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Research Article

Short Term Effects of Childhood Cancer and its Treatments on Nutritional Status: a Prospective Cohort Study

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Abstract

Introduction: Few studies have identified the nutritional risks of children treated for cancer in the western world. This study aimed to assess the effect of cancer and its treatment on nutritional status.

Methods: Nutritional status assessment measures (body mass index centiles, triceps skin fold thickness and middle upper arm circumference) were taken at diagnosis and three months. Daily energy intake and macronutrients intake were compared against individual requirements matched for age, gender and physical activity and expressed as percentage to standardise the results. Dietary intake was assessed both *ad libitum* and with Nutrition Support (NS) to assess the energy and macronutrients contributed by the NS towards meeting the energy and dietary requirements. Results are median; Inter Quartile Range (IQR).

Results: 26 children (18 (69%) were male and 8 (315) were female) participated. At both diagnosis and three months, the 'leukaemias' group (n = 10, median age 6.3; IQR 4.2-10.5 years) demonstrated excess Body Mass Index (BMI) centiles (66.0; 41.5-82.2 and 79.5; 70- 94.2; $p < 0.05$) and high fat mass (Upper Arm Fat Area UAFA) % (102.0; 78.6-153.0 and 129.4; 96.5-202.6; $p > 0.05$) , plus excessive energy intake *ad libitum* at diagnosis only (% of Estimate Average Requirement (EAR) (102; 91-137; $p < 0.05$) compared to the 'other cancers' group . The 'other cancers' group (n = 16, median age 3.1; IQR 0.8-6.6 years) were undernourished at diagnosis and three months: low BMI centile (25.5; 5.5-60.5 and 18.0; 7.5-54.2; $p < 0.05$), low fat mass (UAFA) % (76.3; 48.5-99.1 and 70.8; 62.6-124.8; $p > 0.05$), and had low energy intake *ad libitum* (% of EAR) 63; 51-129 at diagnosis ($p < 0.05$) and high need (35%)for enteral feeding (ENF).

Conclusions: Children undergoing cancer therapy are at high risk of malnutrition at diagnosis and early in treatment course with clear differences between leukaemias and other type of cancer.

Keywords: *Children; Cancer; Nutritional Status; Tricepts Skinfold; Middle Upper Arcircumference*

Abbreviations: BMI: Body Mass Index; CNS: Central Nervous System; DRV: Diet Reference Value; EAR: Estimate Average Requirements; ETF: Enteral Tube Feeding; ICCC-3: The International Classification of Childhood Cancer, third edition; MUAC: Middle upper arm circumference; NHS: National Health Service; NS: Nutrition Support; OCS: Oral Calorie Supplements; PN: Parenteral Nutrition; RHSC: Royal Hospital for Sick Children; RNI: Reference Nutrient Intake; TEM: Technical error of measurement; TSF: Triceps Skin Fold; UAFA: Upper arm fat area; UAMA:Upper arm muscle area;

Introduction

For many childhood cancer patients, the early progression of the disease and the start of cancer treatments can bias the nutritional status towards malnutrition (undernutrition or overnutrition) with many detrimental consequences [1-6]. The prevalence of undernutrition has been described at different stages and in specific diagnoses. Prevalence figures vary considerably from around 10% to 50%

[4,6,7-9]. The heterogeneity of diagnosis, different stage of treatment, treatment protocol, definition of undernutrition used, and methodology used to assess nutritional status make an accurate estimate very difficult. The difficulty of estimating the prevalence of undernutrition is a major limiting factor in research in this area [1].

Cancer associated undernutrition is a complex and multi-factorial phenomena. Factors implicated in the development of undernutrition in childhood cancer are: reduced dietary intake [10-13], mal absorption [14] and altered metabolism [12,15].

Overnutrition also has detrimental effects during cancer therapy. It has been suggested that obesity during cancer therapy can increase the risk of mortality, morbidity and chemotherapy induced toxicity [16-17]. Additionally, survivors of childhood Acute Lymphoblastic Leukaemia (ALL) seem to gain weight excessively during and after therapy and become overweight and obese [18]. Hence, identification of patients at nutritional risk from diagnosis and throughout treatment is essential to allow close nutritional monitoring and prompt nutrition support (NS). Although a recent UK nutritional care pathway has been developed [18], there is a lack of national or consistent approach to both nutritional assessment and nutrition support (NS) [19].

