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Meta-analysis

Valid food intake measures of adult patients for use within the GLIM framework: A scoping review

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SUMMARY

Background: Reduced food intake is one of the etiologic criteria proposed by the Global Leadership Initiative on Malnutrition (GLIM). Various tools for the assessment of food intake exist, however, to diagnose malnutrition, as in GLIM, they should be validated against established reference standards, and quick and easy to complete by various members of the health care team.
Aim: This scoping review synthesizes the current evidence related to validated assessment measures of food intake for adult patients in healthcare settings and reports on the application of these measures within the GLIM diagnostic framework.
Methods: A comprehensive search strategy was performed using four bibliographic databases. To be included, studies needed to be conducted on adults in a healthcare setting, have a dietary intake assessment component (i.e. index method) that can be completed by various healthcare staff members, with minimal training and in a short time period, and make comparison of this method to an established dietary assessment reference. Studies needed to report energy and protein intake data and provide appropriate validation statistics. Two reviewers independently reviewed all abstracts and relevant full-text articles, and extracted data.
Results: After duplicate removal, 7866 abstracts were screened; 51 articles were eligible for full article review, 13 articles fulfilled the inclusion criteria and one further article was obtained from grey literature, for a total of 14 articles included in the scoping review. Food weighing before and after consumption was used as a reference method by most studies. For index methods, four different measurement tools, with variations, were used. This included visual estimation methods (VEM) using a 1–10-point scale without any pictorials (2 studies); VEM based on plate-model pictures (8 studies); VEM based on plate-models with associated defined nutritional values (4 studies) and digital technology (2 studies). Various levels of accuracy were found, with accuracy increasing when more options are provided and when employing digital technology. Index methods could be completed by participants themselves, nurses, food service workers and dietitians. Adequate training on completion of the tools is associated with improved results.

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Conclusion: Index methods to assess food intake accurately for energy and protein intake can determine inadequate intake as compared to the reference method. Yet, a further step is required to interpret food intake relative to the patient's energy requirement to determine sufficiency of that intake for determination of the GLIM criterion. However, visual estimation methods identified in this review can be used by diverse clinicians with confidence to determine patient food intake.

1. Introduction

The Global Leadership Initiative on Malnutrition (GLIM) proposed a three-step approach for the diagnosis of malnutrition in adult populations. This approach includes a screening for risk of malnutrition component, followed by the diagnosis of malnutrition by evaluating three phenotypic criteria (weight loss, low body mass index and reduced muscle mass) and two etiologic criteria (reduced food intake/or assimilation and the presence of inflammation/disease burden). The presence of at least one phenotypic and one etiologic criterion constitutes a malnutrition diagnosis [1,2]. The last step involves quantifying disease severity. This process will be imperative to feed into the new ICD-11 code for malnutrition in adults, now called "undernutrition in adults". This etiology-based diagnosis classification makes allowance for defining three subcategories, namely "Undernutrition in adults related to disease with moderate to severe inflammation"; "Undernutrition in adults related to disease with non-discernible inflammation" and "Undernutrition in adults related to starvation" [3].

A key benefit of the GLIM approach is that diagnosis of malnutrition is streamlined so that any clinician world-wide can determine if their patient has malnutrition. Since the original GLIM criteria were proposed, papers were developed on the specific indicators and how to perform validity assessment [4–7]. Reduced food intake or assimilation is the only remaining criteria that remains to be well-defined for clinical care.

In preparation for a guidance document on the diet/assimilation criteria, we decided that a scoping review of available literature focusing on validated measures of assessing food intake in any clinical setting was needed. A narrative review on visual estimation methods (VEM) for assessment of food intake was published in 2022 and provides a detailed explanation of the use of various methods, including the general validity and applicability of these tools in the hospital setting [8]. A scoping review on dietary assessment methods for oral intake was published in 2023 [9]. This review also focused only on hospitalized patients and included assessment methods that require time and specialized skills. As neither of these reviews included articles for clinical practice as whole, regardless of specific setting, further identification of potential brief measures that can be completed by any clinician is needed for use with the GLIM framework. Further, recommended methods to support guidance for the GLIM framework need to be quick and easy to complete by various members of the healthcare team in various healthcare systems.

To address this gap in the literature and need for GLIM guidance, we planned a scoping review to answer the following research question: "What are valid, brief measures for determination of food intake of adult patients in healthcare settings?" We aimed to critically appraise the validated measures for food intake of adult patients in various settings, with the objective to synthesize the current evidence related to brief validated assessment measures of food intake of adult patients in those settings and report on the potential application of these methods within the GLIM diagnostic framework.

2. Methods

2.1. Protocol and registration

The study protocol was approved by all authors and registered on Open Science Framework in August 2024 (https://doi.org/10.17605/OSF.IO/KNQB6).

