, current laboratory practice requires clinicians to wait 340 days for a re-request (30). There was no way for healthcare professionals to attach a note to the biochemistry results on TrakCare as to why an assessment was not carried out.

In total, 50 criteria were audited across all data collection locations; 18% met the 100% RHSC nutritional standard, 28% were between 99-70% of the RHSC nutritional standard and 52% were 69% or below the RHSC nutritional standard. The areas which were 69% or below were height and weight for DC, HC for IP, MUAC and TSF for all locations, BMI documentation for IP and DC, PYMS screening for DC and OP, PYMS rescreening for IP and Vitamin D, E, A, B_{12} and PTH assessment (and reassessment) for all appropriate patients.

Discussion

The audit successfully established current nutritional practice in Oncology and Haematology department; identifying areas of both good and sub-optimal practice and setting a baseline for the

next stage of the audit. Good practices included PYMS screening in IP, height and weight documentation in OP, and potassium, magnesium, phosphate, calcium and albumin assessment and re-assessment. Areas for improvement included anthropometric assessment in DC, malnutrition screening in DC and OP, and the incorporation of arm anthropometry and Vitamins E, A, B_{12}, D and PTH nutritional bloods as a part of routine practice. These results are not surprising considering the lack of national or world-wide agreed nutritional standards and variable nutritional practice within paediatric oncology(32). While there has been a long interest in improving oncological outcomes, focusing on the nutritional status of patients to improve health outcomes has become a more recent focus, with an interest in establishing basic standards of nutritional assessment(7,20,32,33). In lieu of no nutritional standards, a minimum of recommended British Dietetic Association nutritional practice should be met in the UK(14). Currently, there are no other published projects assessing the implementation of paediatric oncology specific nutritional standards in the UK.

Anthropometry

Linear growth and weight assessment are critical in nutritional care(24); regular and accurate measurements are used to assess and monitor nutritional status(7,34), and body weight are required for chemotherapy/treatment dose calculations(14). With regular measurements, height, weight and height for weight z-scores can be tracked and discrepancies can be highlighted, examined and action taken(24,27,35). Patients who are at risk of poor linear growth(36) or at risk of protein energy malnutrition(12) may go unrecognised if unmonitored. This is particularly important in paediatric oncology because different tumour types have different effects on the child's body composition, fluid shifts and development(6). Regular anthropometric assessment throughout treatment allows clinicians to monitor development and changes(6). Patients diagnosed with aAcute Lymphoblastic Leukaemia (ALL) have been observed to have a slower height growth during treatment, whereas the height growth of patients with solid tumour diagnosis do not seem to be affected(36). This is

mirrored in survivorship and late effects where body composition varies between the different diagnosis' and treatments, and monitoring anthropometry is critical for catch-up growth(7). While height and weight anthropometry documentation were achieved in IP and OP, DC documentation (TRAK or patient records) left the majority of patients without appropriate anthropometric monitoring. Furthermore, patient records without a calculated BMI and no other means of anthropometric assessment provided limited means of tracking growth or weight stability throughout treatment. Head circumference (cm) for age is used to assess growth in children aged <2 years and used to detect severe PEM, faltering growth or extreme chronic malnutrition in the first few months after birth(37). Only one of the five applicable patients were measured (IP); however, there is no documentation prompt for HC, increasing the chances of incompletion.

Arm anthropometry is not currently part of RHSC regular clinical practice. There is strong scientific evidence that arm anthropometry should be included in regular anthropometric assessment, as BMI and weight for height can be affected by oedema and tumour weight, disguising changes in body composition(6,20,38). Arm anthropometry is also recommended as a part of appropriate dietetic practice in paediatric oncology(14,39,40) and a means of assessing those where weight and height are unavailable(41). MUAC and TSF measurements in relation to population reference ranges(24) have been shown to be more consistent at measuring undernutrition and overnutrition prevalence in relation to body composition than BMI in paediatric cancer patients at diagnosis, throughout treatment and into survivorship(6,40,42). Where the gold standard dual-energy X-ray absorptiometry (DEXA) assessment is unavailable, MUAC and TSF are an effective and cheaper evaluation of body composition changes and the detection of sarcopenic obesity(6,7,14,18,43,44); which are currently undetectable with BMI and height for weight alone. Arm anthropometry is currently recommended as a nutritional assessment method for paediatric oncology patients world-wide(18,39,40,44–46); particularly when resources are limited. However, more research in establishing updated reference ranges(47–49) is critical to accurate assessment and monitoring.

