Validity of dietary intake methods in cancer cachexia

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Keywords: cachexia; dietary intake methods; validation; biomarkers

Abstract

Purpose of review: Accurate assessment of dietary intake, especially energy and protein intake, is crucial for optimizing nutritional care and outcomes in patients with cancer. Validation of dietary assessment methods is necessary to ensure accuracy, but the validity of these methods in patients with cancer, and especially in those with cancer cachexia, is uncertain. Validating nutritional intake is complex because of the variety of dietary methods, lack of a gold standard method, and diverse validation measures. Here, we review the literature on validations of dietary intake methods in patients with cancer, including those with cachexia, and highlight the gap between current validation efforts and the need for accurate dietary assessment methods in this population.

Recent findings: We analyzed eight studies involving 1479 patients with cancer to evaluate the accuracy and reliability of 24-hour recalls, food records, and food frequency questionnaires (FFQs) in estimating energy and protein intake. We discuss validation methods, including comparison with biomarkers, indirect calorimetry, and relative validation of dietary intake methods.

Summary: Few have validated dietary intake methods against objective markers in patients with cancer. While food records and 24-hour recalls show potential accuracy for energy and protein intake, this may be compromised in hypermetabolic patients. Additionally, under- and overreporting of intake may be less frequent, and the reliability of urinary nitrogen as a protein intake marker in patients with cachexia needs further investigation. Accurate dietary assessment is important for enhancing nutritional care outcomes in cachexia trials, requiring validation at multiple time points throughout the cancer trajectory.

Keywords: dietary intake methods, dietary assessment, cancer, cancer cachexia, validation

Introduction

Cachexia is defined by progressive weight loss, skeletal muscle atrophy, loss of appetite and inadequate food intake (1). It is a complex condition and occurs in up to 80% of patients with incurable cancer (2). Adverse consequences include loss of physical function, reduced quality of life and tolerance to anticancer therapy, and increased mortality (3, 4). The pathophysiology of cancer cachexia is multifactorial, involving alterations in both the homeostatic control of energy balance and the hypothalamic regulation of appetite and satiety (2).

According to the guidelines from the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Society for Medical Oncology (ESMO) (5, 6), assessing nutritional status in patients with cancer should include an objective assessment of food intake, with particular emphasis on energy and protein consumption. Nutritional support in patients with cancer aims to counteract the negative energy balance as well as the net protein breakdown. However, the limited use of dietary intake methods in cachexia trials combined with the need to better understand the relationship between food intake and body weight, emphasizes the limitations and challenges in evaluation of energy and protein intake in this patient population (7).

Various methods for assessing dietary intake are available, each with strengths and limitations (8). However, all methods are prone to measurement errors and require motivation and memory from participants, as well as skilled investigators in dietary assessment methods. The 24-hours recall method is retrospective, requiring participants to recall all foods and beverages, along with portion sizes, consumed in the last 24 hours. Food records, also known as food diaries, involve participants recording their food and beverage intake, along with necessary information for estimating portion sizes, for one or more days. A food frequency questionnaire (FFQ) consists of a list of foods and beverages, with categories indicating usual intake over a certain time.

Challenges in validating dietary intake methods include the absence of a gold standard method, the diversity of validation measures being used, and the potential for poor validity in certain populations. Relative validity is also common, where results from one dietary intake method are compared to a method considered accurate. Objective validation involves direct observation or the use of biomarkers. Patients with cancer and cachexia face many nutritional challenges, including increased needs and fluctuations in appetite and dietary intake. To address these challenges, it is essential to use properly validated dietary assessment methods. These methods should ensure that dietary plans meet requirements and facilitate consistency across research studies, allowing for reliable comparisons and conclusions regarding the significance of food intake in cancer cachexia. In this scoping review, we discuss the validity of dietary assessment methods in patients with cancer and cancer cachexia and emphasize the necessity for validation studies tailored to these patient populations.