2.2. Eligibility criteria

Studies were included based on the following inclusion and exclusion criteria (Table 1). To be included, these studies needed to be conducted on adults in a healthcare setting. They needed to have a dietary intake assessment component consisting of less than 20 items and one that could be completed in about 5 min by various healthcare staff members with minimal training. The method needed to translate the findings to energy (and protein) content to answer the original dietary intake criteria of GLIM at $\leq$ 50 % of energy requirement. For the reference test, an established and accurate assessment of dietary intake was required (e.g. food record), and appropriate validation statistics needed to be reported.

2.3. Information sources

A comprehensive search strategy was used, including the following electronic bibliographic databases: EBSCOhost (CINAHL); Scopus; Web of Science and PubMed and covering all publications to date. Only English language studies were included.

2.4. Search

A trained research librarian assisted with developing a search string, based on the scoping review objectives. The search string was adapted according to the requirements of all the databases and based on the following key concepts: terms related to eating or intake; intake assessment tools; and validation terminology. We searched for relevant studies using various databases from inception to 29 May 2024. An updated search was performed one year later on 13 May 2025. Refer to Supplementary Table 1 for the detailed search string used for PubMed.

2.5. Selection of sources of evidence

Search results were exported to Covidence systematic review software [10] to assist with the process of screening and selecting studies. Inclusion and exclusion criteria were applied to determine the final selection of relevant articles for data extraction. The research team was trained on Covidence and practiced identification of abstracts (n = 25) that met inclusion criteria. All of the

Table 1
Scoping review inclusion and exclusion criteria.

Component	Include	Exclude
Population	Adults Hospital/clinics Primary care Long-term care Older adult community (at risk of poor food intake)	Paediatrics Pregnancy Prisons Animal studies Athletes Healthy individuals, non-older adult Overweight, noncommunicable diseases e.g. diabetes
Index measurement	Variables or brief measures assessing food intake e.g. self-report of decreased intake; takes less than 5 min to complete (e.g. < 20 items) Minimal burden to the patient Focused on energy and protein consumed Assessed at first/only visit	Risk factors for low food intake Micronutrients Diet quality scores e.g. HEI Food groups
Reference standard	Assessment of food intake for comparison to variable/brief measure e.g. observation, weighed food record, photographs, food diary Administered by any relevant staff	Lack of comparator
Outcome	Validity of variable/brief measure for assessing food intake e.g. correlation, association, agreement, sensitivity, specificity, area under the curve	No statistics on comparison
Study type	Primary studies Pilot studies	Letter to the editor Case reports Reviews Protocols Abstracts

research team was involved in screening abstracts with two reviewers independently reviewing the abstracts and determining if the paper met inclusion criteria. Full-text article reviews was also completed in duplicate by a subset of authors. Disagreements were resolved by team discussion.

2.6. Data charting process and data items

A data-extraction form was developed and used to extract data from each relevant study. The research team determined which variables to extract (based on the research questions), including author(s), year of publication, country of origin, study setting and design, study population, methodology, index and reference methods, details of how these methods were employed, how outcomes were measured, relevant validity data and key findings that relate to the review question. The first and senior author independently extracted data and consulted in cases of disagreement.

2.7. Synthesis of results

PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines are used as reporting guidelines for this scoping review and a PRISMA flow diagram (Fig. 1) is used to graphically depict the process [11].

Data are summarized in table format, including general study features (authors, publication year, country, study setting, study design, study population and sample size (Table 2). Table 3 depicts the information on index and reference methods, including implementation information, with more detailed information in Supplementary Table 2. Validity data (sensitivity and specificity, interclass correlation and Bland Altman results) are provided in Table 4. Lastly, all excluded studies are listed in Supplementary Table 3.

3. Results

3.1. Selection of sources of evidence

In total 12225 articles were sourced. After duplicate removal, 7866 abstracts were screened and 51 articles were eligible for full article review, of which 13 articles fulfilled the selection criteria. One article was obtained from grey literature and in total 14 articles were included (Fig. 1).

3.2. Characteristics of sources of evidence

As can be seen in Table 2, the studies were published between 2013 and 2025. Investigators in France [12–14] and the Netherlands [15–17] produced three studies each, two were from each of Australia [18,19], and Denmark [20,21]. One study was included from Canada [22,23], Iceland [24], Indonesia [25] and Japan [26]. All studies were conducted on hospitalized in-patients, with one also including outpatients [14]. The ages ranged from 15 to 96 years, with three studies focused on older adults (>65 years of age) [12,20–22].

