



Food habits during treatment of childhood cancer: a critical review

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Abstract

Several factors can affect the nutritional status of children undergoing cancer therapy. The present review aims to describe children's food intake during cancer treatments and to explore the contributing determinants. It also assesses the nutritional educational interventions developed for this clientele. Scientific literature from January 1995 to January 2018 was searched through PubMed and MEDLINE using keywords related to childhood cancer and nutritional intake. Quantitative and qualitative studies were reviewed: forty-seven articles were selected: thirty-eight related to food intake and parental practices and nine related to nutritional interventions. Patients' intakes in energy, macronutrients and micronutrients were compared with those of healthy controls or with requirement standards. Generally, patients ate less energy and proteins than healthy children, but adhered similarly to national guidelines. There is a lack of consensus for standard nutrient requirement in this population and a need for more prospective evaluations. Qualitative studies provide an insight into the perceptions of children, parents and nurses on several determinants influencing eating behaviours, including the type of treatment and their side effects. Parental practices were found to be diverse. In general, savoury and salty foods were preferred to sweet foods. Finally, most interventional studies in childhood cancer have presented their protocol or assessed the feasibility of an intervention. Therefore, because of the variability of study designs and since only a few studies have presented results, their impact on the development of healthful eating habits remains unclear. A better understanding of children's nutritional intakes and eating behaviours during cancer treatment could guide future nutritional interventions.

Key words: Childhood cancer: Nutrition: Eating behaviours: Parental practices: Food preferences

Introduction

Malnutrition in children undergoing antineoplastic treatment has been much studied throughout the years. Childhood cancer patients are at risk of weight loss, particularly lean body mass loss, in part due to cancer-related cachexia. Dysfunctional metabolic reactions including increased lipolysis, glucose resistance and muscle wasting can occur during cancer^(1–3). In parallel, treatment side effects such as nausea, vomiting and dysgeusia can reduce appetite and contribute to deteriorate nutritional status⁽¹⁾. Malnutrition may lead to a suboptimal response to treatment and worsen side effects. At the moment, most literature on nutrition in childhood cancer is related to those difficulties. However, excessive weight gain during certain phases of cancer treatment is common. A meta-analysis of growth patterns in children with acute lymphoblastic leukaemia (ALL) showed an unhealthy increase in BMI Z-score in the early phase of their treatment and during the maintenance phase⁽⁴⁾. Importantly, that weight gain was maintained during survivorship⁽⁴⁾. In young adult survivors of childhood cancer, inactivity and unhealthy food habits have been identified as contributors to the development of health complications⁽⁵⁾. Therefore, nutritional intervention during treatment could help prevent these problems. Not only could it contribute to decrease the risk of late sequelae, but it could also benefit patients' nutritional status that is

associated with treatment side effects and risk of infections⁽¹⁾. In the present critical review, we aim to describe the literature on children's food intake during cancer treatment, to explore the determinants contributing to their food habits and to assess the nutritional educational intervention developed for this clientele.

Methodology

For this critical review, literature was searched through MEDLINE and PubMed and included articles from January 1995 to January 2018 (Fig. 1). Search terms were: Children: children or child or infant or adoles* or teen* or kid or kids or toddler or youth or pediatric* or paediatric*; Childhood cancer: leukaem* or leukem* or hematological malignanc* or haematological malignanc* or cancer or childhood cancer or lymphom* or neoplasm* or tumor or sarcoma* or chemotherapy or radiotherapy or pediatric oncology or paediatric oncology or pediatric cancer or paediatric cancer; Nutritional status/eating habits: diet* or food habit* or nutrition* or feeding or dietary intake or nutritional status or micronutrient intake or macronutrient intake or energy intake or protein intake or eating* or inadequate food intake or food intake or pleasure from food. Reviews were excluded from the results of the search strategy. Google Scholar was also screened to find additional articles.

Abbreviations: ALL, acute lymphoblastic leukaemia; DRI, dietary reference intake; RDI, recommended daily intake; RNI, recommended nutrient intake.

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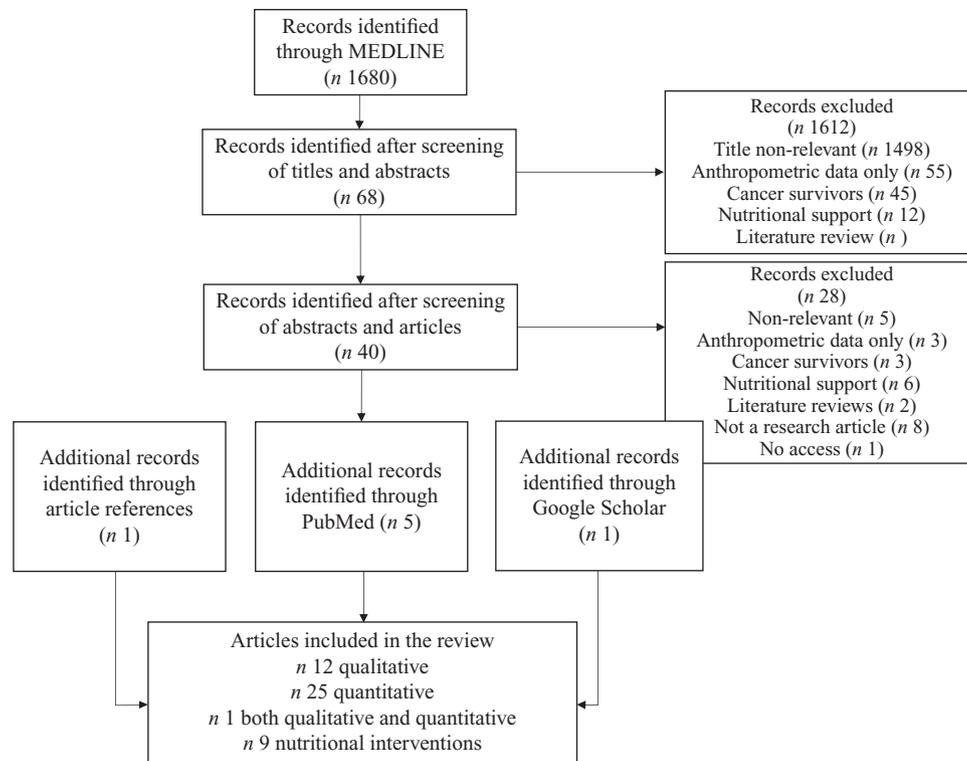


Fig. 1. Flow diagram describing search strategy of the critical review of the literature.

Articles were included if they were published in English in a peer-reviewed journal. Reviews and case reports were excluded. Studies were excluded if they addressed exclusively childhood cancer survivors, cancer prevention, screening evaluation or nutritional support. They were also excluded if the outcomes only included blood tests, anthropometric or body composition data or only compared with energy requirements without reporting nutrient or food intake. For articles reporting behaviours towards food, papers without a food-related thematic were excluded. Finally, for articles related to nutritional interventions, we excluded those without an educational aim, such as papers reporting medication-related interventions or framework development. After screening titles and abstracts, forty-seven articles were selected; thirty-eight studies were related to food intake and parental practices including twenty-five quantitative studies, twelve qualitative, and one both quantitative and qualitative. Nine studies were related to nutritional interventions.

Nutritional intake in children during cancer treatment

Study findings: energy intake

Seventeen articles reported quantitative data on patients' energy intake. Table 1 presents the key findings. Nine of these studies used food records to assess patients' energy intake⁽⁶⁻¹⁴⁾. Three studies compared intakes in subgroups of patients. Patients with haematological malignancies tended to have greater energy intake and were more likely to attain their energy requirements than those with solid tumours⁽⁷⁾. Sgarbieri *et al.*⁽¹⁵⁾ compared

low- and high-risk ALL and showed no difference in energy intake. Williams *et al.*⁽⁹⁾ found that, in children aged from 3 to 18 years, energy intake did not differ in the presence or absence of the caregiver. Furthermore, using ANOVA, the authors showed that age and time since diagnosis were positively associated with energy intake.