Methods

A systematic search of peer-reviewed literature was conducted by a trained research librarian in the databases Medline and Embase. The search covers literature from January 2004 to January 2024, and was limited to adults (18 years and older). Additionally, the ChatGTP Consensus app built on open artificial intelligence was used to complement the search and screening for articles in traditional databases. Queries in ChatGTP involved various search steps to generate an overview of relevant

literature. The questions asked were e.g. “Have dietary methods been validated in patients with cancer?”, “Can you do a new search and exclude in risk of cancer but include studies that validated dietary intake methods?”.

This review scoped the validity of estimated energy and nutrient intake. Validation methods, such as comparison with objective measures like biomarkers, doubly labelled water, nitrogen in urine, and objective measures of energy expenditure, were included. Additionally, relative validation comparing various dietary intake methods was also included.

Discussing the validity of a dietary method as a general concept is challenging, as the validity depends on how the study is designed and executed, as well as the population included. There is no set of criteria for assessing validity, instead a combination of different approaches is often used. In this review, the validity of a dietary method was generally deemed as “good” if there was substantial agreement between the reported measures of dietary intake compared to those obtained from another dietary assessment method or objective biomarker. Conversely validity was deemed “poor” if there was little or no agreement with other methods. Moreover, we included the criteria set by the authors to assess the validity, conclusion, and significance levels/associations as well as the reporting of clinically relevant differences/similarity were also considered when determining validity of the included articles.

Retrieved studies

Eight studies involving 1479 cancer patients were identified, examining various validation methods for dietary intake (Table 1). Among these, four specifically addressed the validation of dietary intake in patients prone to cancer cachexia (9-11). However, in the remaining studies, classifying cachexia was challenging due to insufficient information regarding disease stage, treatment, weight, body composition, or inflammation status. Table 1 provides an overview of the studies included, detailing the validation methods, results, and conclusions.

According to the studies included and presented in Table 1, only food records and 24-h recalls were validated against objective measures of energy and protein intake, showing potential accuracy, except in hypermetabolic patients with cancer (Table 2). The remaining studies either conducted relative validation by comparing different dietary intake methods or compared energy intake to energy expenditure. Moreover, two studies validated fruit and vegetables intake using FFQs against objective circulating biomarkers (Table 2).

Moses *et al.* (12) validated a 3-day **food records** against **doubly labelled water (DLW).** The accuracy of **energy** intake was compared to measured total energy expenditure (TEE). The mean reported energy intake was **similar** to measured TEE.

Bosaeus *et al.* (9) validated a 4-day **food record** against **indirect calorimetry** and **Harris-Benedict (H-B) equation and** the accuracy of energy intake was compared to Resting Energy Expenditure

(REE) and Basal Metabolic Rate (BMR), respectively. The mean **energy intake exceeded** measured **REE** and **Resting Metabolic Rate** (**RMR)**, but it was insufficient to prevent weight loss.

Bosaeus *et al.* (9) also validated 4-day **food record** against **24-hour urinary nitrogen.** A **good validity** between **protein intake** was observed when compared to protein estimated from the **24-hour urinary nitrogen**.

Vazeille *et al*. (11) compared **24-hour recall** with **indirect calorimetry.** They found **reasonable** overall **validity** between **energy intake** and measured **REE**. Mean daily energy intakes did not differ significantly between the normo-, hypo- and hypermetabolic patients, but negative energy balance and weight loss were more likely to occur among the hypermetabolic cancer patients.

Bye *et al.* (10) investigated the reliability of food intake questions in a patient-reported instrument for assessment of nutrition status, Patient-Generated Subjective Global Assessment (**PG-SGA),** against the **24-hour recall** method. They found **good reliability** between reporting **"food intake less than usual"** in PG-SGA, and **lower protein and energy intake** assessed by the 24-hour recall. Additionally, good agreement between "food intake less than usual" in PG-SGA and occurrence of weight loss was observed.