Many issues have been identified in the current assessment and interpretation of nutritional status in children with cancer [20]. Remarkably, there is no nutrition screening tool specifically designed for use in paediatric oncology. Moreover, nutritional status assessment during cancer treatments is difficult as actual weight can be affected by hydration status and tumour mass, masking body weight loss [21]. Additionally, it has been shown that children treated for cancer experience a change in the distribution of body compartments [22]. For this reason, many authors argue [13,22,23] that the measurement of body composition can provide additional valuable information about nutritional status beyond weight related measurements alone.

Furthermore, a rapid identification of those patients at high risk of becoming overweight and obese is now pivotal as it would permit a preventative intervention targeting potentially modifiable risk factors, such as diet and sedentary life-style to be initiated from an early stage. Lastly, the need for clear, prospective, longitudinal studies of malnutrition in childhood cancer is emphasised in two recent systematic reviews [1,24].

In light of this, this prospective cohort study aimed to both determine the prevalence of undernutrition and overnutrition (overweight plus obesity) using several parameters (dietary intake, body mass index (BMI) centile, triceps skin fold (TSF) and middle upper arm circumference (MUAC)) from diagnosis to three months and monitor acute changes in nutritional status, with regard to tumour type, treatments and nutritional interventions.

Methods

Patient Selection and recruitment

The inclusion criteria included: Children under the age of 18 years; diagnosed with cancer according to The International Classification of Childhood Cancer, third edition (ICCC-3) [25] between August 2010 and January 2012 while attending the Haematology and Oncology Clinic at the Royal Hospital for Sick Children (RHSC), Edinburgh; resident in SE Scotland. Exclusion criteria included: children on palliative care. The study had ethical approval from NHS Scotland. The child and the parents were provided with full written information regarding the project and provided informed consent. Patient data remained confidential and all data was anonymised.

Data collection

Clinical information was collected from medical notes. Due to the numbers available in the study and the wide range of childhood cancer diagnosis, the cohort was grouped according to both ICCC-3 [15] and clinical practice in this centre into Leukaemias (I-Leukaemias) and other cancers (II- Lymphomas ,III -CNS, IV- Neuroblastoma, V- Retinoblastoma, VI- Renal, VII-Hepatic tumors, VIII -Bone, IX-Soft tissue sarcomas and X- Germ cell tumour).

The patients were recruited immediately after diagnosis. Height, weight, TSF and MUAC measurements were taken by a single trained research nutritionist at diagnosis and again at three months using standard techniques. BMI centiles for children were calculated using

the LMS Growth application (Harlow Healthcare, UK) based on UK published reference data [26]. We decide to use BMI centiles over Z scores to allow comparison to national data [27] and to be in line with the dietetic practice in this centre. Overweight was defined as ≥ 85th < 95th BMI centile and obesity as ≥ 95th BMI centile; the observed rates of overweight and obesity were compared to the current frequencies for UK children aged 1.5 to 18 years (15% and 18.5% respectively) reported in the National Diet and Nutrition Survey [27]. Undernutrition was defined as ≤ 2.3th BMI; observed frequencies of undernutrition were compared to the expected frequencies for the UK population. [28] The arm anthropometry raw data were converted to centiles. [29,30] To allow comparisons between genders and diagnostic group, arm anthropometry measurements were also normalised for age and gender by expressing the as percentage of standard (50th centile) [30]. The crude measures of TSF (mm) and MUAC (mm) were used to calculate upper arm muscle area (UAMA) and upper arm fat area (UAFA) using the Frisancho equation [30]. The authors' known technical error of measurement (TEM) for skin folds and circumferences were derived prior to the commencement of the study. From these repeated measures of 10 subjects TEM's are as follows: mid arm circumference = 0.12 cm (0.6%), tricep skin fold = 0.17 mm (1.3%), The intra class correlation coefficient (ICC) for these measurements was 1.0.

Due to the impact of fluid balance on weight and body composition the measurements were not taken on the same day as a course of hyper hydration.