For the reference method, the majority of studies used food weighing before and after consumption [12,16,18–21,23–27]. Other reference methods included 3-day reported food record [14] and 24-hour recall [13]. One study used visual estimation of food waste as the reference method [17,22] (Table 3 and Supplementary Table 2).

A variety of index methods were evaluated (Table 3 and Supplementary Table 2). Visual plate pictorials depicting four options [18,20,24] and five options [20,22,23] were most common. One study used 11 options to depict food consumed based on the whole tray [26]. Four studies used a visual rating of food consumed and allocated nutritional value accordingly. These included the Rate-a-plate concept calculating energy and protein content based on food consumption [15]; Calorie Intake Tool (CIT) calculating only energy value based on consumption [12]; Meal Intake Points (MIP), which is similar to CIT, but calculating energy and protein content [19] and Pictorial Dietary Assessment Tool (PDAT) calculating energy and protein content based on six consumption options [25]. The Self-Evaluation of Food Intake (SEFI) Tool was used by two studies [14,17], with an earlier version of SEFI, the Ingesta-VVAS (Visual/verbal analogue scale of food ingested) was used by another [13]. Lastly, digital technology was used in two studies with a digital camara image comparing before and after consumption pictures with either a trained rater [16,21] or weighing of the food [16,21].

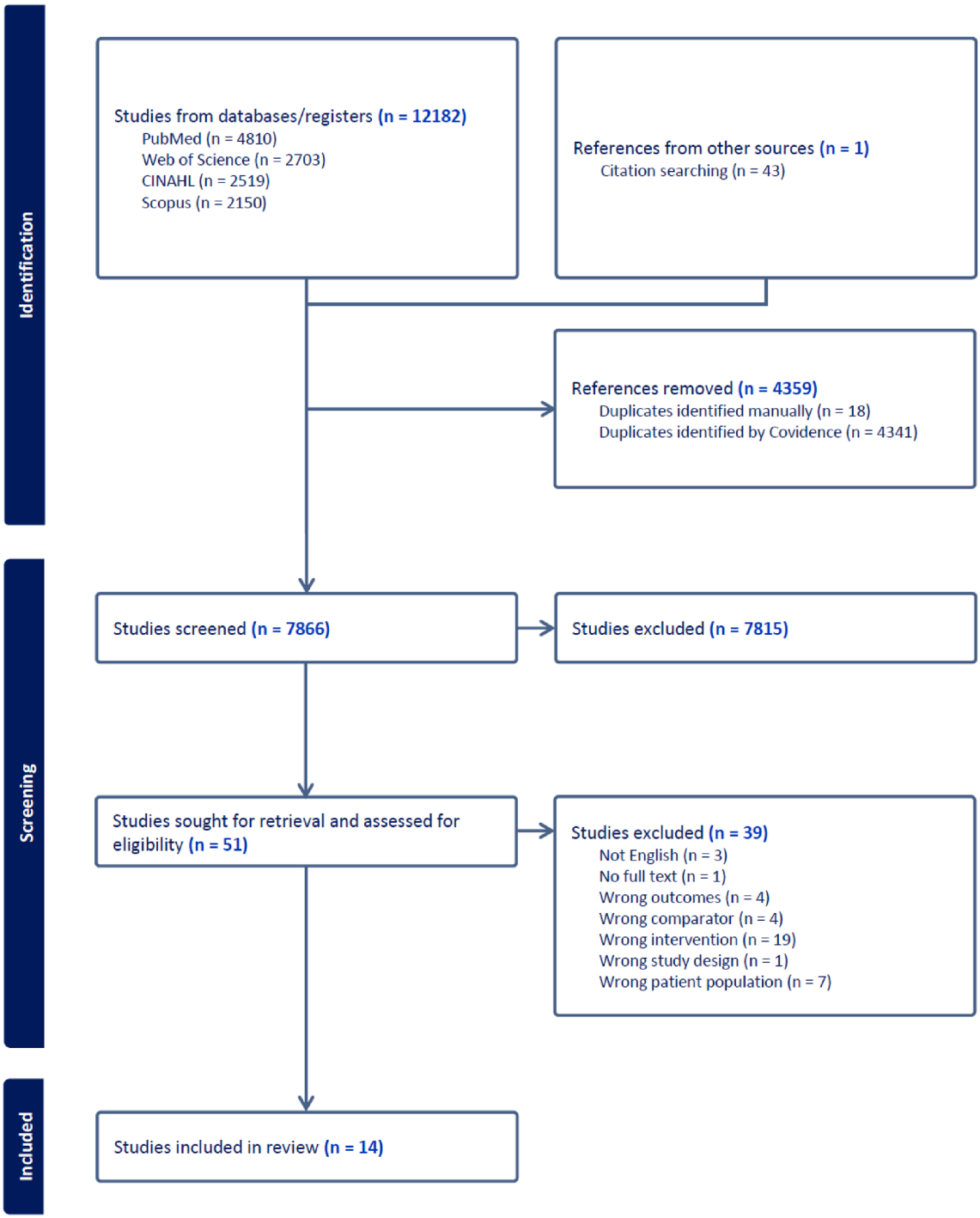

Fig. 1. PRISMA flow diagram. Graphic depiction of the process followed to select the included studies.