Jin *et al.* (13) compared estimated energy intake from a **simple diet self-assessment tool (SDSAT) Likert scale** with energy intake from a 3x **24-hour recall method** and found **good** overall **agreement** between **energy intake** from SDSAT score and 24-hour dietary recall. Additionally, the SDSAT score predicted weight loss.

The validity of selected **FFQ questions** have been assessed in three studies (14-16). In two studies, validation was against **plasma biomarkers** (14, 15), while in one study, the FFQ was validated against a dietary intake method (**dietary history**) (16). Cartmel *et al.* (14) found **good validity** between reported fruit and vegetable intakes and corresponding plasma carotenoids. Meyerhardt *et al*. (15) found **good validity** between carotenoids, tocopherols and dietary fatty acid content in food and corresponding plasma biomarkers. Mukherjee *et al*. (16) found **adequate validity** between FFQ and dietary history for several micronutrients, but energy and protein intake were not compared.

Discussion

Eight studies evaluating the validity of dietary intake methods were analyzed in this review (9-16), of which four addressed methods used in patients with cancer cachexia (9-12). Food records and 24-hour recalls were validated in three studies (9, 11, 12), showing good validity for energy and protein intake for normo- and hypometabolic patients. Two studies validated FFQ questions against plasma biomarkers for micronutrients and found adequate to good agreement (14, 15). However, validation of dietary assessment methods in patients with cancer remains limited, with few studies validating energy and protein intake against objective measures or biomarkers. Studies using relative validation methods suggest valuable information about energy and protein intake can be obtained through a Likert scale or similar brief questions (10, 13).

Strength and Limitation

The strength of this scoping review is the evaluation of validity of representative dietary intake methods in patients with cancer, commonly used worldwide in cancer research and clinical practice. Among the limited number of studies identified, a relatively large total number of patients were included, and a strength is that several studies validated dietary intake methods against objective and gold standard measures. However, there are several limitations to this scoping review. First, despite our use of broad search terms, hand-search of reference lists and the utilization of ChatGPT AI technology, we may have missed some relevant publications. Second, although we considered including all relevant studies, our search was limited to literature in English. Third, a few studies were specifically designed for the validation of dietary intake methods, making validation a secondary outcome in the identified studies. Finally, we used criteria for validity such as «good» and «poor» based on the authors' own categorization. Given the lack of a conclusive consensus on cut-offs for valid associations, these criteria may not have been applied consistently across all studies in this scoping review.

alidation of energy intake

In weight-stable healthy individuals, energy intake aligns with total energy expenditure over time, and the energy requirement is determined by the energy expenditure, as indicated by measurements of REE plus a factor for physical activity level (PAL) (17, 18). Energy intake from various dietary intake methods has been validated against the gold standard for estimating TEE, which is the DLW technique (19). These studies consistently reveal underreporting of energy intake by dietary assessment methods compared to DLW in healthy and overweight individuals (19, 20). Since energy intake is estimated from the total amount of food consumed, underreporting not only affects the accuracy of energy intake, but it also affects the precision of all other nutrients estimated.

The advantage of validating energy intake from a dietary assessment method against DLW lies in the objective measurement. We found one study validating energy intake from a 3-day food record against DLW in patients with cancer cachexia, showing good validity between energy intake and TEE (12). This may suggest that individuals with cancer cachexia are more accurate in their reporting of energy intake compared to healthy populations, but more studies are needed to confirm this. However, DLW measurements are costly and time-consuming. As an alternative gold standard for measuring energy expenditure, the ESPEN guidelines suggest indirect calorimetry (5, 20). Still, surprisingly few studies

have validated energy intake methods against indirect calorimetry in patients with cancer (9, 11). Bosaeus *et al.* (9) compared energy intake against REE by indirect calorimetry without correcting for PAL and found that energy intake exceeded measured REE. However, they emphasized that this level of energy intake would be insufficient to avoid weight loss even at a very low physical activity level. Energy intake from 24-hour recall and 4-day food records compared to energy expenditure showed good validity except for patients determined as hypermetabolic.