Nutritional Screening

Quality Improvement Scotland state that all patients should be screened for malnutrition risk with a validated tool appropriate to the patient population in accordance with NICE guidelines(50,51) on admission and re-screened weekly for maximal effectiveness. Nutritional screening tools are designed to alert non-dietetically trained clinical staff of malnutrition risk and provide a clear path for referral to dietetic services(52). IP currently use PYMS(28); a validated tool (which uses the patients' BMI, recent weight loss, current nutrient intake and risk of future reduced nutrition intake to calculate the patients' nutritional risk) to detect energy/protein undernutrition in inpatients aged 1-18 years. Designed for inpatients, PYMS is suitable for this specific population, and in lieu of an alternative tool, should be used in all locations. The inclusion of anthropometric measures of body composition (i.e. MUAC and TSF) or estimation of nutritional risk by diagnosis, cancer type and treatment intensity (ITR-3)(14) into nutritional screening could result in a more thorough and accurate screening(21,53–55). The un-met 72 hr RD follow-up standard may be indicative of incomplete documentation or that dietetic department requires more staff to meet these standards of practice; however, this is speculation and requires further investigation to be conclusive. Both DC and OP do not complete PYMS as a part of regular clinical practice. Instead, if a patient is seen in DC or OP alone, and is not currently known to the dietetic service, clinical staff will refer the patient on to the RD if they feel input is required. However, this risks a patient going unrecognised(14) and potentially compromising early malnutrition detection, particularly if they do not have updated anthropometry and no means of tracking changes. A means of improving practice could be to include a digitised PYMS (or a population specific(54)) tool on TRAK, such as in the adult services. This would allow for all TRAK authorised users to follow their patient's nutritional care more closely, and for the system to flag changes in nutritional status as they appear.

Nutritional Blood Test Monitoring

The audit indicated that current assessment of select plasma and serum parameters are more closely associated with monitoring electrolytes and traditional markers (i.e. albumin) than to assess nutritional abnormalities. Contrary to current vitamin D public health(56) and population specific(57) concerns, serum/plasma vitamin D assessment is not part of routine practice. Of the patients who were measured and received results, vitamin D status varied, with just under half being either insufficient or deficient with no follow-up assessment. This distribution echoes the results found by a systematic review investigating the same clinical population, where 14% of the population was deficient and 23% insufficient(57,58). However, the review highlighted the current lack of evidence for specific cancer/treatment type and stage. There is a demand for further vitamin D assessment in this patient group to fully establish the prevalence of vitamin D insufficiency and deficiency, to minimise the known long-term consequences of rickets, increased risk of bone fractures and osteomalacia later in life(29,56). PTH, calcium and phosphate status are all confounding factors for bone turnover when assessing vitamin D status and should be assessed alongside Vitamin D status(29). While calcium and phosphate assessment were above 90% of the standard, PTH assessment was not, potentially further obstructing the available vitamin D results. Vitamins A, E, and B_{12} did not meet RHSC nutritional standards; however, their assessment is not currently part of routine practice. This is particularly perilous for vitamin A, as it appears to be the most abnormal assessed-nutritional-blood. While there is limited research on plasma micronutrient concentrations and clinical paediatric oncology outcomes, there is a call for an increase in monitoring of nutritional bloods after finding that low vitamin A and antioxidant intake in patients with ALL was associated with adverse chemotherapy side effects(59). Particularly when considering that observed paediatric cancer patients' anti-oxidant (vitamins A, E, C, etc.) intakes are low(60) and oxidative stress is high(61). In addition, several studies have indicated that plasma levels of vitamins A, E and B12 are lower in children with cancer and undergoing treatment than in healthy controls(62,63), and micronutrient insufficiencies may potentially be cancer specific(61). Most plasma micronutrient levels appear to be sub-optimal for this patient group(59), however,

patients may also be at risk of excessive plasma concentrations during treatment due to a suspected clearing impairment(7).