3.3. Synthesis of results based on three main outcomes

3.3.1. Description of index methods used to assess dietary intake

Four types of measurement tools, with variations, were used. These included visual estimation methods (VEM) using a 1–10-point scale, without any pictorials; VEM based on plate-model pictures; VEM based on plate-models with associated defined nutritional values; and digital technology (Table 3, Fig. 2 and Supplementary Table 2).

Three studies used a VEM based on a 10-point scale concept [13,14]. Participants had to indicate on a scale of 0 (eat nothing) to 10 (eat everything) the proportion of food they consume. Two studies were conducted in France with the Ingesta-VVAS [13] regarded as an earlier version of the SEFI tool [14]. In both studies, a verbal and visual format of the tools was used. Another study combined the 10-point scale with a 5-point plate pictorial for different meals [17]. The VEM were completed by patients [17] and dietitians [13] in a hospital setting and by patients in both an inpatient and out-patient setting [14]. Different reference tools were used, namely 24-hour recall [13] and 3-day food record [14], as well as visual assessment of food intake based on 5-options [17].

VEM based on visual plate pictorials, depicting four options [18,20,24]); 5 options and eleven options [26] were used. The four-

Table 2
Included articles – General features.

	Authors	Year	Country	Study setting	Study design	Population	Sample size enrolled
1	Bjornsdottir R, Oskarsdottir ES, Thordardottir FR, Ramel A, Thorsdottir I, Gunnarsdottir I [24]	2013	Iceland	Hospital	Cross-sectional	Adults, 19–94 years; mean age 63 ± 17 years	73 patients
2	Budiningsari D, Shahar S, Manaf ZA, Susetyowati S. [25]	2016	Indonesia	Hospital	Cross-sectional,	Adults; mean age of patients 44 ± 15.4 years and staff 40 ± 6.6 years	67 patients, 37 staff including dietitians, nurses and serving assistants
3	Dekker IM, Langius JAE, Stelten S, de Vet HCW, Kruizenga HM, de van der Schueren MAE [15]	2020	Netherlands	Hospital	Validation study	Adults >55 years; mean age 80.5 ± 10.3 years (phase 1) and 83.2 ± 10,1 years (phase 2)	Phase 1 = 24 - 1 patient for 1 day, 3 patients for 2 days and 20 patients for 3 days. Phase 2 = 14 patients for 2 days
4	Ghisolfi A, Dupuy C, Gines-Farano A, Lepage B, Vellas B, Ritz P [12]	2014	France	Hospital	Validation study	Older adults >65 years; mean age 83.1 ± 7.2 years	100 patients
5	Guerdoux-Ninot E, Flori N, Janiszewski C, Vaille A, de Forges H, Raynard B, Baracos VE, Thezenas S, Senesse P [13]	2018	France	Hospital	Cross-sectional	Adults 15–96 years; Mean age 61.7 ± 12.9 years.	1762 patients
6	Husted MM, Fournaise A, Matzen L, Scheller RA [20]	2017	Denmark	Hospital	Validation study	Older adults	103 meals
7	Kawasaki Y, Sakai M, Nishimura K, Fujiwara K, Fujisaki K, SM, Akamatsu R [26]	2016	Japan	Hospital	Validation study	Adults	450 trays assessed and 412 trays used in analysis
8	Ofei KT, Mikkelsen BE, Scheller RA [21]	2018	Denmark	Hospital	Validation study	Older adults	17 meals
9	Palmer M, Miller K, Noble S [18]	2015	Australia	Hospital	Observational study	Adults, mean age 77 ± 8 years	15 patients, 43 intake days
10	Schumacker CSM, Paulus MC, Boelens YFN, van Zanten ARH & Kouw IWK [16]	2025	Netherlands	Hospital	Prospective study	Hospital meals	27 food trays, comprising 108 food items
11	Tan J, Lau KM, Ross L, Kinneally J, Banks M, Pelecanos A, Young A [19]	2021	Australia	Hospital	Cross-sectional	Adults	90 trays retrieved from trolleys from 24 wards
12	Thibault R, Goujon N, Le Gallic E, Clairand R, Sebille V, Vibert J, Schneider SM, Darmaun D [14]	2009	France	Hospital and at-home	Cross-sectional;	Adults 18–75 years, mean age 56 ± 15 years	114 patients; visual analogue only in 48 undernourished in patients
13	Tulloch H, Cook S, Nasser R, Guo G, Clay A [23]	2019	Canada	Hospital	Validation study	Adults	401 meals from 33 patients
14	Van den Berg G, Van Noort H, Borkent J, Vermeulen H, Huisman-de Waal G, de Van der Schueren M(17)	2025	Netherlands	Hospital	Cross-sectional	Adults	15 patients, 60 patient days