These findings indicate that although the DLW technique may provide accurate measurements and patients with cancer cachexia may reliably report their energy intake, there are discrepancies between measured REE and reported energy intake in hypermetabolic patients. One major challenge in interpreting the validity of dietary intake methods compared to REE in cancer cachexia is determining the factors that limit the accuracy. Patients with cancer experiencing weight loss are in negative energy balance, meaning energy intake is not aligned with energy expenditure. This imbalance may stem from low intake or increased TEE or a combination of both (21). However, some patients might experience weight loss despite not being defined as hypermetabolic and still able to maintain their dietary intake. One explanation might be malabsorption, which leads to reduced uptake of the energy and protein necessary to maintain stable weight. Another possibility is inefficient utilization of energy and protein compared to healthy individuals. Future studies should prioritize distinguishing between methodological weaknesses and cancer cachexia pathophysiology. Additionally, research should also focus on validating energy intake from various dietary intake methods with energy expenditure throughout the disease trajectory.

Validation of protein intake

Protein intake is crucial for maintaining muscle turnover, and 24-h urinary nitrogen is a well-established biomarker of the total dietary protein intake (22). However, the accuracy of urinary nitrogen depends on the assumption of nitrogen balance, which may not hold true in patients with cancer cachexia where negative energy balance and net protein breakdown are common, and with abnormal energy and substrate metabolism that nutritional support may not reverse.

We identified one cross-sectional study demonstrating good agreement between protein intake using a 4-day food record against urinary nitrogen. However, the validation study included weight-losing patients with cancer cachexia. Thus, the conditions required for using the nitrogen urea method were most likely not met. Uncertainty remains whether urea nitrogen is a reliable marker for protein intake in cancer patients (9).

Another study conducted a relative validation by comparing food intake assessed by PG-SGA against protein intake from 24-hour recall at two different time points. There was a correlation between energy- and protein intake; as food intake reduced so did protein intake (10). However, both dietary intake methods are prone to similar bias, such as memory/recall bias, compromising the reliability and validity of these findings.

Because dietary intake methods are associated with measurement error and bias, other metabolites associated with protein intake have been investigated as potential biomarkers for intake. Both routine blood urea measurements (23), and dietary protein-specific biomarkers such as plasma carnitine derivatives, tryptophan betaine, or phosphocholine have been investigated (24, 25). Using urea measurements to estimate protein intake may offer a practical alternative to 24-h urine collection and show good correspondence with total nitrogen to urea nitrogen in individuals with sufficient protein intake (23). However, when protein intake is low, the relative contribution of other nitrogen sources, particularly creatinine, becomes more pronounced (22). Further research is needed to explore whether these biomarkers could offer valuable insights in the assessment of protein intake and quality.

In summary, few dietary assessment methods have been validated for protein intake in patients with cancer. While 4-day food records may capture protein intake precisely, further validation at multiple time points is needed throughout the cancer treatment trajectory. Additionally, commonly used methods like 24-hour recall should be validated against objective biomarkers. Finally, exploring new methods for validating and assessing protein intake and quality, such as urea nitrogen if the conditions for using this method are met, as well as dietary protein-specific biomarkers, could improve assessment accuracy.

Circulation biomarkers of dietary intake

Due to bias associated with dietary intake methods and their cumbersome and time-consuming nature for both use and analysis, dietary biomarkers are an attractive alternative. Metabolomics technologies are rapidly identifying biomarkers for a more objective assessment of dietary intake. Currently, aside from urinary nitrogen and the DLW technique, which are somewhat invasive and demanding, there are no readily available plasma biomarkers for energy and protein intake that are both accurate and easily measurable.