Five studies have compared patients' energy intakes with those of healthy controls. Typically, they consumed less energy than controls^(8,10,16) while the difference did not reach significance in two studies^(17,18). Galati *et al.*⁽¹⁷⁾ and Delbecque-Boussard *et al.*⁽¹⁶⁾ used indirect calorimetry to study energy expenditure in children with cancer^(16,17). Both found no difference between patients' and healthy controls' energy expenditure. However, Galati *et al.*⁽¹⁷⁾ showed that patients' metabolic rate was higher at diagnosis, but had decreased to be similar to controls after two cycles of chemotherapy.

Patients' intakes were also evaluated in comparison with reference values or standard requirements. Results are inconsistent: recently diagnosed patients had either similar^(12,19,20), lower^(6,10,15) or higher^(10,11,21) energy intake compared with standard requirements. Two studies showed that while mean energy intake was in line with requirements, results varied widely between individuals, especially at diagnosis^(6,20). Standards of energy intakes referred principally to dietary reference intakes (DRI) (*n* 2), RDA (*n* 2), recommended daily intakes (RDI) (*n* 1) and recommended nutrient intakes (RNI) (Canadian RNI, *n* 1; Malaysian RNI, *n* 1). Estimation equations such as Seashore and Schofield were used in three studies. Only a few studies mentioned the physical activity level used to determine patients' individual energy requirement^(10,11,21). Delbecque-



Table 1. Key findings on energy and protein intakes compared with various standard requirements in cross-sectional and longitudinal studies

Study and country	Participants (n)	Main objective(s)	Diagnosis	Tool(s) for nutritional data collection	Follow-up duration	Data collecting point(s)	Standard requirement(s)	Selected key findings related to standard requirements
Brinksma <i>et al.</i> ⁽¹¹⁾ The Netherlands	133, aged 0–18 years	To determine when changes in body composition occur during paediatric cancer treatment and which factors affect these changes	Various	3 d dietary records	1 year	0 (diagnosis), 3, 6, 12 months	Schofield's formula	Mean energy intake as a percentage of individual requirement varied from the beginning of the study (111 % of needs) to the end (96 % of needs) ($P=0.002$)
Brinksma <i>et al.</i> ⁽¹⁰⁾ The Netherlands	115, aged 0–18 years	To assess the adequacy of energy and protein intakes against three different norms	Various	3 d dietary records	1 year	0 (diagnosis), 3, 6, 12 months	Schofield's formula Healthy controls RDA	Energy intake was lower than RDA and controls at all time points. Mean patients' energy intake was higher than the needs determined with the formulas at 3 months and lower at 12 months. Energy intakes at diagnosis and at 6 months fulfilled patients' needs. Protein intake was higher than RDA and lower than healthy controls at all time points
Collins <i>et al.</i> ⁽²⁰⁾ Canada	99, aged 2–18 years	To segregate to the maximal extent the impacts of disease and treatment on nutritional status at the time of the diagnosis	Various	24 h recalls	–	Diagnosis	DRI	Mean energy intake was similar to the DRI (104 %) but individual results varied (range 29 to 203 %). The group mean protein intake exceeded the DRI (340 %, range 35 to 629 %)
Delbecque-Boussard <i>et al.</i> ⁽¹⁶⁾ France	15, aged 2–11 years	To determine the nutritional status and resting energy expenditure of children at diagnosis of leukaemia and their evolution during the initial 3-month period of intensive treatment	cALL	24 h recalls Indirect calorimetry	71 d	Diagnosis, days 22, 36 and 71	Healthy controls RDA	Patients' energy intake was lower than healthy controls at days 1 and 22 ($P<0.001$). Mean group intake at day 71 was significantly higher than at diagnosis ($P=0.01$). At all time points, mean group intake was lower than controls, but differences were only significant at diagnosis and day 22. At day 1, all patients had a protein intake above RDA (data not reported) and below healthy controls ($P<0.001$)
Fuemmeler <i>et al.</i> ⁽¹⁸⁾ USA	15, aged 4–18 years	To evaluate changes in physical activity and body composition, body mass and diet	Various	2 d dietary records	1 year	0 (diagnosis), 6, 12 months	Healthy controls	At each time point, there was a trend for lower energy intake in patients compared with controls. No difference between patients and controls was found for the mean percentage of energy from proteins
Galati <i>et al.</i> ⁽¹⁷⁾ Brazil	16, aged 7–15 years	To describe the nutritional status, energy expenditure, and substrate utilisation of children and adolescents with cancer compared with healthy children	Various	Usual intake FFQ Indirect calorimetry	–	Phases of the treatment not specified	Healthy controls	No significant difference between patients and controls was found for energy intake. Patients consumed significantly less energy from proteins than controls (15.81 v. 17.57 %; $P<0.05$)

Food habits during treatment of cancer

Table 1 *Continued*

Study and country	Participants (<i>n</i>)	Main objective(s)	Diagnosis	Tool(s) for nutritional data collection	Follow-up duration	Data collecting point(s)	Standard requirement(s)	Selected key findings related to standard requirements
Halton <i>et al.</i> ⁽¹²⁾ Canada	116, aged 2–15 years	To describe the impact of the disease and its treatment on growth and body composition in children with ALL from population-based referral areas in Canada	cALL	3 d estimated food records	2 years	0 (Diagnosis), 6, 12, 18, 24 months	Canadian RNI	Average energy intake during treatment was more than two-thirds of the RNI for 11 patients out of 16. Dietary intake was constant during the 2 years of therapy. Protein intake was over 100 % of RNI for all but one patient
Jansen <i>et al.</i> ⁽²²⁾ The Netherlands	16, aged 4–15 years	To describe energy intake and physical activity during treatment for ALL with intermittent dexamethasone	cALL	2 d dietary records	Unspecified	On- v. off-steroids treatment periods	Own control, healthy controls	Mean energy intake increased significantly when on steroids compared with off steroids: 63 % ($P < 0.001$). Mean intake on steroids was higher than healthy control energy intake ($P < 0.05$), while it was lower off steroids ($P < 0.05$)
Ladas <i>et al.</i> ⁽²¹⁾ USA, Canada	640, aged 1–18 years	To describe dietary intakes during cancer therapy among children with ALL	cALL	Indirect calorimetry FFQ	6 months	0 (Diagnosis), 3, 6 months (baseline data)	DRI (energy) RDA (proteins)	No difference in total energy intake was found between high-risk and low-risk groups and between males and females. No difference in protein intake was found between high-risk and low-risk groups and between males and females. Depending on their sex and risk classification, the percentage of patients achieving the acceptable macronutrient distribution range for protein was 98 to 100 %
Reilly <i>et al.</i> ⁽¹³⁾ UK	26, aged 4–10 years	To quantify the effect of dexamethasone and prednisone treatment on energy intake in children treated for ALL on MRC-97 during the maintenance phase	cALL	4 d of 24 h recalls	28 d	On- and off-steroids periods	Own control	Steroid treatment was significantly related to an increase in energy intake (approximately 20 %). No differences were found between dexamethasone and prednisone treatments
Sgarbieri <i>et al.</i> ⁽¹⁹⁾ Brazil	23, aged 1–10 years	To describe the protein–energy nutritional status and serum Zn and Cu of children with newly diagnosed leukaemia	cALL Various	24 h recalls	–	Diagnosis (before chemotherapy)	RDA	Patients' energy intake was similar to RDA. In all age groups, protein intake exceeded the RDA
Sgarbieri <i>et al.</i> ⁽¹⁵⁾ Brazil	45, aged 1–11 years	To follow anthropometric parameters and serum levels of Zn and Cu in a group of children undergoing ALL treatment	cALL	24 h recalls	18 months	Diagnosis, during induction, reinduction and maintenance therapy	RDA, DRI	At diagnosis, there was a reduced energy intake in 76 % of patients when compared with standard requirements. There was an increase in intake during induction and reinduction phases (130 % compared with diagnosis). A decrease in energy intake was recorded during maintenance. At diagnosis, 9 % of patients had protein intake below the RDA