option studies [18,20,24] asked participants to indicate intake based on 0 %, 25 %, 50 % and 100 % of intake. All determined energy and protein intake, and used the weighed plate waste as the reference test. To transfer estimated intakes to nutritional value, Palmer et al. [18] determined nutritional estimations in two ways: by using supplier information or using a computer programmed to provide energy and protein content for each grouped menu item, e.g. the average for all desserts on the menu. Bjornsdottir et al. [24] used the proportion of known energy and protein content of the meal, and Husted et al. [20] used proportions of calculated reference food.

VEM based on visual plate pictorials, depicting five options was used in one study from Canada [22,23] and one from Denmark [20]. Different staff members were asked to complete the index tests, including nursing staff [20] and food service workers [23] after receiving training on the tools. Kawasaki et al. [26] assessed food intake of hospitalized patients using a 11-point scale for visual estimation of whole tray consumption by nursing assistants and dietitians, and for consumption of individual food items, grouped by food category, by dietitians only [26].

VEM, based on visual plate pictorials with associated predefined nutritional value, was used by four studies [12,15,19,25]. Dekker et al. [15] used researchers and nutrition assistants to complete a visual estimation of foods and fluids consumed after receiving training on the tools. Points are awarded based on predetermined energy and protein content of the menu items, with 1

Table 3
Included articles – Information about index and reference methods.

	Authors	Index method	Person responsible for completion of index method[a]	Reference method	Person responsible for completion of reference method
1	Bjornsdottir R, Oskarsdottir ES, Thordardottir FR, Ramel A, Thorsdottir I, Gunnarsdottir I [24]	Plate diagram sheet with four options	Trained nursing staff	Weighed plate wastage	Trained research staff
2	Budiningsari D, Shahar S, Manaf ZA, Susetyowati S. [25]	Pictorial Dietary Assessment Tool (PDAT) using six options	Staff consisting of dietitians, nurses and serving assistants	Weighed plate wastage	Researcher
3	Dekker IM, Langius JAE, Stelten S, de Vet HCW, Kruizenga HM, de van der Schueren MAE [15]	Rate a plate where points scored are linked to nutritional value	Trained Researcher and nutrition assistants	Weighed plate wastage	Researcher and Research assistant
4	Ghisolfi A, Dupuy C, Gines-Farano A, Lepage B, Vellas B, Ritz P [12]	Calorie Intake Tool (CIT) where menu items are assigned points based on nutritional value.	Trained nursing staff	Weighed plate waste.	Dietitian
5	Guerdoux-Ninot E, Flori N, Janiszewski C, Vaille A, de Forges H, Raynard B, Baracos VE, Thezenas S, Senesse P [13]	Visual/verbal analogue scale of food ingested (Ingesta-VVAS) on a scale of 0–10.	Dietitians	24-h recall	Dietitian
6	Husted MM, Fournaise A, Matzen L, Scheller RA [20]	Plate diagram methods with four or five options.	Trained nursing staff	Weighed plate wastage	Dietitian
7	Kawasaki Y, Sakai M, Nishimura K, Fujiwara K, Fujisaki K, SM, Akamatsu R [26]	Visual estimation of whole tray and food items using a 11-point scale.	Non-trained nursing assistants and dietitians	Weighed plate wastage	Research staff
8	Ofei KT, Mikkelsen BE, Scheller RA [21]	Dietary Intake Monitoring System (DIMS) using a digital camera.	Non-trained assessors	Weighed plate wastage	Not stated
9	Palmer M, Miller K, Noble S [18]	Food intake charts using four options.	Non-trained nursing staff	Weighed plate wastage	Dietetic staff and dietetic students
10	Schumacker CSM, Paulus MC, Boelens YFN, van Zanten ARH & Kouw IWK [16]	Food record charts using 6 options and digital photography.	Non-trained healthcare professionals (16 nurses, 10 healthcare assistants, 4 researchers)	Weighed plate waste	Researcher
11	Tan J, Lau KM, Ross L, Kinneally J, Banks M, Pelecanos A, Young A [19]	Meal Intake Points (MIP) where menu items are assigned points based on nutritional value.	Trained researcher	Weighed plate wastage	Researcher
12	Thibault R, Goujon N, Le Gallic E, Clairand R, Sebille V, Vibert J, Schneider SM, Darmaun D [14]	Self-Evaluation of Food Intake (SEFI) tool estimating food intake on a 1–10 scale	Patients provided answers based on instructions from interviewer. Visual scales were only administered on a sub-group of malnourished in-patients.	3-day diet record	Nursing staff for in-patients, patients themselves for out-patients following training by a dietitian
13	Tulloch H, Cook S, Nasser R, Guo G, Clay A [23]	Visual assessment of whole tray using meal plate pictorial rating scale based on the My Meal Intake Tool	Trained food service workers	Weighed plate wastage	Research assistant
14	Van den Berg G, Van Noort H, Borkent J, Vermeulen H, Huisman-de Waal G, de Van der Schueren M(17)	Self-Evaluation of Food Intake (SEFI) tool estimating food intake on a 1–10 scale	Patient Participant	Visual assessment of food intake directly after removal of meal trays as 0 %, 25 %, 50 %, 75 % or 100 %	Nutrition assistants and nursing staff