Dietary intake was assessed using the 24h multiple pass diet recall [31] which uses multiple memory wording to elicit recall of all possible foods. Energy and macronutrients intake were calculated using the computer programme WINDIETS (Univation Ltd 2005). WINDIETS contains a complete UK food and portion size database. When the composition of a food consumed by a patient was not available on WINDIET, the manufacturer's information was used. The composition of NS was obtained from the manufacturer and used to calculate nutrient intake in relation to the quantity consumed. The dietary intake for macronutrients was assessed at each time point. Dietary intake was assessed both ad libitum and with NS. This was essential to assess the energy and macronutrients contributed by the NS towards meeting the energy and dietary requirements. The type and dosage of NS were used to calculate nutrient intake with NS by adding the energy and micronutrients coming from the nutrition support to those coming from the intake ad libitum. Daily energy intake was compared against individual requirements calculated using the Oxford equation [32] adjusted for low physical activity. Protein intake was compared against the Diet Re reference Value (DRV) matched for age and gender [33].

Nutrition support was defined as the use of Oral Calorie Supplements (OCS) , Enteral Tube Feeding (ETF) or Parenteral Nutrition (PN) or any combination of these

Data analysis

The data were analysed using IBM-SPSS 19. The data were tested for normal distribution by the Shapiro-Wilk Test. The results are presented as median (inter quartile range (IQR)) as they were not normally distributed.Comparisons between results according to diagnosis (other cancers vs. leukaemias) were tested by the Mann-Whitney test.Comparison between measurements at baseline and at three months were tested by Wilcoxon Matched-Pairs Signed-Ranks Test. Differences between observed and expected frequencies of malnutrition were tested for significance using the Z test.Nutrition support categorical data were compared by Fisher's exact test. Patients with missing data were excluded from the relevant analyses. Results are expressed as median; IQR.

STROBE initiative was followed in presentation of the data (www.strobe-statement.org).

Results

51 patients were diagnosed with childhood cancer during the data collection period. Median age at diagnosis was 6.3; IQR 4.2-10.5 years for the 'leukaemias ' group and 3.1; IQR 0.8-6.6 years 'other cancers' group ($p > 0.05$). The clinical characteristics of the participants are shown in Table 1. Sixteen patients were not eligible for a variety of reasons (n = 2 palliative; n = 1 deceased; n = 2 unsuitable due to social circumstances; n = 1-unsuitable for clinical reasons; n= 10 no ongoing care). Thirty-five patients met the eligibility criteria for the study; 26 (74%) patients were recruited and 9 (26%) declined to participate, all because it was too stressful for the families. At three moths 6 patients were excluded (n = 2 became palliative, n = 1 died, 3 = unavailable measurements). Figure 1 displays the number

of patients with available data of interest at each stage of the study. Table 2 shows primary cancer diagnosis (n = 10 in the 'leukaemia group', n=16 in the 'other cancers' group) and type of treatment.

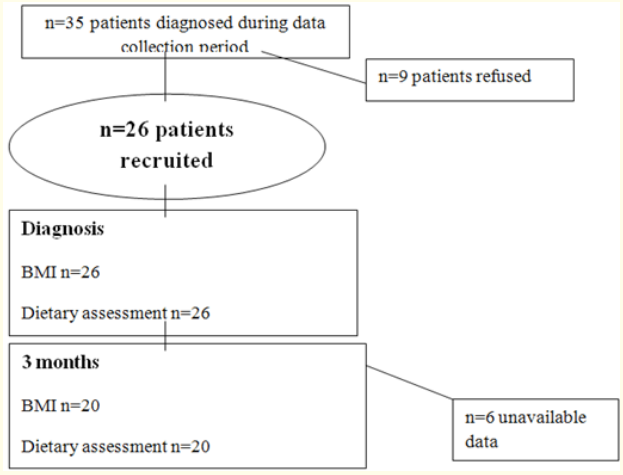

Figure 1: *Flow diagram showing all children and young people in cohort.*

Parameters	Participants (n = 26)		Non-participants (n = 9)		p
	Median	IQR	Median	IQ	
Age at Diagnosis (years)	5.1	2.3-7.9	8.9	4.1-12.52	0.05 ł
	n	%	n	%	
Gender					-
Male	18	69	4	44	
Female	8	31	5	56	
ICCC-3					-
Leukaemias	10	38	5	55	
Other cancers	16	62	4	45	