Nonetheless, we identified two studies that validated sub-questions of fruit and vegetable intakes in two FFQs (14, 15). Despite the known inaccuracy in recalling habitual intake over time, the FFQ showed good validity for intake of carotenoids and tocopherols (14, 15). Although fruit and vegetable intake may not be the primary focus in patients with cancer, these studies suggest that patients with cancer may accurately report their intake when completing FFQs.

Additionally, good validity was found between dietary fatty acid intakes and plasma concentrations (15), which may be relevant as patients are often advised to consume energy-dense foods, including those rich in fats. Validating dietary fatty acid intake through fatty acid biomarkers could indicate whether patients are following this dietary advice to increase their consumption of energy-dense foods.

Body weight as a surrogate for energy balance

Accurate measurement of food and nutrient intake using various dietary assessment methods is essential for understanding the relationship between energy intake, energy balance and body weight. In patients with cancer cachexia, alterations in metabolism, body composition, and increased inflammation can disrupt energy balance, impacting the ability to predict weight loss from intake.

Additionally, the commonly used rule of thumb that 1 kg of weight loss corresponds to a 7,000 kcal intake deficit does not hold true (26). Thus, body weight as a surrogate for energy balance should be interpreted with caution, and weight loss alone should not be solely relied upon to estimate caloric deficit, especially in patients with cancer cachexia.

In conclusion

Our findings suggest that patients with cancer neither overestimate nor underestimate their dietary intake. This provides a crucial foundation for further validation of dietary intake methods in this population. Moving forward, Figure 1 highlights the specific needs for cancer-specific validation studies, which are essential for improving the accuracy and reliability of these methods in patients with cancer.

In patients with cancer cachexia, negative energy balance and weight loss are not always reversible with increased energy intake. Valid dietary intake methods for measuring energy and protein intake at multiple time points throughout the treatment trajectory could help clinicians determine whether weight and/or muscle loss is due to reduced intake, hypermetabolism, cancer cachexia, or a combination of such.

Acknowledgements

None.

Financial support and sponsorship

None.

Conflict of interest

There are no conflicts of interest.

Key points

- Validation of dietary intake methods against objective gold standards in patients with cancer, is challenged by the complex pathophysiology of cachexia.
- Food records and 24-hour dietary recalls show potential accuracy in estimating energy and protein intake, except in hypermetabolic patients.
- Future validation research should prioritize validating dietary intake methods across the cancer trajectory, emphasizing novel approaches such as biomarker utilization to enhance the precision of energy and protein intake assessment.

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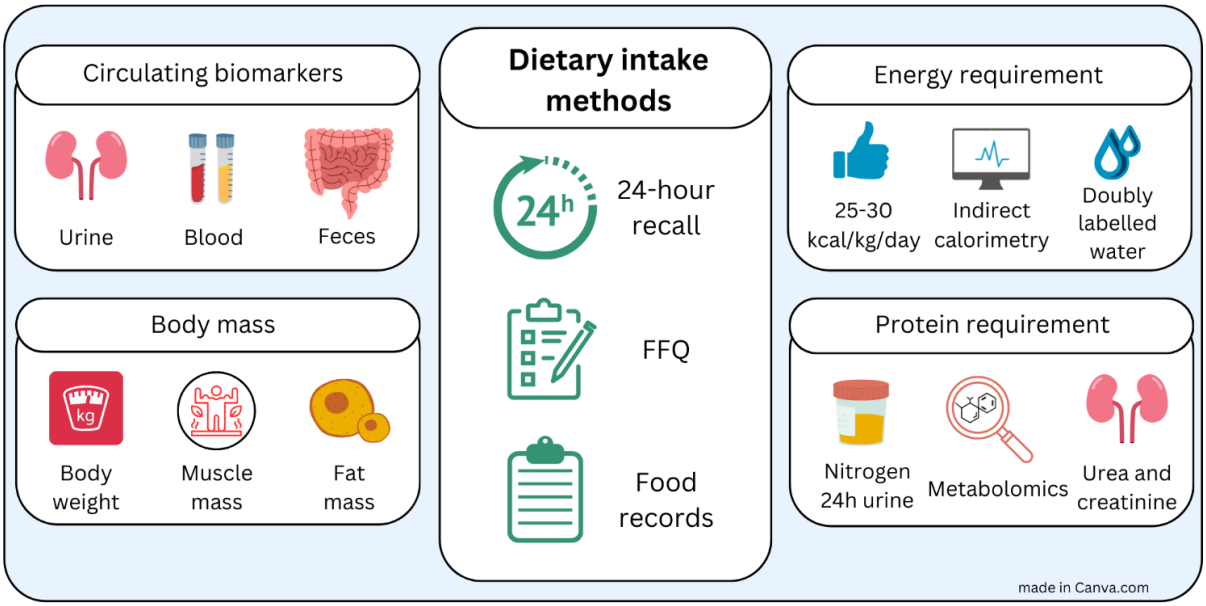