[a] Training refers to specific training on how to complete the index method.

Table 4
Included articles – Validity data pertaining to energy and/or protein intake.

	Authors	Nutrients measured	Sensitivity (95 % CI)	Specificity (95 % CI)	Correlation data	Bland-Altman bias [Limits of agreement]	General comments
1	Bjornsdottir R, Oskarsdottir ES, Thordardottir FR, Ramel A, Thorsdottir I, Gunnarsdottir I [24]	Energy, protein			**CC:** Energy: r = 0.92; p < 0.001 Protein: r = 0.89; p < 0.001	For all meals: Energy: overestimation bias = 45 kcal/day [-231; 322 kcal/day] Protein: bias = 1.5 g/day [-14.0; 16.9 g/day] For meals with intake ≤ 50 % of meal served: Energy: underestimation bias = 97 kcal/day Protein: underestimation bias = 4.3 g/day	Cut-off for Inadequate intake: ≤50 % consumed
2	Budiningsari D, Shahar S, Manaf ZA, Susetyowati S. [25]	Energy, protein, CHO, fat	Sensitivity to identify those consuming ≤ 50 % of intake: Starch = 97 % Animal protein = 98.2 % Non-animal protein = 93.9 %	Specificity to identify those consuming ≤ 50 % of intake: Starch = 90 % Animal protein = 75 % Non-animal protein = 87 %	**ICC:** Energy: 0.96 (0.94–0.97) Protein: 0.91 (0.88–0.91) **CC:** Energy: r = 0.92; p < 0.01 Protein: r = 0.849; p < 0.01	Energy: [-108 to 115 kcal/day] Protein: [-7.2 to 6.8 g/day]	Accuracy for assessment within 15 % of true value: Energy: 93.9 %; bias = 6.2 % Protein: 90 %; bias = 10 %
3	Dekker IM, Langius JAE, Stelten S, de Vet HCW, Kruizenga HM, de van der Schueren MAE [15]	Energy, protein			**ICC:** Research assistants Energy: 0.788 (-273, 56) Protein: 0.905 (−8.4, 1.0) Trained researchers Energy: 0.819 (−193, 119) Protein: 0.961 (−4, 2.2)	Research assistants Energy: bias = −109 kcal; 7 % [-273; 56 kcal] Protein: bias = −3.7 g, 6 % [-8.4; 1.0 g] Trained researchers Energy: bias = 37 kcal; 2,3 % [-193; 119 kcal] Protein: bias = 0.9 g, 1.5 % [-4.0; 2.2 g]	Accurate assessment of intake by tool: Research assistants: Energy: 61 % Protein: 61 % Trained researchers: Energy: 61 % Protein: 79 %
4	Ghisolfi A, Dupuy C, Gines-Farano A, Lepage B, Vellas B, Ritz P [12]	Energy			**ICC:** Energy: 0.96 (0.94–0.97)	Energy: bias = 35 kcal [± 420 kcal]	
5	Guerdoux-Ninot E, Flori N, Janiszewski C, Vaille A, de Forges H, Raynard B, Baracos VE, Thezenas S, Senesse P [13]	Energy	80.8 % compared to intake < or >25 kcal/kg/day	67.5 % (for low food intake <25 kcal/kg)	**CC:** Energy: Rho = 0.67, p < 0.05		Used cutoff of≤7 on the ingesta-VVAS to indicate low intake as compared to < or >25 kcal/kg/day Feasibility of tool = 97.7 %
6	Husted MM, Fournaise A, Matzen L, Scheller RA [20]	Energy, protein				Plate method Energy: bias = −40.6 kcal Protein: bias = −1.0 g Reduced plate method Energy: bias = −118.8 kcal Protein: bias = −2.3 g	
7		Energy, protein					