Abnormal nutritional plasma concentrations in paediatric oncology patients could compound existing complications; exacerbating cancer and treatment side-effects, such as reduced peak bone mass in patients with undetected Vitamin D(57,64) or oxidation damage in patients with anti-oxidant (vitamins A, and E) deficiencies(61,65). Patients suffering from side-effects which affect dietary intake may have greater difficulties in replenishing micronutrient deficiencies or inadequacies(7). Additionally, micronutrient deficiency/excess can be masked by a patient's phenotypic nutritional status, placing both normally-nourished and over-nourished patients at risk of micronutrient malnutrition if micronutrient assessment is not a part of routine practice(9). Since micronutrient concentrations are rarely assessed within paediatric oncological research, the prevalence of plasma micronutrient levels at diagnosis and throughout treatment are relatively unknown. This could be due to non-standardised assessment, lack of nutrient specific research and/or a scarcity of incorporating regular nutritional blood assessment into clinical practice. Whether abnormal plasma micronutrient concentrations are due to cancer aetiology or other factors, it highlights a nutritional risk and a need for intervention in this population. Routine assessment and monitoring of nutritional blood tests is an important aspect of providing a complete nutritional assessment to paediatric cancer patients(7,61).

Improving Practice

The first thing to consider is that this is the first stage of an audit. It is neither unexpected for the standards to have not met the 100% compliance target, nor are these results indicative of "poor" nutritional care; this is the first time such an audit has been carried out on this ward. The staff and department's desire to both assess and improve their clinical practice is exemplary. The next stage of the audit is to implement changes so that the standards are met in the future(22). Changes should not increase current work load yet should minimise complications, maximise efficacy, and take

current routine into consideration; such measures will help ensure their long-term sustainability(66). Changes should be implemented systematically with planned checks and support along the way; it may be advisable to use a guide or model designed specifically for NHS institutions(67). While conducting the audit, communication difficulties were observed between different specialties (i.e. doctors, nurses, HCPs) and between different locations (i.e. IP vs. OP); these and further barriers need to be identified and amended so that the suggested changes can be effectively implemented(68). A critical factor dictating the success of an audit is the leader(ship)s' ability to adapt solutions and strategies to implement the improvements(22). The clinical staff who will be implementing the changes need to have the power to act and receive the appropriate support from all applicable disciplines; to ensure that this is possible further clinical training may be required(66,68).

The main staff-perceived barrier to meeting the standards was time and staffing. Open discussion amongst team leads is required to establish why certain standards (i.e. anthropometry in DC) were not met. Three general recommendations are made to improve the clinical practice highlighted through this audit: development of more nutrition standard friendly documentation, incorporation of digitised versions of all amended documentation onto TrakCare and improvement in documentation compliance of all RHSC nutritional standards (Table 7). It is of utmost importance that the identified issues are addressed, and improvements are incorporated/implemented into clinical practice to the highest possible standard. To aide in this endeavour, the locations where practice met the standards could be observed to find a solution for other locations (i.e. anthropometry in OP). Several standards could improve when the transition to digital documentation is complete and all anthropometry is entered onto TrakCare, as seen in OP where all measurements were recorded. There were mixed feelings of willingness to incorporate arm anthropometry into routine practice. Those who did express enthusiasm felt that they would benefit from further training and those who were more uncertain felt as if they were not qualified to conduct these measurements. These areas would need to be addressed when implementing changes. One way of improving documentation

could be to include a digitised version of the PYMS tool on TRAK, such as in the adult services with the digitised version of MUST (BAPEN's Malnutrition Universal Screening Tool)). This would allow for all TRAK authorised users to follow their patient's nutritional care more closely, and any anthropometry entries to automatically calculate the patient's malnutrition score; raising dietetic awareness sooner and reducing staff workload. Finally, the lack of achieved anthropometry standards could be as a result of a lack of understanding of the importance and sensitivity of these measurements in this vulnerable patient population; this could be rectified by additional training. However, this would need to take current staff workload into consideration. If standards are not met, current patient care can become compromised, potentially affecting short- and long-term outcomes. In addition, a medical institution which does not meet their standards, reduces their focus on furthering clinical care and evidence based practice; thereby compromising future patient care(69).