Figure 1. Conceptual representation of dietary intake methods and validation components for patients with cancer. Assessment of dietary intake among patients with cancer involves various methods and validation components. These include paper-based assessments or digital methods through apps or electronic patient records. Although dietary intake methods provide estimates of intake, using only body weight is insufficient for determining whether energy and protein requirements are covered. Analysis of body composition, such as muscle and fat mass, can provide additional information on nutritional adequacy. Accurate assessment of dietary intake is prone to measurement errors and bias, necessitating the importance of utilizing objective biomarkers. By also including circulating biomarkers (in urine, blood, and feces), a more comprehensive understanding of nutrient intake, absorption, distribution, and excretion is obtained. A common rule of thumb when estimating energy requirements is 25-30 kcal/kg/day, however, this estimate is rough and often imprecise on the individual level. For validation studies, more accurate measurements such as indirect calorimetry and doubly labelled water are preferable.

Table 1. Studies validating dietary intake methods in patients with cancer.

Study	Cancer disease Treatment Cachexia[1]	Dietary assessment method	Validation	Result	Conclusion
Moses *et al*, 2004 (12) RCT N=24	Type: Pancreatic. Stage: II-IV Treatment: No current. Cachexia: Yes.	3-day food record	Compare mean energy intakes against TEE measured from DLW at baseline.	Mean energy intakes (1754 ± 95) were similar to TEE (1732 ± 82).	Good validity between 3-day food record and TEE from DBW.
Bosaeus *et al*, 2001 (9) Cross-sectional N=297	Type: Colorectal, pancreatic, upper GI, biliary and others. Stage: NA. Treatment: No current. Cachexia: Yes.	4-day food record (3 weekdays, 1 weekend day).	Compare mean EI from 4-day food record with: REE, BMR[2] and WL. Validate protein intake from 4-day food record with 24h urinary nitrogen (n = 53).	EI from 4-day food record compared to REE (EI/REE) had a mean (SD) of 1.13 (0.39). EI compared to predicted BMR (EI/BMR) was 1.26 (0.44). Protein intake and urine nitrogen was similar [67.7 (22.4) g/day vs. 65.0 (28.6) g/day[*]].	EI exceeded predicted BMR and measured REE but was insufficient to avoid WL. Good validity between dietary protein intake and estimated protein intake from 24-hour urine nitrogen.
Vazeille *et al,* 2017 (11) Prospective observational study N=390	Type: Genitourinary, gastrointestinal, thoracic, gynecologic, sarcoma and others. Stage: 263 with metastatic disease. Treatment: Before systemic anti-cancer therapy. Cachexia: Yes.	24-hour dietary recall	Compare mean EI from 24h-recall against measured (indirect calorimetry) and estimated REE (Harris-Benedict). Compare REE, EB and WL between hypermetabolic, normometabolic and hypometabolic patients[3].	Mean EI (1668.3 ± 492.4 kcal/d) was slightly higher than mean REE (1547.2 ±421.1 kcal/d). Mean REE was higher in hypermetabolic patients (1819.2 ± 325.1) than normometabolic patients (1449.8 ± 265.4 kcal/d)[**], and lower in hypometabolic (1037.8 ± 237.7) patients[**]. Mean estimated EB was negative in hypermetabolic patients (−111.6 ± 524.0) compared to hyper- and normometabolic patients[**].	Adequate validity between mean REE and mean EI from 24h recall, but not sufficient to avoid WL as PAL is not taken into account. Not adequate validity between mean REE and EI in hypermetabolic patients.