(*continued on next page*)

Table 4 (*continued*)

	Authors	Nutrients measured	Sensitivity (95 % CI)	Specificity (95 % CI)	Correlation data	Bland-Altman bias [Limits of agreement]	General comments
	Kawasaki Y, Sakai M, Nishimura K, Fujiwara K, Fujisaki K, SM, Akamatsu R [26]				**CC:** Nurses – whole trays Energy: Rho = 0.91, p < 0.01 Protein: Rho = 0.88, p < 0.01 Dietitians - whole trays Energy: Rho = 0.94, p < 0.01 Protein: Rho = 0.89, p < 0.01 Dietitians - individual foods Energy: Rho = 0.98, p < 0.01 Protein: Rho = 0.96, p < 0.01	Nurses – whole trays Energy: bias = 41.4 kcal/day [-121 to 147 kcal/day] Protein: bias = 2.1 g/day [-6.4 to 7.0 g/day] Dietitians - whole trays Energy: bias = 36.4 kcal/day [-122 to 106 kcal/day] Protein: bias = 2,0 g/day [-6.7 to 5.5 g/day] Dietitians - individual foods Energy: bias = 23,0 kcal/day [-82 to 66 kcal/day] Protein: bias = 1.0 g/day [-4.3 to 3.9 g/day]	
8	Ofei KT, Mikkelsen BE, Scheller RA [21]	Energy, protein			**ICC:** Energy: 0.99 (0.98–0.99) Protein: 0.99 (0.98–0.99) **CC:** Energy: r = 0.99, p < 0.01 Protein: r = 0.99, p < 0.01	Energy: bias = 13.49 kJ [-75.07 to 102.01 kJ] Protein: bias = 0.04 g [-1.5 to 1.59 g]	
9	Palmer M, Miller K, Noble S [18]	Energy, protein			**CC:** Breakfast: r = 0.793; p < 0.001 Lunch: r = 0.352; NS Supper: r = 0.393; NS	Energy: bias = −55 ± 317 kcal/day Protein: bias = 0.5 ± 16.2 g/day	Up to 93 % of daily food records were incomplete
10	Schumacker CSM, Paulus MC, Boelens YFN, van Zanten ARH & Kouw IWK [16]	Energy, protein				Overestimation of food consumption: Food record charts bias = 3.2 % [-25.7 to 31.9 %] Digital photography bias = 4.7 % [-26.2 to 35.5 %] Food record charts vs weighed food Energy: bias = −4.9 ± 92.0 kJ Protein: bias = −0.2 ± 1.3 g Digital photography vs weighed food Energy: bias = 1.0 ± 108.8 kJ Protein: bias = −0.1 ± 1.3 g	Cut-off for Inadequate intake: ≤50 % consumed Both Food Record Charts and Digital Photography overestimated food items if consumed <50 % (range +3.0 to +11.5 %) and underestimated when consumption was >50 % (range −2.2 to −6.7 %). Both methods slightly overestimated intake of liquids (2,3–6,9 %) and semi-solids (7,4–7,8 %) compared to solids (1,7-1,8 %).
11	Tan J, Lau KM, Ross L, Kinneally J, Banks M, Pelecanos A, Young A [19]	Energy, protein	Original and revised Energy: 100 % (69.2–100 %) Protein: 100 % (71.5–100 %)	Original Energy: 61.3 % (49.7–71.9 %) Protein: 62 %	**CC:** Energy: r = 0.85, p < 0.001		Based on cut point of poor energy intake at the meal≤1000 kJ and≤10 g protein