Table 1 *Continued*

Study and country	Participants (<i>n</i>)	Main objective(s)	Diagnosis	Tool(s) for nutritional data collection	Follow-up duration	Data collecting point(s)	Standard requirement(s)	Selected key findings related to standard requirements
Skolinet <i>et al.</i> ⁽⁶⁾ Sweden	14, aged 5–16 years	To assess the daily oral intake of energy, protein, fat and carbohydrate in relation to current recommendations in children with a malignant disease during chemotherapy and to follow their weight development	Various	7 d dietary records	3 weeks	Diagnosis	RDI	At 1 d before chemotherapy, mean energy intake represented 91 % of the RDI and mean protein intake was 85 % of the DRI. Mean energy intake varied between individuals: three patients consumed less than 50 % of the DRI, six from 50 to 90 % and five above 90 %
Tah <i>et al.</i> ⁽⁷⁾ Malaysia	74, aged 3–15 years	To compare the nutritional status of paediatric patients with haematological malignancies and solid tumours	Various	3 d dietary records	–	Phases of treatment not specified	Seashore formula	More patients with solid tumours had energy intakes below requirements than haematological patients (89.2 and 67.6 %, respectively; $P < 0.05$). Energy intake was higher in the haematological group compared with the solid tumour group (1340 v. 1141 kcal (5607 v. 4774 kJ); $P < 0.05$). Mean protein intake was higher in haematological patients when compared with patients with solid tumours (53.4 v. 44.9 g; $P < 0.05$). The percentage of patients below the protein requirement was not different between the two groups
Tan <i>et al.</i> ⁽⁸⁾ Malaysia	64, aged 3–12 years	To evaluate the nutritional status and dietary intake among children with acute leukaemia	cALL Various	3 d dietary records	–	Undergoing chemotherapy Induction or consolidation phases	Malaysian RNI Healthy controls	Energy and protein intakes were significantly lower in patients compared with healthy controls (1370 v. 1660 kcal (5732 v. 6945 kJ), $P < 0.01$; 50 v. 62.3 g, $P = 0.003$). As a group, patients were achieving 95 % of the Malaysian RNI for energy and 185 % for protein (compared with 116 and 234 % for controls, respectively)
Warris <i>et al.</i> ⁽¹⁴⁾ USA	44, aged 3–16 years	To investigate the dexamethasone-induced changes in nutrients and energy intake in patients with ALL during dexamethasone pulses	cALL	4 d dietary records Dutch Eating Behaviour Questionnaire	5 d	On a corticosteroid treatment	Own control, Seashore formula	On day 1 on corticosteroid treatment, median intake was 19 % below the individual requirement. On day 4, it was 9 % superior. The increase between the two time points was significant (1103 v. 1482 kcal (4615 v. 6201 kJ); $P < 0.01$)
Williams <i>et al.</i> ⁽⁹⁾ USA	200, aged 3–18 years	To compare energy and protein intakes and the satisfaction of food services in hospitalised children when they dine with their caregivers or alone	cALL Various	3 d dietary records	–	Unspecified	With and without the caregiver	Similar energy and protein intakes were recorded when eating with a caregiver and alone (931 v. 934 kcal (3895 v. 3908 kJ) and 30.9 g v. 30.5 g)

DRI, dietary reference intake; cALL, childhood acute lymphoblastic leukaemia; RNI, recommended nutrient intake; ALL, acute lymphoblastic leukaemia; MRC-97, Medical Research Council protocol 97; RDI, recommended daily intake.

Boussard *et al.*⁽¹⁶⁾ raised the importance of assessing intake across time: ALL patients consumed less energy when compared with healthy peers at diagnosis and at day 22 of treatment, but this did not persist at days 36 and 72. Other prospective studies showed no significant variations across time^(10,11,18), only presented baseline data⁽²¹⁾ or reported the mean intake of all the data collected during treatment⁽¹²⁾. Ladas *et al.*⁽²¹⁾ presented a multicentric study on 640 patients with ALL and found no difference in the baseline energy intake in function of level of risk at diagnosis (standard and high-risk) and sex. More than 70 % of the patients had an energy intake that exceeded the recommendation⁽²¹⁾. Some studies assessed food intakes during different chemotherapy cycles, while others assessed them between. In children with various diagnoses (n 14), Skolin *et al.*⁽⁶⁾ found that median energy intake was 91 % of RDI at 1 d before the first chemotherapy and decreased weekly thereafter to 71, 66 and 54 % of RDI.

Three studies described the changes in energy intake before and during the administration of corticosteroids^(13,14,22). They all showed an elevated energy intake when on steroids compared with off-steroid periods. Jansen *et al.*⁽²²⁾ found that patients' intakes were significantly lower than controls when off steroids and significantly higher when on steroids. Warris *et al.*⁽¹⁴⁾ found similar results. When using Schofield formulas to calculate the energy requirement adjusted for disease, activity, growth and energy absorption factors (for enteral feeding), they found that, off steroids, the mean intakes represented 81 % of individual requirement, compared with 109 % when on steroids.

Study findings: macronutrient intake.

Protein intake. In the general adult and paediatric population, a sufficient protein intake is necessary to maintain adequate lean body mass. Protein intake during childhood cancer has been examined in twelve studies (Table 1). Of the studies, seven found that, at diagnosis, children's protein intake met^(12,15,21) or exceeded^(8,10,16,19,20) the recommendations. Skolin *et al.*⁽⁶⁾ found that the mean protein intake of fourteen patients was 85 % of the requirement, being the first study to show a mean intake below the standard requirement⁽⁶⁾. Only Tah *et al.*⁽⁷⁾ used the Seashore formulas based on the N:energy ratio. Specifically, 65 % of those with solid tumours did not attain Seashore recommendations compared with 43 % of haematological patients⁽⁷⁾. All other studies used general protein recommendations based on sex and age without correction for hospitalisation or disease. On the other hand, when compared with healthy peers, four studies found lower protein intake in children undergoing cancer treatment^(8,10,16,17) and two did not observe a significant difference^(18,19). In two studies conducted in Brazil, in which the majority of patients met or exceeded the RDA for proteins, the main sources varied from rice, beans and milk in one study⁽¹⁵⁾ to milk, meat, eggs, pasta and cereals in the other⁽¹⁹⁾.

Fat and carbohydrate intakes. Fat and carbohydrate intakes have been less studied in the context of paediatric cancer. In a prospective study, Delbecque-Boussard *et al.*⁽¹⁶⁾ found that

the lipid intake of patients with ALL was lower than of healthy controls at diagnosis, 22 and 36 d post-diagnosis. The authors also recorded, compared with controls, lower carbohydrate intake at diagnosis and at day 22⁽¹⁶⁾. Another study showed no difference for these macronutrients between controls, children with solid tumours and with non-solid tumours⁽¹⁷⁾. Finally, Tan *et al.*⁽⁸⁾ found that lipid intake was significantly lower in patients with ALL at induction or consolidation phases, compared with healthy controls. No further analysis was made to determine if the intake of these macronutrients was associated with treatment phase.

Micronutrient intake and deficiency. Several studies have reported intakes of Mg⁽²³⁾, Ca⁽¹⁸⁾, antioxidant vitamins (vitamins A, E and C)^(7,21,24-27), Zn and Cu^(15,19), Na⁽¹⁴⁾ or of a variety of other micronutrients^(8,17) during childhood cancer. Considering these studies, vitamin C was the vitamin for which the RNI was the most frequently reached by patients^(7,25,27). Conversely, one study conducted in Brazil found that, based on serum levels, 70 % of patients had vitamin C deficiency (serum levels below 0.2 mg/dl (11.4 μ mol/l))⁽²⁶⁾. They also pointed out that patients who consumed less than three portions of food sources of vitamin C tended to be more deficient, without describing their intake. Neyastani *et al.*⁽²⁷⁾ and Atkinson *et al.*⁽²³⁾ showed that assessing micronutrient intake alone may not estimate status adequately: while patients attained their needs in vitamin C and Mg, blood concentrations of these nutrients were below the normal range for Mg and within the normal range for vitamin C^(23,27). Compared with healthy controls, ALL patients consumed twice the vitamin C intake, but their mean serum levels were ten times lower⁽²⁷⁾. Serum total antioxidant capacity was also lower in ALL patients than controls and the authors hypothesised a perturbed vitamin C utilisation and/or absorption⁽²⁷⁾. Of note, in controls, vitamin C intake was obtained mostly from fresh fruits and vegetables while, in patients, fruit juices, fresh fruits and vitamin supplements were the main sources.