				Both hypermetabolism and negative estimated EB were associated with increased WL[**].	
Bye *et al,* 2019 (10) Combined intervention study and prospective observational study N=85	Type: NSCLC and pancreatic. Stage: I-IV. Treatment: chemotherapy, palliative. Cachexia: Probably	PG-SGA question about food intake (unchanged, increased, less than usual) the past mo.	Compare PG-SGA food intake question against energy and protein intake from a 24-hour dietary recall at baseline and after 4-6 wk. Compare food intake question in PG-SGA against WL at baseline and after 4-6 wk.	At baseline and 4-6 wk, patients reporting food intake less than usual had lower energy ([*]only at baseline) and protein intake[*] compared to those reporting no change or increased intake. At baseline, patients eating less than usual had a mean (SD) WL of 7.8% over 6 mo, and those reporting no change or more lost 8.2%[*]. Patients reporting intake less than usual had a mean (SD) WL of 2.6 (2.9) kg from baseline to 4-6 wk[**].	Good validity between food intake "less than usual" in PG-SGA and lower intake of protein and energy from the 24-hour dietary recall. Good validity between food intake less than usual in PG-SGA and WL.
Jin *et al,* 2020 (13) Prospective, longitudinal, observational study N=304	Type: Head and neck. Stage: I-IV. Treatment: Radiotherapy, alone or in combination with/sequential to chemotherapy/ surgery. Cachexia: Not possible to evaluate.	SDSAT (Likert scale from 1-5 where 1 = <300 kcal/d, 2 = 300-600 kcal/d, 3 = 600-900 kcal/d, 4 = 900-1200 kcal/d, 5= >1200 kcal/d).	Compare estimated energy intake from the SDSAT against EI from 3x 24-hour dietary recall. Determine predictive validity by impact of the SDSAT-score on WL at three time points.	Overall agreement rate between SDSAT-score and EI from the 24-hour dietary recall was 62.9 % (574/912) and weighted kappa was 0.66 (95% CI = 0.63-0.70[**]). SDSAT-score had a significant effect on WL (β = 1.40, 95% CI = 1.21 -1.59[**]).	Good overall validity between SDSAT score and estimated energy intake from 24-hour recall. Good predictive validity between SDSAT-score and WL.
Cartmel *et al,* 2005 (14) RCT N=75	Type: Curative head and neck. Stage: I-II. Treatment: Curative treatment finished. Cachexia: Probably not.	FFQ capturing food intake the previous month.	Compare fruit and vegetable intake with blood plasma carotenoid levels at baseline in a RCT.	Fruit and vegetable intakes correlated with plasma cryptoxanthin (r 0.31[*] and r 0.35[**], respectively). Vegetable intake correlated with total plasma carotenoids (r 0.3[*]) and α-carotene (r 0.26[*]), but not with β-carotene, lutein and lycopene.	Good validity between fruit and vegetable intakes and plasma cryptoxanthin levels. Good validity between vegetable intake and plasma total carotenoids and α-carotene, but not for β-carotene, lutein, and lycopene.