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Table 1: *Characteristics of the n = 26 Paediatric Oncology "participants" and n = 9 "non-participants".*

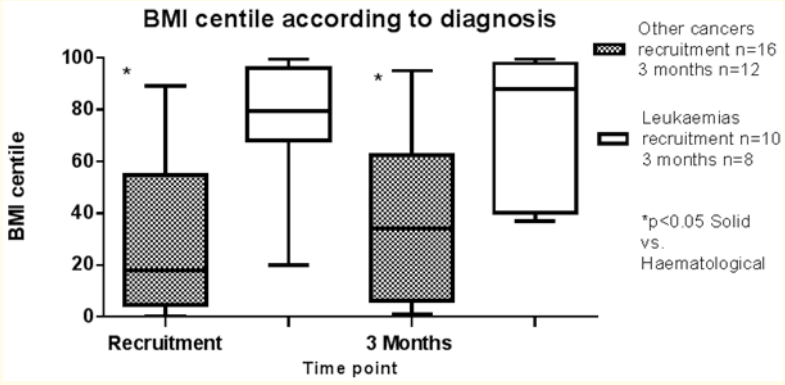
Diagnosis	Cases (% within cohort)	Treatment
I - Leukaemia	10 (38)	
ALL	8 (31)	n = 8 Chemotherapy only (including high dose steroids)
AML	2 (7)	n = 1 Chemotherapy only n = 1 Chemotherapy and radiotherapy
CML	0	-
Other cancers	16 (62)	
II- Lymphoma	2 (8)	n = 1 Chemotherapy only (including high dose steroids) n = 1 Chemotherapy and radiotherapy

III -CNS tumour	4 (15)	n = 1 Chemotherapy only n = 1 Chemotherapy and surgery n = 1 Chemotherapy, radiotherapy and surgery n = 1 Surgery only
IV- Neuroblastoma	3 (11)	n = 2 Chemotherapy and surgery
n = 1 Chemotherapy, radiotherapy and surgery		
V- Retinoblastoma	1 (4)	n = 1Chemotherapy only
VI -Renal tumour	2 (8)	n = 1 Chemotherapy and surgery n = 1 Chemotherapy, radiotherapy and surgery
VII -Hepatic tumour	0 (-)	-
VIII -Malignant bone tumours	0 (-)	-
IX- Soft tissue sarcoma	3 (11)	n = 1 Chemotherapy only n = 1 Chemotherapy and surgery n = 1 Chemotherapy, radiotherapy and surgery
X -GCT	1 (4)	n = 1 Surgery only
XI - Malignant epithelial oplasm	0 (-)	-
XII-Others and unspecified malignat neoplasms	0 (-)	-

Table 2: *Primary cancer diagnosis percentage within the cohort and type of treatment.*

BMI centiles

All participants received cancer treatment at the time of the first measurement; the duration of time from diagnosis to measurement was 14 (10-21) days. BMI centile was significantly higher in the leukaemias group compared to the other cancers group at both time points ($p < 0.05$ for all) (Figure 2). There were no statistically significant differences in BMI centiles between measurements at diagnosis and at 3 months within both other cancers and leukaemias groups ($p > 0.05$). Table 3 shows the prevalence of undernutrition at each measurement. The highest observed frequency of undernourished children was among the other cancers group at diagnosis (25 %; n = 4) compared to 0% at every time point for the leukaemias group. The highest observed frequency of obesity occurred in the leukaemias group at three months (50%, n = 4).



** Mann-Whitney test $p < 0.05$.*

Figure 2: *BMI centile according to diagnosis.*

		Diagnosis		3 months	
		Other cancers % (n)	Leukaemias % (n)	Other cancers % (n)	Leukaemias % (n)
BMI centiles					
	≤ 2.3th centile	25(4)*	0(0)	17(2)*	0(0)
	≥ 85th/< 95th centile	6(1)	10(1)	0(0)	13(1)
	≥ 95th centile	0(0)	30(3)	8(1)	50(4)*
TSF	≤ 5th centile	30(6)	0(0)	18(3)	0(0)
MUAC	≤ 5th centile	38(6)	0(0)	33(3)	0(0)