In turn, Sgarbieri *et al.*⁽¹⁵⁾ found that Zn intake at diagnosis was below the RNI in 24 % of children, although the mean serum levels remained in the normal range. Compared with healthy controls, Galati *et al.*⁽¹⁷⁾ observed that patients had lower intakes of Zn, P, riboflavin and vitamin B₁₂ and a higher intake of K. Conversely, Tan *et al.*⁽⁸⁾ reported that patients' micronutrient intake was not significantly different from controls. In general, regardless of time point or country, patients generally did not achieve the standard requirement (RDA and RNI) for vitamin E^(21,24), vitamin A or β -carotene^(7,24), vitamin D⁽²¹⁾, Zn⁽¹⁹⁾ and Cu⁽¹⁹⁾.

Food groups. When considering food groups, the most studied has been fruit, vegetable and milk consumption. Milk consumption was not found different between patients and controls. Paediatric cancer patients had a lower^(28,29) or similar^(17,18) consumption of fruits and vegetables when compared with healthy peers. The consumption of fruits and vegetables ranged from no to two portions daily, which is drastically below the five portions recommended by the USDA (United States Department of Agriculture) guidelines⁽¹⁸⁾. In the study of Galati *et al.*⁽¹⁷⁾,

children with cancer and controls consumed fewer portions of vegetables and dairy products than recommended but ate enough fruits. A trend for higher meat consumption than recommended was seen in the cancer group. Fast food and salty snack consumption was similar between patients and controls, except for on-steroid patients who consumed more non-core foods compared with controls and with off-steroid groups^(18,28). In the study, parents were asked to report non-core foods, defined as non-healthy foods that include, for example, pizza, ice cream and hot dogs, chips and French fries⁽²⁸⁾. Only one study assessed soft drinks and found limited intakes in both patients and controls (3 d mean intake of 50 ml in patients and 325 ml in controls)⁽¹⁸⁾. Finally, So *et al.*⁽³⁰⁾ described three meal patterns in children with cancer, based on the consumption of meat, fish, fruits and vegetables, rice and fried chicken. They stratified the risk of being overweight at diagnosis according to the score of each pattern. Patients with high scores for fish, eggs, fruits and vegetables were less likely to be overweight at diagnosis and after 24 months. The group with a high score for fried meat and fish were more likely to be overweight at diagnosis and after 6 months. Also, patients included in the highest tertile of this group were at increased risk of premature death when compared with those in the lowest tertile. No correlation was established between other food patterns and all-cause mortality. This study stresses that the quality of food can influence patients' weight gain patterns and survival.

Limitations

Energy intake. One of the difficulties in assessing the adequacy of intake in childhood cancer is to determine the appropriate standard reference value. It has been pointed out that, because of the lower lean mass and reduced physical activity during cancer treatment, comparing energy intake with those of healthy children is debatable even though differences in energy expenditure were not found^(1,16,18,29). Also, with the exception of the DRI, all the reference values used in the reviewed articles were determined as ranges of values for a specific population of age and sex and did not take into account physical activity, weight or height. The RDA is defined as the average daily intake sufficient to meet the nutrient requirements of 97–98 % of a population⁽³¹⁾. It has been suggested that the RDA does not accurately define intakes of individuals or groups, because it could overestimate energy needs^(3,31). In 1990, the RDA and Canadian RNI were replaced by the DRI in Canada and the USA. The DRI for energy are based on the estimated energy requirement, that is the need for energy to maintain health according to age, weight, height and level of physical activity and are adapted for children's growth needs⁽³¹⁾. Assessing the adequacy of intakes of individuals or groups by comparing with the RDA or another reference value is not recommended by the Institute of Medicine of the National Academy of Sciences in the USA⁽³¹⁾. To conclude on the sufficiency of energy intake, it is rather essential to consider individual variations in weight since specific needs vary. Accordingly, one study using RDA as a reference concluded that children with cancer have reduced energy needs due to lower physical activity, lesser lean body mass and stagnation in growth⁽¹⁰⁾. Also, interpretation of data

is difficult because only a few studies have defined the thresholds of adequate intake. For example, a mean intake reaching 85 % of the reference value was classified as insufficient in a study⁽⁷⁾, but other authors have not defined the minimum values that were considered sufficient^(15,20).

In children with cancer, depending on their condition, adding activity and stress factors to energy needs has been proposed⁽³²⁾. None of the studies reviewed measuring general energy intake has used an adjustment factor, with the exception of one that employed the Seashore equation which includes adjustment factors for hospitalisation, illness and growth⁽⁷⁾. Conversely, Brinksma *et al.*⁽¹⁰⁾ justified not using an illness adjustment factor by the lack of studies to support it.

The small sample sizes make difficult the interpretation of data relative to energy intake during childhood cancer. In many studies, differences did not reach statistical significance because of limited power. Sample sizes were too small to be stratified into subgroups of interest such as diagnosis, age, time since diagnosis, chemotherapy cycles and nutritional status.

Moreover, often the only data available were the mean group intake and/or individual mean intake gathered at selected time points during treatment. Studying mean energy intake in heterogeneous populations may not represent specific subpatterns of individuals. These limitations could perhaps mislead on patients' actual nutritional intake or on intake patterns during treatment or among subgroups.

Macronutrient and micronutrient intake. It is difficult to establish a reference value for protein consumption in childhood cancer, knowing that healthy children typically eat more proteins than needed^(33,34). The optimal protein requirement to support physiological functions according to age, sex and stage of the treatment remains unknown. As mentioned by some authors, it is important to detail the benefits and risks associated with an increased consumption of proteins⁽¹⁰⁾, especially the impact on lean body mass and the immune system. Also, no detailed analysis has been made to assess the type of proteins, carbohydrates or lipids consumed. For example, the studies included in the present review were performed in six countries, which could result in regional and cultural differences affecting the type and quality of the macronutrient consumed.

Moreover, it is important to point out that micronutrient intake below the RDA does not indicate deficiency, which requires clinical and biochemical assessments. However, seven of the thirteen studies that have evaluated micronutrients in paediatric cancer only gathered data on nutritional intake without considering deficiency^(7,8,14,17,18,21,25).

Editorial comments

Considering the many factors that can influence dietary intake and requirements, such as phase of treatment, infections, chemotherapy agents^(15,35) and eating patterns, it would be ideal to consider these factors when collecting and analysing nutritional data. The methodology used has a great impact on the external validity of the data collected. Receiving chemotherapy or not at the moment of nutritional evaluation can

contribute to explain the discrepancies between studies. For example, three studies on patients with ALL have confirmed the considerable impact of steroids on energy intake and highlighted the importance to carefully consider treatment when assessing intake or developing nutritional interventions^(13,14,22). Also, a considerable number of studies had a cross-sectional design that does not provide a representative evolution of patients' nutritional profile. A prospective evaluation of children's intakes and needs could benefit the development of personalised interventions tailored for each phase of cancer treatment. Moreover, it is possible that the counselling provided during studies influences or modifies patients' diet. In the study of Galati *et al.*⁽¹⁷⁾, patients tended to consume more portions of meat than recommended by the national guidelines, but if nutritional counselling addressed protein intake and quality was not documented in the study.