Table 7 Suggested Clinical Changes to Meet RHSC Nutritional Standards

Audit Criteria not meeting RHSC Nutritional Standard	Location	Suggested Clinical Change	Clinical Staff to Implement Change	Training Required
Lead staff member responsible for implementing changes and ensuring appropriate training (or re-training) is received: ward consultant on QIP.				
Height and Weight Assessment and Documentation (Section 1)	DC	Ensure all appropriate patients have their height and weight measured and documented; enter all measurements onto TrakCare.	Nursing Staff	×
	DC/IP	As long as not entered on TrakCare: Introduce appropriate growth charts to document, pot and track patient's height and weight.	Department/ Profession Leads and Nursing Staff	?
Head Circumference (Section 1)	IP	Ensure all appropriate patients have their HC measured and documented; enter all measurements onto TrakCare.	All Department Staff	?
	ALL	Amend documentation (include on malnutrition tool) to avoid in-complete assessment.	Department Leads	✓*
Arm Anthropometry (Section 1)	ALL	Incorporate arm anthropometry into routine practice.	Nursing Staff and RD	✓
	ALL	Amend documentation (include on malnutrition tool/anthropometry charts) to avoid in-complete assessment.	Department Leads and IT Department (TrakCare)	✓*
	ALL	Amend TrakCare Anthropometry Chart to include Arm Anthropometry fields (MUAC and TSF).	Department Leads and IT Department (TrackCare)	✓*
PYMS completion (Section 2)	DC/OP	Incorporate PYMS into routine practice.	Nursing Staff	?

	ALL	Digitise PYMS and add tool to TrakCare.	IT Department (TrakCare)	✓*
Nutritional Bloods (Section 7)	ALL	Incorporate assessment of Vitamins D, E, A, B_{12} and PTH into routine practice.	Department/ Profession Leads, Consultants, relevant Technicians	?
	ALL	Ensure all nutritional bloods are re-assessed.	Relevant Clinical Staff	×
General Recommendations	ALL	Develop Checklist to ensure all diagnosed patients receive standardised basic care.	All relevant authorities and affected staff	✓*
	ALL	Ensure full documentation of all nutritional standards until documentations amendments made.	All relevant authorities and affected staff	?
	ALL	All clinical staff involved in patient assessment should have access to TrakCare and ensure all documentation available on TrakCare.	All relevant authorities and affected staff	✓*

Table 7 presents the suggested clinical changes based on the audit shortcomings so that RHSC nutritional standards are met in the future. Training Required Answer Key: ✓, training required; ×, no training required; ?, potential re-training required; ✓*, training required if proposed change is implemented. *Abbreviations: IP, Inpatient, DC; Day-care; OP, Outpatient; RHSC, Royal Hospital for Sick Children in Edinburgh; Registered Dietitian, RD; IT, Information Technology*

Limitations

Study limitations included that the hospital was converting from paper to digital record keeping, and that the RHSC is relocating to a new location; added confusion to clinical practice and the auditing process. In addition, there were staff shortages and the ward staff suffered an unexpected loss during the 2017 audit, placing an even greater demand on an already strained workload.

Conclusion

The audit successfully compared current paediatric RHSC oncology nutritional practice to internal RHSC nutritional standards and established baseline practice. 82% of the 50 audit criteria did not meet the 100% standard, highlighting areas for improvement and the next step in the audit cycle. The audit areas requiring improvement were appropriate height and weight assessment and documentation in DC; head-circumference measurements in IP; incorporating arm anthropometry assessment into routine clinical dietetic practice; introduction of malnutrition screening in DC and OP; and routine nutritional biochemistry assessment throughout the department. Appropriate recommendations will be made so that RHSC nutritional standards are met in the future. If

successfully executed, these changes could progress clinical nutritional practice and thereby improve short and long term clinical and nutritional outcomes in paediatric Oncology and malignant Haematology patients.

Acknowledgments: We would like to thank the staff in the department of oncology and haematology at the RHSC, Edinburgh. We are extremely grateful for your patience, cooperation and enthusiasm for making this research possible.

Funding: This project was funded by the Fergus Maclay Leukaemia Trust and by the GI-Nutrition Research fund of Child Life and Health, University of Edinburgh.