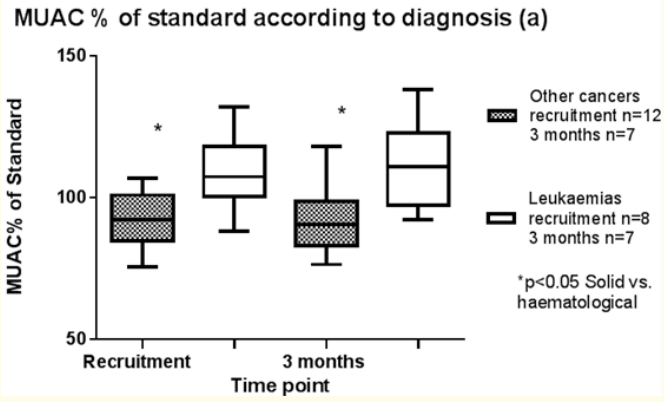
**Z test p < 0.05 BMI centile vs. UK prevalence*

Table 3: *Prevalence of malnutrition according to diagnosis at each measurement expressed as percentage (%) and number (n).*

There was a significantly higher prevalence of undernutrition as determined by BMI centiles in the other cancers group at diagnosis (25% p < 0.05; 95% CI 3.8% to 46.2%) and three months (17 % p < 0.05; 95% CI 4.2% to 38.2 %) compared to the 2.3% expected frequencies for the UK. [28] The observed frequency of obese children was statistically higher than the expected frequency of 18% for boys and 19% for girls [27] for the leukaemias group at three months (50% p < 0.05; 95% CI 19% to 80.6%).

Arm anthropometry

Arm anthropometry expressed as % of standard value at each time point according to diagnostic groups is shown in figure 3. Patients with other cancers had lower TSF, MUAC, UAMA and UAFA than the leukaemias patients for the first months of treatments; of these, only MUAC (Figure 3a) and UAMA (Figure 3c), reached statistical significance (p < 0.05). In the other cancers group, the highest prevalence of undernutrition was observed at three months, where TSF and UAFA were 73.3 % (IQR 68.3-93.0) and 70.8 % (IQR 62.6-124.8) of the standards, respectively. On the contrary, the leukaemias group showed excess body fat accumulation at three months with the median UAFA being 129.4 % (IQR 96.5-202.6) of standard.



** Mann-Whitney test p < 0.05*

Figure 3a: *MUAC (a), TSF (b), UAFA (c) and UAMA (d) according to diagnostic group expressed as % of standard value.*

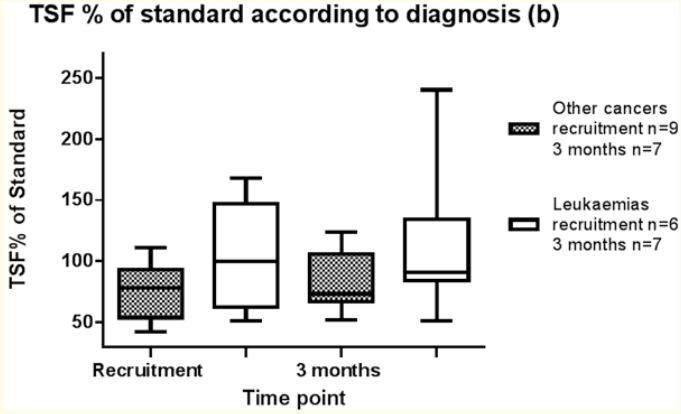
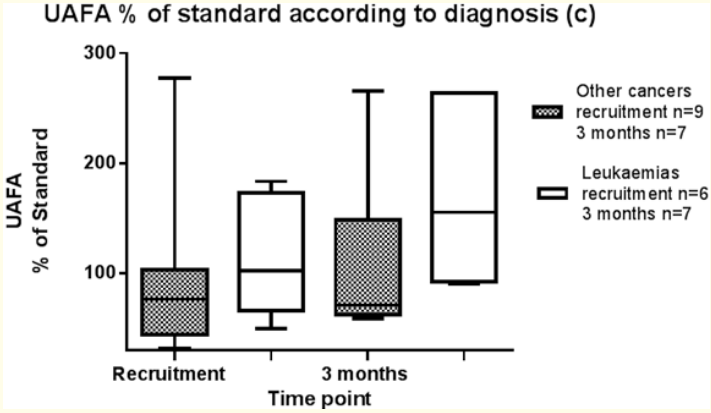