Describing nutrient and energy needs in paediatric cancer patients is complex because of the many factors that could make an impact on energy balance. This population is at risk of malnutrition, lean-mass deficit and weight loss and, on the other hand, of overnutrition, fat mass increase and obesity. It is still unknown how cancer and treatment could affect the absorption, metabolism and utilisation of various vitamins and elements, which could alter patients' needs and modify normal range values for this population. It is our opinion that it might be inappropriate to use a value of requirement only based on weight and age to classify the energy and nutrient intake of a heterogeneous group of patients that are undergoing various stages of treatments and have different diagnoses. While the above-mentioned factors are poorly documented in most studies, they could contribute to explain the discrepancies in macronutrient and micronutrient status observed in the literature. Also, it would be relevant to examine in depth the quality of children's diet. This could be studied with dietary patterns (for example, Mediterranean, prudent, Western) or with macronutrient content, food groups or diet types (for example, polyunsaturated fats, red meat, vegetarian diet).

Briefly, there is a need to harmonise the reference values for energy and nutrient requirements and to exhaustively document the collection methods used to assess and compare nutritional intake in this population. A multitude of factors appears to affect dietary intake and thus alter the accuracy of the mean intake within a group. It is our opinion that prospective studies should be prioritised. Moreover, it would be important to document the phase of treatment and the medication taken when collecting nutritional data. This would improve result interpretation and comparisons between studies. Besides, numerous standard reference values have been used to assess adequacy of intake. Providing data on absolute energy intake, and not only as percentage of a standard reference, could allow comparison between studies and consequently lead to new findings on the nutritional status of children with cancer. We believe that all these aspects should be documented when assessing nutritional intake and analysing data.

Principal determinants of behaviours towards food

Study findings

Here, we report the perceptions of patients, parents and nurses to describe the determinants of behaviours towards food in children with cancer. This section mostly refers to twelve qualitative studies^(36–47), to one study reporting parental practices using quantitative analysis⁽⁴⁸⁾ and to another one describing both qualitative and quantitative data⁽²⁸⁾. Most of the studies reviewed have collected data with in-depth or semi-structured interviews, while one study used only focus groups⁽⁴³⁾ and two used photo-voice as stimuli for focus groups⁽⁴⁴⁾ or interviews⁽³⁶⁾.

Treatments and side effects. Qualitative studies raise possible causes that can explain the reduced intake reported in some quantitative studies. Parents, children and nurses reported that side effects including nausea, sore mouth, vomiting and altered smell or taste were associated with lower food intake and appetite^(36–38,40–43). Interviews with twenty-nine parents (including eight parent dyads) exposed that altered taste is the main disruptor of children's eating habits, leading to food aversions⁽³⁸⁾. In a study that aimed to better understand how children were coping with nausea and mucositis during chemotherapy, three of eight children mentioned having developed their own strategies to limit treatment side effects, such as choosing well-tolerated foods⁽³⁷⁾. Neutropenia and fear of infections were also reported as important factors that affect children's food intake^(36,40,44,45). Food restrictions were mentioned by the five mothers in a focus group as a cause of frustration related to their child's food intake and affecting the pleasure of eating⁽⁴⁴⁾. These restrictions, combined with treatment side effects such as altered taste and smell, were also identified as lessening the pleasure of eating in interviews with thirty-one patients aged between 5 and 21 years⁽⁴⁵⁾.

Regarding the administration of corticosteroids, parents have expressed their difficulties in managing their child's cravings, urgency to eat and pickiness^(36,38,46), but studies have not assessed a specific time pattern for these behaviours. In one study, it was reported that cravings and unhealthy nutritional habits could persist weeks after active treatment⁽⁴⁶⁾. A study comparing forty-three parents of children with ALL and thirty of healthy controls showed that parental practices have a different impact on intake depending if the child is on steroid treatment or not. In the on-steroids group, parental overprotection and inconsistent discipline were associated with an increase in non-core food intake, but this was not observed in off-steroid and control children⁽²⁸⁾.

Three studies have described parental concerns about their child's weight and growth^(39,41,48). Fleming *et al.*⁽⁴¹⁾ exposed that more than half of the parents (thirty-eight in total) expressed concerns about weight loss, whereas only a small proportion was preoccupied with weight gain. Parents were afraid that weight loss would affect treatment efficacy, a preoccupation that was confirmed by Skolin *et al.*⁽³⁹⁾. In this study, parents of eleven children were interviewed. When asked about their perception of their child's eating, six parents reported that the child was eating poorly. One parent explained that the prolonged reduced intake was stressful because of its potential to negatively affect

treatment outcome. Three parents reported increased appetite during steroid treatments and two of them considered this as reassuring⁽³⁹⁾. This was corroborated by another study that found that the majority of fifteen mothers interviewed were pleased when their child's appetite was increased, as it could counterbalance the poor eating periods⁽⁴⁶⁾.

Parental feeding practices. Parental feeding practices influence eating patterns of young children and teenagers^(49,50). Practices reported from the qualitative studies included in the present review are summarised in Table 2. Briefly, the majority of parents of a child with cancer have expressed frustration, anxiety or concerns over their child's eating patterns^(36,39,41–44). Using questionnaires, 37.5 % of nurses (*n* 24) reported that children with cancer might refuse to eat in order to prove their autonomy and to gain control, especially during hospitalisation⁽⁴⁰⁾. This issue was reported in another study by 12 % of the nurses interviewed⁽³⁸⁾.

During cancer treatment, parents feel responsible for their child's food intake but are rather powerless at facing some treatment-related difficulties such as cravings or increased risk of food poisoning^(36,42,47). Interviews with twelve parents revealed their high level of anxiety towards the risk of infections⁽⁴²⁾. Other parents reported to have changed their feeding approach and became laxer in regards to their eating rules^(28,46). In a study including forty-three parents of children from 2 to 6 years old treated for ALL, Williams *et al.*⁽²⁸⁾ assessed parents' discipline and feeding practices. They associated the different styles with children's intake and compared the results with parents of healthy children. They found that parents of a child with cancer were more permissive for house and eating rules than controls. They concluded that, for healthy children, overprotection was associated with an increased consumption of fruits and vegetables whereas it had the opposite effect for children with cancer. In another qualitative study, most of the fifteen parents interviewed reported increased laxness in their parenting rules since the diagnosis, as they believed it could help them and their child overcome medical appointments and procedures⁽⁴⁶⁾.

To better handle the difficulties during treatment, parents have reported adapting their strategies according to side effects and the child's behaviour. For example, parents typically fed their child certain types of foods when he feels nauseated or is on steroids⁽³⁷⁾. Coercion, pressure and threatening to use nutritional support are strategies that are utilised by parents^(39,41,47), but they were not associated with increased intake in healthy children^(51,52).

Parents have reported that a positive ambiance and the presence of family members during mealtime encourage the child to eat during periods of poor appetite^(36,39). One mother stated that the ambiance was more important than the food itself to make her child eat⁽³⁶⁾. A parent reported that a child who has developed a trusting relationship with a nurse will, in his or her presence, better accept hospital food⁽³⁹⁾. Via questionnaire, 41 % of nurses (*n* 24) reported that feelings of loneliness or boredom negatively affect children's eating⁽⁴⁰⁾. Having parents going through a divorce or conflicts during mealtimes were also identified as factors negatively affecting food intake⁽⁴¹⁾.