Conflicts of Interest: The authors declare no conflict of interest.

Transparency declaration:

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned (audit was registered with the NHS Scotland Ethics committee (NHS REC 06-51104-52)) have been explained. This work has not been submitted has not been published previously nor is it under consideration for publication elsewhere.

References

1. Parker SL, Tong T, Bolden S, Wingo PA. Cancer statistics, 1997. CA Cancer J Clin. 1997 Feb;47(1):5–27.

2. Cancer Research UK. Children's cancer statistics [Internet]. Cancer Research UK. 2015 [cited 2019 Feb 18]. Available from: https://www.cancerresearchuk.org/health-professional/cancer-statistics/childrens-cancers

3. Reulen RC, Winter DL, Frobisher C, Lancashire ER, Stiller CA, Jenney ME, et al. Long-term cause-specific mortality among survivors of childhood cancer. JAMA. 2010 Jul 14;304(2):172–9.

4. Ladas EJ, Sacks N, Meacham L, Henry D, Enriquez L, Lowry G, et al. A Multidisciplinary Review of Nutrition Considerations in the Pediatric Oncology Population: A Perspective From Children's Oncology Group. Nutr Clin Pract. 2005;20(4):377–93.

5. Stratton R, Green C, Elia M. Disease-related malnutrition: an evidence-based approach to treatment. Oxon, UK: CABI Publishing; 2003. 3 p.

6. Sala A, Pencharz P, Barr RD. Children, cancer, and nutrition--A dynamic triangle in review. Cancer. 2004 Feb 15;100(4):677–87.

7. Iniesta RR, Paciarotti I, Brougham MFH, McKenzie JM, Wilson DC. Effects of pediatric cancer and its treatment on nutritional status: a systematic review. Nutr Rev. 2015 May;73(5):276–95.

8. Steliarova-Foucher E, Stiller C, Lacour B, Kaatsch P. International Classification of Childhood Cancer, third edition. Cancer. 2005 Apr 1;103(7):1457–67.

9. Bauer J, Jürgens H, Frühwald MC. Important Aspects of Nutrition in Children with Cancer. Adv Nutr. 2011 Mar 1;2(2):67–77.

10. Brinksma A, Roodbol PF, Sulkers E, Kamps WA, de Bont ESJM, Boot AM, et al. Changes in nutritional status in childhood cancer patients: a prospective cohort study. Clin Nutr Edinb Scotl. 2015 Feb;34(1):66–73.

11. Bosaeus I, Daneryd P, Svanberg E, Lundholm K. Dietary intake and resting energy expenditure in relation to weight loss in unselected cancer patients. Int J Cancer. 2001 Aug 1;93(3):380–3.

12. NICE. Improving outcomes in children and young people with cancer; Cancer Service Guidelines [CSG7] [Internet]. National Institute for Health and Clinical Excellence (NICE). 2005 [cited 2019 Feb 18]. Available from: https://www.nice.org.uk/guidance/csg7

13. Reilly JJ, Weir J, McColl JH, Gibson BE. Prevalence of protein-energy malnutrition at diagnosis in children with acute lymphoblastic leukemia. J Pediatr Gastroenterol Nutr. 1999 Aug;29(2):194–7.

14. Ward E. Childhood Cancers (Chapter 21). In: Clinical Paediatric Dietetics. 4th ed. Chichester: JohnWiley & Sons, Ltd; 2015.

15. Brougham MFH, Kelnar CJH, Wallace WHB. The late endocrine effects of childhood cancer treatment. Pediatr Rehabil. 2002 Dec;5(4):191–201.

16. Wallace WHB, Thompson L, Anderson RA. Long term follow-up of survivors of childhood cancer: summary of updated SIGN guidance. BMJ. 2013 Mar 27;346:f1190.

17. Iughetti L, Bruzzi P, Predieri B, Paolucci P. Obesity in patients with acute lymphoblastic leukemia in childhood. Ital J Pediatr. 2012 Jan 27;38:4.

18. Revuelta Iniesta R, Paciarotti I, Davidson I, McKenzie JM, Brougham MFH, Wilson DC. Nutritional status of children and adolescents with cancer in Scotland: A prospective cohort study. Clin Nutr ESPEN. 2019 Aug 1;32:96–106.