Figure 3b:



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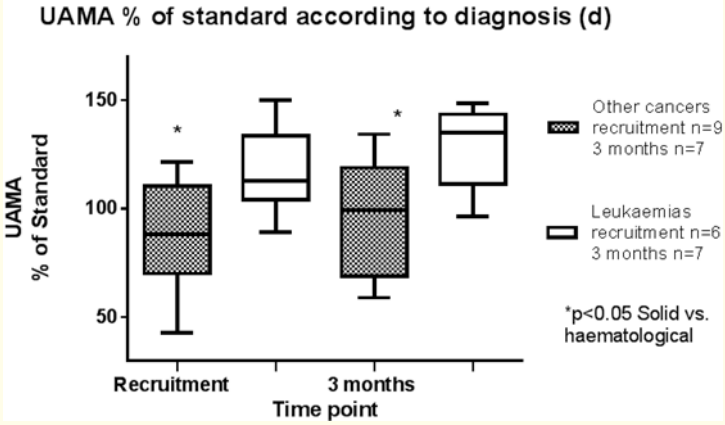

Figure 3d:

The prevalence of undernutrition was assessed using MUAC and TSF centiles (Table 3). The highest prevalence of undernutrition was observed at diagnosis (MUAC n= 6, 38%; TSF n = 6; 30%). There was not a significant difference in arm anthropometry between measurements.

Energy and protein intake

15 patients (58%) were recorded as having a need for NS as defined by the use of OCS (n = 9 (35%); n = 5 (50%) hamatological group and n = 4 (25%) other cancers group) , ETF (n = 9 (35%) ; n = 1 (10%) hamatological group and n = 8 (20%) other cancers group) or PN (n = 1, 4%; n = 1 (4%) other cancers group), or any combination of these.There was not adifference ($p > 0.05$ for all) in the need for any type of NS between the two cancer groups. The reasons for NS were: poor intake for the 9 patients receiving OCS and poor intake associated with low weight, weight loss, and chemotherapy side effects for the 10 patients receiving ETF (n = 9) and PN (n = 1). Energy intake *ad libitum* as % of EARs was significantly higher in the leukaemias group (102; 91-137) compared to the other cancers group (63; 51-129) at diagnosis. Two patients in the leukaemias group (20%) and 4 patients in the other cancers group (25%) had a daily energy intake *ad libitum* below 80% of the EAR.

At three months, energy intake *ad libitum* as % of EARs was significantly higher in the other cancers group (105; 65-131) compared to the leukaemias group (63; 56-129). There were no significant differences between energy intake at both *ad libitum* and with NS and the energy requirements between the two time points ($p > 0.05$ for all) (Table 4). Eight patients in the leukaemias group (100%) and 4 patients in the other cancers group (33%) had a daily energy intake *ad libitum* below 80% of the EAR.

	Time point	Energy requirement Kcal/d (Henry 2005)	Energy intake ad libitum Kcal/d	Energy intake ad libitum as % of EARs (Henry 2005)	Energy intake Kcal/d with NS	Energy intake with NS as % of EARs (Henry 2005)	Protein intake ad libitum g/d	RNI (g/d)
Leukaemias	Diagnosis n = 10	1529 (1494-1842)	2076 (1340-2525)	102 (91-137)*	2076 (1453-2525)	105 (99-137)	70.8 (60.0-101.3)	28.3 (19.7-42.1)
	3 months n = 8	1532 (1423-1896)	928 (906-1017)	57 (46-62)*	1078 (919-1206)	62 (46-72)*	31.6 (25.9-35.6)	28.3 (19.7-42.1)
Other cancers	Diagnosis n = 16	1249 (577-1359)	782 (321-1747)	63 (51-129)*	1200 (866-1970)	135 (88-184)	31.7 (9.6-61.6)	19.7 (14.5-19.7)
	3 months n = 12	1165 (708- 1340)	1076 (709-1243)	105 (65-131)*	1305 (901-1488)	120 (96-149)*	40.7 (11.2-46.4)	14.5 (14.5-28.3)