Table 2. Strategies used to manage poor appetite as reported by parents or nurses

Type of strategy	Specific strategies
Social impact	To eat together as a family or with a significant person ⁽³⁶⁾
Impact of food offered	To experiment different foods ^(36,37)
	To honour preferences ^(37,39)
	To reduce fast food, spicy, strong-odoured and heavy meals ⁽³⁷⁾
	To optimise hydration ⁽³⁷⁾
	To purvey food to the ward ^(37,38,40,47)
	To not verify if the meal is nutritious or not ⁽³⁸⁾
	To provide nutritious meals ^(37,41,43,44)
	To be flexible ^(37,38)
	To eat in a restaurant ⁽³⁶⁾
	To give the child what he asked for ^(36–38,41)
	To enrich foods with fat or sugar ⁽³⁹⁾
	To give familiar food that is better tolerated ^(38,40)
	To serve traditional foods (for example, Chinese herbs) ^(43,47)
	To improve the nutritional quality of the recipes ⁽⁴⁶⁾
To have a significant person serve the food ⁽³⁹⁾	
To prepare specific meals ^(46,47)	
To restricted the intake of certain foods according to parents' beliefs ⁽⁴³⁾	
Timing impact	To be flexible when the child is hungry or is disposed to eat ^(37,40)
Strategies on how to present food	To use a distraction ⁽³⁷⁾
	To use medication to prevent side effects ⁽³⁷⁾
	To take naps ⁽³⁷⁾
	To serve foods and commercial energy drinks in an attractive way ^(38,40)
	To be coercive ⁽³⁹⁾
	To enter in a conflict with the child ^(41,47)
	To let the problems solve by themselves ⁽³⁹⁾
	To have parents support each other ⁽⁴¹⁾
	To use verbal pressure ⁽⁴¹⁾
	To threaten the child with using a nasogastric tube ⁽⁴¹⁾
	To use food and non-food rewards ^(41,46)
	To explain to the child why he needs to eat ⁽⁴¹⁾ and to encourage him ⁽⁴⁶⁾
	To provide food according to blood values ⁽⁴²⁾
	To involve the child in meal preparation ⁽³⁶⁾
To watch cooking television programmes or to play food games ⁽³⁶⁾	
To maintain normal routines ⁽³⁶⁾	
To offer food constantly ^(41,46)	
To avoid conflict ⁽³⁹⁾	
To offer forbidden foods occasionally ⁽⁴²⁾	

Beliefs and culture can also influence how parents cope with their child's disease: those who believe that healthy habits can improve the efficacy of treatment will be more prompt to offer foods with higher nutritional value^(42,43). Focus groups highlighted strategies to provide adequate nutrition including to stimulate the child's appetite, to provide food supplements, to restrict some forbidden foods and to prepare soup⁽⁴³⁾. Other strategies reported by parents include adjusting nutrition according to blood values and preferring organic foods⁽⁴²⁾. In some countries, the use of alternative therapies such as Chinese herbs or soups is also a reassuring strategy for parents^(43,47). Generally, when asked about nutrition appointments during treatments, parents only remember the pieces of advice related to food

Table 3. Food preferences during cancer treatment reported by children, parents and nurses

	Children	Parents	Nurses
Preferred foods	Savoury foods/salty snacks ⁽³⁶⁾ Foods strong in flavour ⁽³⁶⁾ Pancakes ⁽³⁸⁾ Pasta/rice/potato dishes/bagels ^(37,38) Taco shells ⁽³⁸⁾ Popcorn ⁽³⁸⁾ Fried meals (chicken or fish) ⁽³⁸⁾ Hot dogs ⁽³⁸⁾ Soups and liquids ⁽³⁷⁾ French fries ⁽³⁷⁾ 'Steak and cheese subs' ⁽³⁷⁾	Salty foods ⁽³⁸⁾ Spicy and sour foods (for example, tomato soup, pickles, olives) ⁽³⁸⁾ French fries ^(37,38) Fried chicken ^(37,39) Broccoli and vegetables ⁽³⁹⁾ Combinations of foods not usually eaten together (for example, pickled cucumber + sour milk) ⁽³⁹⁾ Foods rich in carbohydrates ⁽³⁹⁾ Ice cream ⁽³⁷⁾ Hard-boiled eggs ⁽³⁷⁾ Cold cereals ⁽³⁷⁾ 'Tuna Helper' ⁽³⁷⁾ Hamburgers ⁽³⁷⁾ Bland, light foods (for example, jello, cheese, Cheerios, applesauce, yogurt) ⁽³⁷⁾	Salty foods and snacks ⁽⁴⁰⁾ Soups ⁽⁴⁰⁾ Pasta ⁽⁴⁰⁾ French fries ⁽⁴⁰⁾ Chips ⁽⁴⁰⁾ Hamburgers ⁽⁴⁰⁾ Hot dogs ⁽⁴⁰⁾ Food strong in flavour ⁽⁴⁰⁾ Carbonated drinks ⁽⁴⁰⁾ Foods/drinks from well-known brands ⁽⁴⁰⁾ Foods atypical for the season (for example, berries in the winter) ⁽⁴⁰⁾
Disliked foods	Sweet foods ^(36,38) Hospital food ^(36,38,45) Red meat/hot dogs/chicken ⁽³⁸⁾ Potato/rice ⁽³⁸⁾ Chocolate ⁽³⁸⁾ Commercial energy-dense drinks ⁽³⁸⁾	Chocolate ⁽³⁸⁾ Hospital food ⁽³⁸⁾ Commercial energy-dense drinks ⁽³⁸⁾ Meat ⁽³⁹⁾ Ginger ale ⁽³⁷⁾	Sweets ⁽⁴⁰⁾ Pork ⁽⁴⁰⁾ Bitter beverages ⁽⁴⁰⁾ Commercial energy-dense drinks ⁽⁴⁰⁾

enrichment or to limit weight gain⁽³⁷⁾. Sari *et al.*⁽⁴²⁾ found that, globally, most parents do not understand or recall information provided by the nurse or the doctor before hospital discharge. Also, parents have reported being hesitant to ask for nutrition advice from health professionals^(36,42). In fact, their principal sources of information are the Internet, magazines and other parents⁽³⁶⁾.

Food preferences during cancer treatment. Children's food preferences during cancer treatment are not well studied or understood. Table 3 lists the food preferences reported in qualitative studies. Children and their parents stated that savoury and salty foods are preferred to sweet foods^(36,38,40), which was confirmed by nurses⁽⁴⁰⁾. Bland and light foods, such as pasta and yogurt, are preferred and well tolerated during periods of poor appetite or nausea, while strong-flavoured and fried foods are favoured when on steroids^(37,39). Familiar foods were also reported as well tolerated, especially compared with hospital food or during periods of poor appetite⁽³⁹⁾. Some parents stated that they constantly offer a variety of foods in order to tempt their child to eat even though they found that practice burdensome⁽³⁶⁾. Likewise, more than the half of the eight parents in the study of Green *et al.*⁽³⁷⁾ stated this tactic as an effective strategy to get their child to eat.

Meat, energy-dense commercial drinks and hospital foods were mostly disliked by patients^(36,38,39,45). For example, interviews with twenty-one children revealed that 38, 33 and 29 % disliked meat, hospital food and sweets, respectively⁽³⁸⁾. In this study, a teenager reported consuming energy-dense commercial drinks only to avoid enteral feeding⁽³⁸⁾. Skolin *et al.*⁽³⁹⁾ proposed that energy drinks are perceived by children as medication rather than food, which could explain their poor appreciation.

Refusing to eat hospital foods has been reported in almost all studies included in the present review. This was observed in children of all ages^(36–39,45), but was more frequent in teenagers^(38,40).

The look, taste and smell of food were the main reasons evoked by children not to eat. Moody *et al.*⁽⁴⁵⁾ reported that 33 % of teenagers aged 8–17 years disapproved of the preparation and the selection of meals, and sometimes their smell. Gibson *et al.*⁽³⁶⁾ described the same complaint in twenty-three of the twenty-four children interviewed who also criticised the unfamiliar taste and repulsing aspect of foods. Parents also often criticised the hospital meal schedule, describing it as inflexible and non-favourable to optimise the child's intake^(36–38,40,47). While nurses emphasised the importance of a flexible meal schedule, they also stated that the majority of parents had a favourable opinion of the hospital food service, but the authors did not explain this positive perception⁽⁴⁰⁾.

Children have reported that foods purveyed by their parents and familiar foods were better tolerated^(38,39). Accordingly, six of eleven parents reported bringing food to their child during hospitalisation⁽³⁹⁾. The majority of the seventeen nurses interviewed mentioned that most of the food consumed by the children on the ward was purveyed by parents⁽³⁸⁾. Besides, a quantitative study comparing in-home with hospital daily intake showed a higher intake at home⁽⁶⁾.