19. Selwood K, Ward E, Gibson F. Assessment and management of nutritional challenges in children's cancer care: a survey of current practice in the United Kingdom. Eur J Oncol Nurs Off J Eur Oncol Nurs Soc. 2010;14(5):439–46.

20. Owens JL, Hanson SJ, McArthur JA, Mikhailov TA. The need for evidence based nutritional guidelines for pediatric acute lymphoblastic leukemia patients: acute and long-term following treatment. Nutrients. 2013 Oct 31;5(11):4333–46.

21. Hughes C. An audit of baselines measurements and nutritional practice in paediatric cancer patients. [MSc Thesis]. Queen Margaret University; 2015.

22. Burgess R, Burgess editor Robin. New principles of best practice in clinical audit [Internet]. Second Edition. Oxford : CRC Press; 2011 [cited 2019 Feb 18]. Available from: https://trove.nla.gov.au/version/51580487

23. Tanner JM, Karlberg J. Principles of Growth Standards. Acta Paediatr. 1990;79(10):963–7.

24. WHO Child Growth Standards: Methods and development; Head circumference-for-age, arm circumference-for-age, triceps skinfold-for-age and subscapular skinfold-for-age. [Internet]. WHO. 2007 [cited 2019 Feb 18]. Available from: https://www.who.int/childgrowth/standards/second_set/technical_report_2/en/

25. Frisancho AR. Triceps skin fold and upper arm muscle size norms for assessment of nutrition status. Am J Clin Nutr. 1974 Oct;27(10):1052–8.

26. Frisancho AR. New norms of upper limb fat and muscle areas for assessment of nutritional status. Am J Clin Nutr. 1981 Nov;34(11):2540–5.

27. Royal College of Paediatrics and Child Health (RCPCH). UK-WHO Growth charts | RCPCH [Internet]. 2016 [cited 2019 Feb 18]. Available from: https://www.rcpch.ac.uk/resources/growth-charts

28. Women and Children's Directorate. Paediatric Yorkhill Malnutrition Score. Nutrition Tool Steering Group. NHS Greater Glasgow and Clyde; 2009.

29. Holick MF, Binkley NC, Bischoff-Ferrari HA, Gordon CM, Hanley DA, Heaney RP, et al. Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab. 2011 Jul;96(7):1911–30.

30. NHS Greater Glasgow and Clyde. North Glasgow Clinical Biochemistry Service, User Handbook (CLIN003) [Internet]. Glasgow; 2018. Available from:

https://www.nhsggc.org.uk/media/245218/north-glasgow-biochemistry-user-handbook-r24-oct-2017.pdf

31. SPSS Statistics Tutorials and Statistical Guides | Laerd Statistics [Internet]. Laerd Statistics. 2013 [cited 2019 Feb 18]. Available from: https://statistics.laerd.com/

32. Ladas EJ, Sacks N, Brophy P, Rogers PC. Standards of nutritional care in pediatric oncology: results from a nationwide survey on the standards of practice in pediatric oncology. A Children's Oncology Group study. Pediatr Blood Cancer. 2006 Mar;46(3):339–44.

33. Hesseling PB, Tamannai M, Ladas E, Afungchwi G, Katayi E, Kouya F. Burkitt lymphoma – Nutritional support during induction treatment: Effect on anthropometric parameters and morbidity of treatment. South Afr J Oncol. 2018 Oct 22;2(0):5.

34. Mejía-Aranguré JM, Fajardo-Gutiérrez A, Reyes-Ruíz NI, Bernáldez-Ríos R, Mejía-Domínguez AM, Navarrete-Navarro S, et al. Malnutrition in childhood lymphoblastic leukemia: a predictor of early mortality during the induction-to-remission phase of the treatment. Arch Med Res. 1999 Apr;30(2):150–3.

35. WHO Expert Committee on Physical Status: the Use and Interpretation of Anthropometry. Physical status: the use and interpretation of anthropometry: report of a WHO Expert Committee [Internet]. Geneva, Switzerland: World Health Organization; 1995. Available from: http://www.who.int/iris/handle/10665/37003

36. Murphy AJ, Wells JC, Williams JE, Fewtrell MS, Davies PS, Webb DK. Body composition in children in remission from acute lymphoblastic leukemia. Am J Clin Nutr. 2006 Jan 1;83(1):70–4.