Table 4: *Energy (kcal/d) and protein intake (median, IQR) ad libitum and with NS is shown at each time point according to diagnostic group.*

** Mann-Whitney test $p < 0.05$ leukaemias group vs. other cancers group.*

Even though not significant, intake (kcal/d) *ad libitum* and with NS for the leukaemias group was higher than recommendations at diagnosis (2076; 1340-2525 and 2076; 1453-2525 *ad libitum* and with NS respectively vs. 1529; 1494 -1842, $p > 0.05$) but lower at three months (928; 906-1017 and 1078; 919-1206 *ad libitum* and with NS respectively vs. 1532; 1422-1896). The intake (kcal/d) *ad libitum* for the other cancers group was lower than recommendations at diagnosis but not with NS (782; 321-1747 and 1200; 866-1970 *ad libitum* and with NS respectively vs. 1249; 629 -1359, $p > 0.05$) (Table 4).

Protein intake *ad libitum* and with NS was significantly higher than RNI at each measurement in each diagnostic group ($p < 0.05$ for all).

Discussion

The current study has prospectively examined the changes in nutritional status with simultaneous anthropometry and dietary intake data in children with several types of cancer during the first three months of treatments. These results showed that both undernutrition and obesity are common features in the first phase of treatments for paediatric cancer. The highest prevalence of undernutrition was among the other cancers group with BMI centile median below the 50th centile for the entire data collection period. The low BMI centiles were associated with an increased prevalence of undernourished children compared to the expected prevalence of undernutrition for the UK population [27]. By contrast, the leukaemias group had a BMI centile median above the 50th centile, and the prevalence of obesity was higher than the expected prevalence for the UK population.

The BMI changes over time were associated with anthropometrical changes. The leukaemias patients had excess fat reserves during treatments measured by UAFA, being 130% of standard at three months, whereas the other cancers group had depleted fat stores during the first three months of treatments, with UAFA values decreasing from 78% at diagnosis to around 70% of standard at three months. This indicates that the other cancers group had depleted fat stores during the first three months of treatments, suggesting a negative energy status existing from pre-diagnosis. In contrast, ALL patients are at increased risk of excess fat and weight gain during treatments as reported elsewhere [34-36]. It could be argued that the inclusion of CNS cancers in the other cancer group may theoretically have skewed the results towards a higher BMI centile due to their increased risk of obesity, but this did not occur given that none of the patients in the CNS were classified as obese or overweight.

These findings support the observation that nutritional undernutrition is common during treatment for other cancers especially at diagnosis [7,13]. Comparable to this current study, several authors have reported no indication of nutritional deprivation in children treated for ALL at diagnosis [37] or during treatment [12] when compared against healthy subjects. However one study [8] showed a significant increase in the prevalence of undernutrition assessed by BMI SDS compared to the expected frequencies for the UK population in a cohort of 1019 ALL patients. This inconsistency is probably due to both the small sample size of this study and the Reilly et al [8]. study including patients with high risk ALL a group at higher risk of nutritional deprivation and which was not present in this study. Moreover, BMI centiles should be interpreted in relation to pre-illness weight and weight loss;, this information was not available in the current study, mainly because most parents were unable to recall the information. Therefore, although 25% of the leukaemias patients were classified as obese by BMI centiles at diagnosis, they might have been undernourished if assessed using a weight loss parameter.

The current investigation showed an increased overall energy intake (both *ad libitum* and with NS) from diagnosis to three months in the other cancers group, which was associated with an overall increase in BMI centile. The reason for the observed increase in energy intake *ad libitum* may be explained by some patients affected by lymphoma being on steroid treatments which may have caused excessive intake. In contrast, the daily energy intake of the leukaemias group at diagnosis was exceeding the daily energy requirements. However, at three months, whilst daily energy intake was reduced, BMI centiles and FM were at their peak. The reasons for the dramatic energy intake fluctuations in the patients treated for ALL in the present study may be explained by the different use of steroids during the induction to remission phase. ALL patients are likely to experience phases of excessive intake when on steroids, followed by a reduced intake when off steroids due to treatment side effects. Since data collection in this study was based on time intervals (three months) more than events (chemotherapy protocol phases), many patients were assessed during the off-steroid period. Even though it was attempted to record whether they were on- or off- steroids, data analysis using this variable was not limited by the cohort size.