Limitations

Qualitative studies allow to better comprehend the motivations and difficulties that parents experience in the context of childhood cancer, but these perceptions cannot be generalised to all families. For instance, some parents were interviewed after the acute phase of treatment, so their perception could be different from parents whose children are undergoing treatment at interview^(37,39,41).

Considering the large number of strategies reported by parents, it is possible that they do not understand which one could be helpful or not. Also, parents may not be prepared to respond to sudden changes in their child's food preferences

and selectivity. The sickness and schedule of treatments increase the burden of daily responsibilities. Like every parent, they have to manage the child's normal eating behaviour development such as neophobia, need for familiarity and routine⁽⁵³⁾. Expressing the desire for autonomy at preschool age is a normal behaviour⁽⁵³⁾, but frontiers between normal behaviour and cancer- or side effect-related comportment are unclear. While the increased laxness is not well accepted by the parents themselves, the disease of their child is an emotional challenge. Parents understand that it will not facilitate the development of healthy lifestyle habits, but the need to protect their child surpasses this consideration⁽⁴⁶⁾.

Studies reveal that the sources of information used by parents are variable and that they do not always understand the advice from health professionals. Thus, parents use a variety of strategies to make the child eat without knowing if they are beneficial to the long-term development of healthy nutritional habits⁽⁴¹⁾. Additionally, little to no guidelines are available to guide health professionals on how to inform parents on the strategies to use during treatment.

In summary, results and perceptions presented in this review allow the identification of some general behaviours and certain types of foods preferred and disliked, but do not permit clarification of the impact of treatments and side effects on food preferences.

Editorial comments

A variety of factors can affect how parents manage their child's food intake and behaviours during treatments. For example, periods of poor intakes are difficult for the parents as they valorise weight gain that is perceived as a sign of wellness. Besides, the neutropenic diet is a source of frustration for many parents. As a matter of fact, it can be restrictive and requires, for example, avoiding raw fruits and vegetables in order to reduce the risk of foodborne infections. It is promoted in some hospitals, but not in others, as there is a lack of proof of its efficacy in the paediatric oncology population^(54,55).

As the importance of family mealtime has already been established for the quality of intake in healthy children^(56,57), perceptions of parents and nurses tend to demonstrate that it could have the same positive impact during cancer. In fact, conflicts related to food intake can create a negative ambiance resulting in the child limiting or avoiding mealtime. Also, finding the right timing to promote eating seems to be an important factor: apart from choosing a moment when the child is rested, it is crucial to respect his hunger.

Besides, children typically avoided hospital food and oral supplements. It is our opinion that parental and professional pressure related to the consumption of these types of foods negatively affects their likeability. Finally, children's food preferences are known to vary during the course of cancer treatment as some chemotherapeutic agents' side effects can influence tastes. As pointed out in several studies, treatment-related changes in taste affect children differently. Thus, professionals should advise parents to adapt their feeding strategies to their child's condition and to seize the opportunity to introduce new types of foods.

Interventions on nutritional education

We report nutritional interventions (n 9) (Table 4) that have an educational aim to improve nutritional or cooking knowledge or eating habits in patients with cancer and their families. Almost half (n 4) of the studies were conducted with ALL patients⁽⁵⁸⁻⁶¹⁾ and, in three studies interventions were performed during the maintenance phase⁽⁵⁹⁻⁶¹⁾ when patients are prone to weight gain.

Study findings

In a randomised study, the intervention consisted of monthly nutritional counselling for 1 year⁽⁵⁹⁾. The goal was to limit weight gain in children treated with corticosteroids. The counselling sessions included a motivation component to help families achieve their objectives. The control group received standard nutritional care. The intervention resulted in lower energy intake from baseline to follow-up for the intervention group (25.9%; P = 0.0522), but the difference in intake between groups was not statistically different. The intervention also led to a significant increase in Se and glutamic acid intakes. Anthropometric data, such as BMI and waist circumference, were not different between groups.

Hill *et al.*⁽⁶¹⁾ compared weight gain between a control group (n 34) recruited before the initiation of the intervention and an intervention group (n 33) who received three nutrition sessions with a dietitian during the first 6 months of the maintenance phase. The counselling was standardised and included goal setting for the family. BMI Z-score at diagnosis was documented from files. The authors showed that both the BMI Z-score at diagnosis and its variation from diagnosis to maintenance were associated with BMI during the maintenance phase. When controlling for these factors, multivariate analysis showed a lower increase in BMI Z-score in the intervention group compared with the control group. Since weight gain before the maintenance phase appears to be a determinant for the success of a nutritional intervention, the authors raised the importance of intervening early in the process of cancer treatments.

Moyer-Mileur *et al.*⁽⁶⁰⁾ conducted a 12-month randomised home-based nutritional intervention that included a physical activity component and took place during the maintenance phase. The physical activity and nutrition programme consisted of monthly assessments in which families (n 6) were provided with information and recorded their nutritional achievements. The control families (n 7) received standard nutrition counselling. Energy and nutrient intakes were assessed every 3 months. No intra- or intergroup difference in dietary intake was found at any time point of the study. Level of physical activity improved with time: at 12 months, the total minutes of physical activity was significantly greater in the intervention than in the control group. Also, the total minutes of physical activity were negatively correlated with weight, BMI and lean body mass, although the correlation with lean body mass did not persist after 6 months of intervention.

Similarly, Gibson *et al.*⁽⁵⁸⁾ described the protocol of a randomised technology-based nutrition and physical activity intervention destined to childhood ALL patients during the maintenance phase. The study will consist of a weekly intervention with coaching in nutrition and in physical activity with

Table 4. Summary of interventions on nutritional interventions

Study	Age (years)	Participants (n)	Intervention	Participants	Outcomes	Key results
Beltran <i>et al.</i> ⁽⁶⁴⁾	9–12	28	Assessment of feasibility and acceptability of an intervention destined to enable preadolescents to modify obesity-related lifestyle behaviours using videogame technology by targeting fruit and vegetable intakes, physical activity, and television changes (sedentary behaviour)	Out-patients with cancer and survivors	Qualitative interviews to evaluate: Major barriers to diet- and physical activity behaviour change, videogame function, game play	Some children expressed sadness or frustration with the death of the character if goals are not attained. Most children in all groups reported enjoying the story and games and reported being receptive to a game for health
Chaput <i>et al.</i> ⁽⁶³⁾	< 21	NA	Development of a family-based nutrition education and cooking workshop curriculum in a paediatric oncology setting that addresses the nutritional issues encountered during treatments while promoting the adoption of healthy eating habits for the prevention of long-term cardiometabolic effects	Patients undergoing treatments for childhood cancer and their families	Short term: Participants' perception of knowledge acquisition, behavioural intention and satisfaction. Medium-term: Participants' anthropometric profile, quality of the diet, and circulating biomarkers of metabolic health	Protocol
Garcia <i>et al.</i> ⁽⁶⁷⁾	NA	8	Development and two-step validation of a culturally appropriate nutrition education pamphlet by the International Outreach Program The objective was to determine the content relevance of specific items and of the pamphlet as a whole when applying the content validity index	Five experts (nurses, dietitian, translator) Three nurses from Honduras, Guatemala, and El Salvador	Spanish-language ten-item content validity scale	All three nurses stated that no important food safety recommendations had been omitted from the pamphlet, and no portions of the pamphlet should be removed from the publication
Gibson <i>et al.</i> ⁽⁵⁸⁾	4–12	12	Weekly, coaching sessions on nutrition and physical activity and physical activity classes delivered by group video conferencing. The control group (n 12) will be taught standard recommendations from the paediatric oncologist to eat a well-balanced diet and to perform physical activity as tolerated. Duration: 6 months	Children with ALL in maintenance phase and their family	Anthropometrics Physical activity Energy and macronutrient intakes	Protocol
Hill <i>et al.</i> ⁽⁶¹⁾	1–20	33	The nutrition intervention included three one-on-one visits with a registered dietitian. Patients will get five handouts that address the educational needs of families and children undergoing treatment for ALL. The control group (n 34) received no nutrition intervention. Duration: 3–6 months	ALL patients in maintenance therapy	Anthropometrics	From diagnosis to start of maintenance, the mean BMI Z-score had increased for the intervention group but decreased for the control group. Differential rate of change was not significant
Li <i>et al.</i> ⁽⁶⁶⁾	NA	NA	Development of a web-based cookbook of healthy recipes and nutrition resources to help enable paediatric cancer patients and survivors to lead healthier lifestyles	Committee of researchers, registered dietitian, patients and family members, a hospital chef, community advisors and donors	NA	The article presents @TheTable, including the recipes, the timeline of the development and the number of recipes that have been analysed and categorised The authors consider that @TheTable could be integrated in an intervention with an evaluation tool