37. WHO Child Growth Standards: Methods and development. Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. [Internet]. WHO. 2006 [cited 2019 Feb 18]. Available from: https://www.who.int/childgrowth/standards/technical_report/en/

38. Sala A, Rossi E, Antillon F, Molina AL, de Maselli T, Bonilla M, et al. Nutritional status at diagnosis is related to clinical outcomes in children and adolescents with cancer: a perspective from Central America. Eur J Cancer Oxf Engl 1990. 2012 Jan;48(2):243–52.

39. Ladas EJ, Arora B, Howard SC, Rogers PC, Mosby TT, Barr RD. A Framework for Adapted Nutritional Therapy for Children With Cancer in Low- and Middle-Income Countries: A Report From the SIOP PODC Nutrition Working Group. Pediatr Blood Cancer. 2016;63(8):1339–48.

40. White M, Davies P, Murphy A. Validation of percent body fat indicators in pediatric oncology nutrition assessment. J Pediatr Hematol Oncol. 2008 Feb;30(2):124–9.

41. 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). Nutr Clin Pract Off Publ Am Soc Parenter Enter Nutr. 2015 Feb;30(1):147–61.

42. Karlage RE, Wilson CL, Zhang N, Kaste S, Green DM, Armstrong GT, et al. Validity of anthropometric measurements for characterizing obesity among adult survivors of childhood

cancer: A report from the St. Jude Lifetime Cohort Study. Cancer. 2015 Jun 15;121(12):2036–43.

43. Oğuz A, Karadeniz C, Pelit M, Hasanoğlu A. Arm anthropometry in evaluation of malnutrition in children with cancer. Pediatr Hematol Oncol. 1999 Feb;16(1):35–41.

44. Talma H, Dommelen P van, Schweizer JJ, Bakker B, Holthe JEK, Chinapaw JMM, et al. Is mid-upper arm circumference in Dutch children useful in identifying obesity? Arch Dis Child. 2019 Feb 1;104(2):159–65.

45. Barr R, Nayiager T, Gordon C, Marriott C, Athale U. Body composition and bone health in long-term survivors of acute lymphoblastic leukaemia in childhood and adolescence: the protocol for a cross-sectional cohort study. BMJ Open [Internet]. 2015 Jan 20 [cited 2019 Feb 18];5(1). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4305072/

46. Shah P, Jhaveri U, Idhate TB, Dhingra S, Arolkar P, Arora B. Nutritional status at presentation, comparison of assessment tools, and importance of arm anthropometry in children with cancer in India. Indian J Cancer. 2015 Jan 4;52(2):210.

47. Addo OY, Himes JH, Zemel BS. Reference ranges for midupper arm circumference, upper arm muscle area, and upper arm fat area in US children and adolescents aged 1–20 y. Am J Clin Nutr. 2017 Jan;105(1):111–20.

48. Collins L, Beaumont L, Cranston A, Savoie S, Nayiager T, Barr R. Anthropometry in Long-Term Survivors of Acute Lymphoblastic Leukemia in Childhood and Adolescence. J Adolesc Young Adult Oncol. 2017 Jun;6(2):294–8.

49. Mramba L, Ngari M, Mwangome M, Muchai L, Bauni E, Walker AS, et al. A growth reference for mid upper arm circumference for age among school age children and adolescents, and validation for mortality: growth curve construction and longitudinal cohort study. BMJ. 2017 Aug 3;358:j3423.

50. Nutrition support for adults: oral nutrition support, enteral tube feeding and parenteral nutrition; Clinical guidelines [CG32] [Internet]. National Institute for Health and Clinical Excellence (NICE). 2006 [cited 2019 Feb 18]. Available from: https://www.nice.org.uk/guidance/cg32

51. Scrivener R, National Institute for Clinical Excellence, Royal College of Nursing, University of Leicester, Commission for Health Improvement, editors. Principles for best practice in clinical audit. repr. Abingdon: Radcliffe Medical; 2004. 196 p.