Importantly, this study showed that many patients only achieved their daily energy requirements through NS, highlighting the importance of nutritional assessment and nutrition intervention to achieve daily energy requirements. The overall reduced daily energy intake ad libitum observed in this study is seen in other studies [10,12,13]. Although daily energy intake was below the energy requirements, protein requirements were met by all patients implying that protein-energy undernutrition in this cohort is uncommon as reported by other authors [11,12]. However, in this study and previous studies [11,12] the protein intake was compared to the DRV for the healthy children. This criterion to assess adequacy may be questionable since the specific protein requirement for children treated for cancer is

This study further support the evidence on the increased risk of obesity during ALL treatments [39-42]. Many clinicians and authors [41-43] consider weight gain to be a side effect of steroid therapy, however whilst this contributes to the early weight gain in leukaemias patients, it cannot be the sole cause for the long term increased risk for obesity reported in the literature [18,34,44]. A well-known risk factor for the late onset of obesity with modern treatments is reduced physical activity [45-48]; however it seems unlikely that reduced physical activity and increased energy intake alone can account for the increased risk of obesity in this cohort. It may be speculated that there is an adaptive response caused by chemotherapy that may lead to an early adiposity rebound [49]. There is now evidence to support the need for specific nutritional strategies aiming to address obesity in this particular cohort. Therefore, understanding the mechanisms causing excess body fat in this cohort is now pivotal to implement preventative measures and to stop this sequela.

The main limitation of this prospective study is the limited sample size, a reflection of the low incidence of child hood cancer within a population-based study from a regional cancer centre. For ethical reasons children in palliative care were excluded, however considering the small number, it is unlikely that their exclusion had skewed the results.

The breakdown of the patients according to cancer type would have been very informative on the cancer related effects on nutritional status. However, this was not possible due to the limited sample size. Moreover, some patients declined to have arm anthropometry performed, reflecting the methodological limitations of measuring children. This technique is generally well accepted by adult subjects, but use in sick children is challenging as these children tend to be frightened by the calipers and they do not tolerate this measurement very well. It could be argued that the absence of older patients who declined to participate may have skewed the results due to the differences in body composition during growth and development. However, this is unlikely since the results were standardised using BMI centiles and arm anthropometry was expressed as percentage of standard adjusted for age and.

Although limited in sample size, the observational information obtained in this current research is valuable, providing data which can be validated in larger studies. These findings underlined the common risks of undernutrition and obesity in this childhood cancer cohort, and also indicated apparent differences in nutritional risk according to diagnosis and treatment. This study also highlights the importance of anthropometric monitoring during childhood cancer treatments from diagnosis onwards. Although BMI has the limitation of not measuring body composition, it is still a valuable tool to assess nutritional status and its changes during cancer therapy. The advantages of this method are its simplicity for performance and interpretation. However, the findings of this study also suggest that, given the known masking effect of cancer and its treatment on nutritional status assessed by weight related measurements [13,21], the use of BMI centile alone may leave some undernourished patients undetected. Therefore, TSF and MUAC measurements should become part of the routine nutritional assessment of children treated with cancer, especially in those subjects where the tumour can have a masking effect on weight.

Moreover, this study has shown that energy provided by NS is essential for some patients to achieve their daily energy requirements, even though tolerance of these feeds can be problematic during the cycles of intense chemotherapy. Further studies that focus on the nutritional management of this specific patient group are now pivotal to the development of specific guidelines for the nutritional care of this group.

Conclusions

Nutritional assessment is important in order to assess the prevalence of malnutrition during the different phases of treatment, but also to allow longitudinal comparison from baseline measurements. With this approach, NS can be promptly initiated and the patients' response closely monitored.

Conflict of interest statement

JM and DCW have received research support from Danone Research BV. DCW has received speaker's fees from SMA Nutrition, Nestle and SHS-Nutricia.

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Statement of Authorship

DCW designed the study; IP created the database; IP collected the data; JM,ID, MB, ABE and DCW supervised the study. IP and DCW prepared the manuscript with additions, comments and corrections by all the authors. All authors have read and approved the final draft. DCW is the guarantor of the article.

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