Table 4 Continued

Study	Age (years)	Participants (n)	Intervention	Participants	Outcomes	Key results
Li <i>et al.</i> ⁽⁵⁹⁾	7–18	12	A monthly nutrition counselling intervention in paediatric ALL patients being treated with prednisone and/or dexamethasone. The control group (n 10) received nutrition counselling as per standard protocol. Duration: 12 months	Children aged 7–18 years treated for ALL	Anthropometrics, dietary intake, and oxidative stress measures	Intervention group from baseline to follow-up: Reduced energy intake Increased glutamic acid and Se intake No significant change in control group. No significant decrease in weight, waist circumference, BMI intra-group or inter-group. Average waist circumference and BMI were significantly different between the two groups (higher in the intervention group and lower in the control group)
Moyer-Mileur <i>et al.</i> ⁽⁶⁰⁾	4–10	6	Monthly home-based programme with a registered dietitian also having expertise in exercise. Each month, nutrition education materials based on the USDA food guide pyramid and nutrition-related activities were provided and reviewed with the registered dietitian. The control group (n 7) was taught standard recommendations about a well-balanced diet, taking a multivitamin with low or no folic acid, and to perform activity as tolerated. Duration: 12 months	Children with ALL during maintenance	Anthropometrics, dietary intake, physical activity and fitness	No difference was observed in anthropometric and dietary outcomes from baseline to follow-up in each group and between the groups
Raber <i>et al.</i> ⁽⁶²⁾	6–18	189 patients; 13 parents	Implementation of 45-min cooking classes for childhood cancer survivors and patients based on a recently developed framework of healthy cooking behaviour. They are presented as sleep-away or in-hospital camp or hospital classes	Childhood cancer survivors, patients and siblings	Feasibility and satisfaction Frequency of the promotion of the principal themes	The behaviour that has been the most promoted was to reduce sweeteners and to reduce animal fats. The two that have been less promoted are to avoid processed food and to avoid processed meat. Children did not enjoy the recipes destined to encourage them to eat vegetables. The group discussion with teenagers revealed that they wanted to learn more egg-based recipes. Camp classes were more popular than hospital classes, but these ones were seen by the parents as opportunities to ask their questions about nutrition

NA, non-applicable; ALL, acute lymphoblastic leukaemia; USDA, United States Department of Agriculture.

video-conferencing technology. The authors aim to assess the feasibility, adherence and efficacy of the programme. Food group, energy and nutrient intakes collected from food records will be used to assess the efficacy of the intervention, in addition to BMI, physical activity level and weight.

Two studies have included a culinary element in their intervention. One reported the feasibility of a culinary intervention in a summer camp for patients, survivors and their siblings⁽⁶²⁾. A total of twenty-four cooking classes were presented and 189 children attended the classes. The intervention also included in-hospital cooking classes for children and parents who preferred not to travel (twenty-four children and thirteen parents). The cooking classes aimed to improve children's cooking skills and to discover new foods in a summer camp ambiance. The intervention was based on the promotion of twelve behaviours such as 'adding fruits and vegetables' and 'reduce sweeteners'. Results were mostly obtained from the facilitators' field notes who recorded how frequently thematic behaviours were promoted. According to the authors, some behaviours were difficult to promote (for example, adding vegetables) due to the lack of interest in this type of food. They concluded that the development of future culinary interventions with this population is a promising avenue. Likewise, Chaput *et al.*⁽⁶³⁾ described the development of six culinary and educational workshops aimed at paediatric oncology patients and their families. The themes of the workshops address acute difficulties during treatment and general healthy eating messages to prevent long-term side effects. Each workshop comprises of key messages based on scientific evidence and clinical practice and includes a culinary demonstration with thematic recipes. The study will assess the feasibility of a nutrition education programme coupled with a culinary component. Participants' perception of knowledge acquisition will be measured after each workshop as the principal outcome. Biochemical, anthropometric and nutritional data will also be analysed in relation to workshop attendance.

Another study investigated the acceptability of a videogame-centred programme on healthful nutritional habits in children with cancer⁽⁶⁴⁾. The game had already been validated with healthy children and resulted in an increased consumption of fruits and vegetables in the intervention group compared with the control group⁽⁶⁵⁾. Interviews with patients revealed that the videogame was acceptable and enjoyable, but had components that were less appreciated (for example, sadness linked to the death of a character). However, the impact of the videogame on children's behaviour or nutrition knowledge was not measured.

Two studies described the development of educational tools for parents to improve children's eating habits. Li *et al.*⁽⁶⁶⁾ developed a web-based cookbook to address difficulties during treatment and to propose healthy recipes to patients and survivors. Website traffic will be used to evaluate the utility of the tool. Moreover, Garcia *et al.*⁽⁶⁷⁾ presented the development and validation of an educational pamphlet about healthy eating and the prevention of foodborne infections to fit the need for this type of resource, as expressed by paediatric oncology nurses. None of these studies has described the intention to evaluate their impact on behaviours or knowledge.

Limitations

Determining the general efficacy of nutrition intervention during treatment is a complex task, especially because different outcomes have been measured in the literature. Also, different means were used to promote a healthy lifestyle including culinary demonstrations, summer-camp cooking classes, videogames and technology-based interventions. In some studies, the impact of the intervention on food intake, behaviour or knowledge was not assessed. Some authors have proposed that proving the efficacy of a nutrition education programme is difficult because the interventions are often fairly similar to the standard nutrition treatment^(59,60).

The two studies including a culinary dimension to their intervention involve different methods to present the information to participants: one with hands-on cooking classes⁽⁶²⁾, the other with cooking demonstrations combined with nutritional messages⁽⁶³⁾. Cooking lessons allow the concrete delivery of nutritional knowledge⁽⁶⁸⁾. Studies performed in various populations tend to show that hands-on culinary activities are more promising to improve culinary skills and competency^(69,70), but this has not been explored in the context of paediatric oncology.

Editorial comments

Interventions on nutritional support have not been included in the present review since they have been comprehensively reviewed elsewhere^(71,72). Briefly, it was concluded that nutritional support is safe and efficient to increase weight in malnourished children with cancer. The choice of the route of administration (enteral or parenteral) needs to be determined after evaluation of the patient's individual condition by a dietitian experienced in paediatric oncology.

To this day, most nutritional education studies have been published as protocols or have only assessed feasibility. Although this remains relevant, future studies should also appraise their utility, appreciation and impact on participants' eating habits.

Conclusion

Globally, we conclude on the crucial importance for health professionals to consider the multiple aspects of the patient's condition when developing nutritional evaluation and intervention, including the disease, phase of treatment, food preferences, family's knowledge and beliefs. Therefore, patients could benefit from simple nutrition guidance to improve their dietary habits, which could contribute to a reduction in the risk of unhealthy weight gain and premature mortality during treatment. A better understanding of parents' and caregivers' perceptions could help health professionals to personalise their approach in paediatric oncology. Also, the large variability among study designs makes it difficult to assess the impact of nutritional interventions on dietary intake, nutritional status and other health outcomes. To facilitate interpretation of results, future nutritional studies should document the different factors that influence patients' intake. Finally, it is

important to assess the utility and impact of the interventions on patient nutrition knowledge or behaviour after evaluating their feasibility in this population.

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