52. Gandy J. British Dietetic Association (BDA) Manual of Dietetic Practice. 5th ed. John Wiley & Sons, Ltd; 2014.

53. 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 Off J Br Diet Assoc. 2012 Aug;25(4):311–8.

54. Murphy AJ, White M, Viani K, Mosby TT. Evaluation of the nutrition screening tool for childhood cancer (SCAN). Clin Nutr Edinb Scotl. 2016 Feb;35(1):219–24.

55. Teixeira AF, Viana KDAL. Nutritional screening in hospitalized pediatric patients: a systematic review. J Pediatr (Rio J). 2016 Aug;92(4):343–52.

56. Scientific Advisory Committee on Nutrition (SACN). SACN vitamin D and health report [Internet]. GOV.UK. 2016 [cited 2019 Feb 18]. Available from: https://www.gov.uk/government/publications/sacn-vitamin-d-and-health-report

57. Revuelta Iniesta R, Rush R, Paciarotti I, Rhatigan EB, Brougham FHM, McKenzie JM, et al. Systematic review and meta-analysis: Prevalence and possible causes of vitamin D deficiency and insufficiency in pediatric cancer patients. Clin Nutr Edinb Scotl. 2016 Feb;35(1):95–108.

58. Iniesta RR, Paciarotti I, Davidson I, McKenzie JM, Brand C, Chin RFM, et al. 5-Hydroxyvitamin D concentration in paediatric cancer patients from Scotland: a prospective cohort study. Br J Nutr. 2016 Dec;116(11):1926–34.

59. Kennedy DD, Tucker KL, Ladas ED, Rheingold SR, Blumberg J, Kelly KM. Low antioxidant vitamin intakes are associated with increases in adverse effects of chemotherapy in children with acute lymphoblastic leukemia. Am J Clin Nutr. 2004 Jun;79(6):1029–36.

60. Slegtenhorst S, Visser J, Burke A, Meyer R. Antioxidant intake in paediatric oncology patients. Clin Nutr Edinb Scotl. 2015 Dec;34(6):1210–4.

61. Revuelta Iniesta R, Wilson D, Brougham MFH, Smail N, Davidson I, McKenzie J. Assessment of Plasma Antioxidants, Oxidative Stress and Polyunsaturated Fatty Acids in Paediatric Cancer Patients: A Prospective Cohort Pilot Study. EC Nutrition. 2015;2(4):412–25.

62. Sadananda Adiga MN, Chandy S, Ramaswamy G, Appaji L, Krishnamoorthy L. Homocysteine, vitamin B12 and folate status in pediatric acute lymphoblastic leukemia. Indian J Pediatr. 2008 Mar;75(3):235–8.

63. Fiore P, Castagnola E, Marchese N, Dufour C, Garaventa A, Mangraviti S, et al. Retinol (vitamin A) and retinal-binding protein serum levels in children with cancer at onset. Nutr Burbank Los Angel Cty Calif. 1997 Jan;13(1):17–20.

64. Polgreen LE, Petryk A, Dietz AC, Sinaiko AR, Leisenring W, Goodman P, et al. Modifiable risk factors associated with bone deficits in childhood cancer survivors. BMC Pediatr. 2012 Mar 28;12(1):40.

65. Conklin KA. Dietary Antioxidants During Cancer Chemotherapy: Impact on Chemotherapeutic Effectiveness and Development of Side Effects. Nutr Cancer. 2000 May 1;37(1):1–18.

66. Ashmore S, Ruthven T, Hazelwood L. Stage 3 & 4: Implementing Change and Sustaining improvement. In: New principles of best practice in clinical audit. second. London: Radcliffe Publishing; 2011. p. 81–92.

67. Schofield J, Jenkins J. How to Implement Changes from National Clinical Audit – A Guide for Audit Professionals in Healthcare Organisations. London: Healthcare Quality Improvement Partnership (HQIP; 2010.

68. National Institute for Health and Clinical Excellence. How to Change Practice: Part 2: understand, identify and overcome barriers to change. In: How to change practice. London: NHS NICE; 2007.

69. Flaming D, Barrett-Smith L, Brown N, Corcoran J. Ethics? But it's only quality improvement! Healthc Q Tor Ont. 2009;12(2):50–5.

651