Meyerhardt *et al,* 2005 (15) Cross-sectional N=192	Type: Colorectal, breast and neuroendocrine. Stage: NA. Treatment: Chemotherapy Cachexia: Probably not.	131-item semi-quantitative FFQ capturing dietary intake last 3 months.	Compare intakes of carotenoids, tocopherols and dietary fatty acids from the FFQ against plasma levels of these nutrients.	Intake of carotenoids and total vitamin E correlated with plasma carotenoids (r between 0.33 to 0.44, all**) and α-tocopherol (r = 0.34**). The correlation between intake and plasma trans-fat, EPA and DHA were 0.55**, 0.29** and 0.42**	Good validity between the dietary intake of carotenoids, tocopherols, trans-fat, EPA and DHA, and the corresponding plasma biomarker levels.
Mukherjee *et al*, 2021 (16) Cross-sectional N=112	Type: Wide range of solid tumors and leukemia. Stage: NA. Treatment: Chemotherapy, immunotherapy or combined systemic cancer therapy. Cachexia: Not possible to evaluate.	21-item FFQ.	Compare intake of 14 micronutrients (vitamin C, A, D and E, copper, iron, zinc, ALA, total LC n-3 FA, arginine, glutamic acid, isoleucine, leucine, valine) from a 21-item FFQ against diet history.	Copper, iron, vitamin A, E, D, zinc, ALA, total LC n-3 FA, arginine, glutamic acid, isoleucine, leucine and valine were within pre-defined clinically acceptable bias ranges and within 95% CIs, except vitamin C. The FFQ overestimated vitamin C intakes with higher dietary vitamin C intake.	Adequate validity between the FFQ and diet history for copper, iron, vitamin A, E, D, ALA, total LC n3-FA, arginine, glutamic acid, zinc isoleucine, leucine and valine. Not adequate validity between FFQ and diet history for vitamin C.

ALA; α-linolenic acid, BMR; basal metabolism rate, CI; confidence interval, DHA; docosahexaenoic acid, DLW; doubly labelled water, EB; energy balance, EI; energy intake, EPA; eicosapentaenoic acid, FFQ; food frequency questionnaire, LC n-3 FA; long-chain n-3 fatty acid, NSCLC; non-small cell lung cancer, PAL; physical activity level, PG-SGA; Patient-Generated Subjective Global Assessment, RCT; Randomized Clinical Trial, REE; resting energy expenditure, r; Pearson correlation coefficient, SD; standard deviation, SDSAT; simple diet self-assessment tool, TEE; total energy expenditure, WL; weight loss.

[1]Cachexia described where possible. Classification of cachexia was made according to Fearon et al (1).

[2] BMR calculated by Harris-Benedict equation according to (11).

[3] Hypermetabolism defined as measured REE ≥110% of the calculated REE. Normometabolism defined as measured REE that was 90–110% of the calculated REE, and hypometabolism defined as measured REE <90%).

[*]Indicates P<0.05, [**] indicates P<0.01.

Table 2. Summary of validity of dietary intake methods in patients with cancer.

Validated against	**Dietary intake methods**		
	Food record	24-hour recall	FFQ
Objective methods			
TEE by doubly labelled water	**Good** for energy intake (12)		
REE by indirect calorimetry	**Poor** for energy intake and REE in hypermetabolic patients (9)	**Good** for energy intake and REE for normo- and hypometabolic patients (11) **Poor** for energy intake and REE for hypermetabolic patients (11)	
Urinary nitrogen	**Good** for protein intake (9)		
Plasma nutrient concentrations			**Good** for fatty acids, carotenoids, vitamins and minerals (14, 15)
Relative methods			
Likert scale (1-5) for estimated energy intake		**Good** for energy intake (13)	
Food intake (reduced unchanged, increased) (PG-SGA)		**Good** for identifying reduced energy and protein intake (10)	
Dietary history (typical week representing usual diet)			**Good** for micronutrients, fatty acids and amino acids but **poor** for vitamin C (16)

PG-SGA; Patient-Generated Subjective Global Assessment, REE; resting energy expenditure, TEE; total energy expenditure