				(50.4 %–72.7 %) Revised Energy: 80 % (69.6–88.1) Protein: 75.9 % (65–84.9 %)	Protein: r = 0.83, p < 0.001		Agreement with reference limits of within 250 kJ and 2.5 g protein: Energy: 58.9 % Protein: 44.4 % Agreement with reference limits of within 450 kJ and 4.5 g protein: Energy: 77.8 % Protein: 62.2 % Feasibility: Visual format = 98 % Verbal format: 96 %
12	Thibault R, Goujon N, Le Gallic E, Clairand R, Sebille V, Vibert J, Schneider SM, Darmaun D [14]	Energy			**CC:** Total cohort: Verbal format: rho = 0.66, p < 0.0001 Visual format: rho = 0.74, p < 0.0001 In-patients: Verbal format: rho = 0.73, p < 0.0001 Visual format: rho = 0.74, p < 0.0001 Out-patients: Verbal format: rho = 0.32, p = 0.04 Underweight patients (BMI<19): Verbal format: rho = 0.78, p < 0.0003 Visual format: rho = 0.78, p < 0.0003 Overweight patients (BMI≥ 25): Verbal format: rho = 0.39, p = 0.04		
13	Tulloch H, Cook S, Nasser R, Guo G, Clay A [23]	Energy, protein	Daily average: 81 % (62–94 %) Breakfast: 75 % (53–89 %) Lunch: 93 % (83–97 %) Supper: 100 % (87–100 %)	Daily average: 88 % (77–95 %) Breakfast: 90 % (83–94 %) Lunch: 72 % (61–81 %) Supper: 70 % (60–77 %)	**CC:** Energy Breakfast: rho = 0.624, p < 0.001 Energy Lunch: rho = 0.771, p < 0.001 Energy Supper: rho = 0.892, p < 0.001	Breakfast: bias = −7±22 % Lunch: bias = 3 ± 21 % Supper: bias = 5 ± 18 %	Inadequate food intake:≤50 % consumption Overall agreement = 72 % (Range 55–100 %) Agreement to detect intake ≤50 % = 88 %
14	Van den Berg G, Van Noort H, Borkent J, Vermeulen H, Huisman-de Waal G, de Van der Schueren M(17)	Energy, protein			**CC:** Energy: r = 0.097 Protein: r = 0.167 **ICC:** Lunch: 0.442 Dinner: 0.620		Associations between nurse's records and patient's self-assessment indicated that higher scores on the 1–10 scale corresponded to higher energy and protein values. Every ascending point corresponded to an increase in 52 kcal (955 CI: −8; 113) and 2.6 g protein (95 % CI: 0.4; 4.8).

Abbreviations used: ICC=Interclass correlation coefficient. Presented as ICC (95 % Confidence interval [CI]).
CC=Correlation coefficient. Presented as Pearson correlation: r; p-value or Spearman correlation: rho, p-value.
NS – Non significant difference.

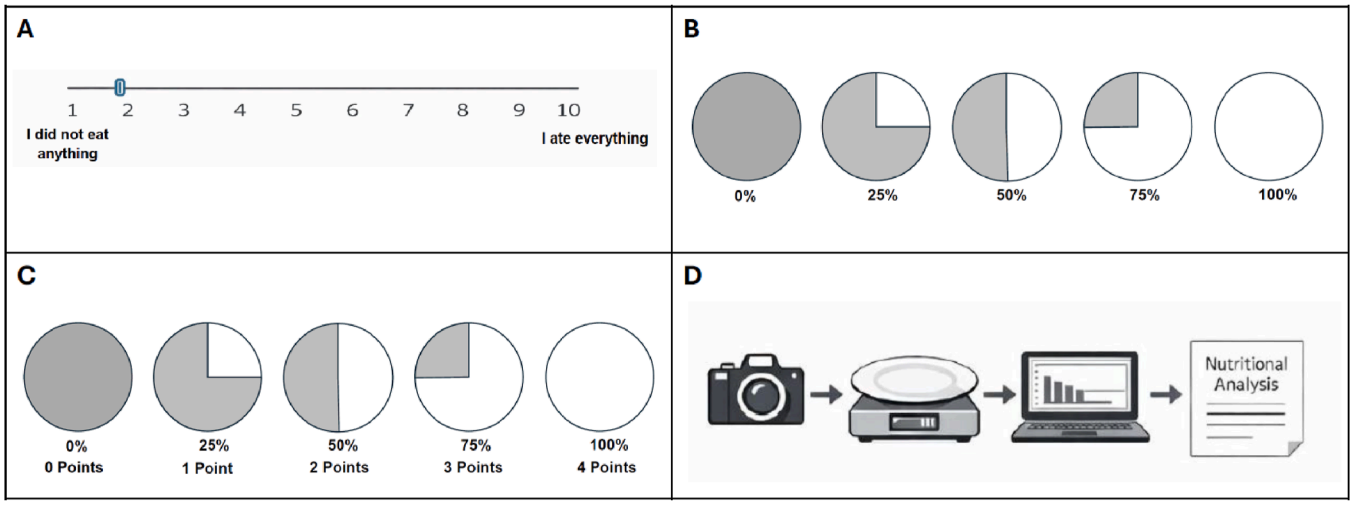

Fig. 2. Measurement tools for assessment of dietary intake. The figure graphically depicts the four types of measurement tools used to assess dietary intake across the included studies. Panel A: Visual estimation method (VEM) using a 10-point scale with slider ranging from 1 (I did not eat anything) to 10 (I ate everything); Panel B: VEM based on plate-model pictures. In this example 5 plate options are used with 0 % (no food was consumed), 25 % (a quarter of food was consumed), 50 % (half of food was consumed), 75 % (three-quarters of food was consumed) and 100 % (all food was consumed). The grey shaded area indicates food left on the plate and the white area indicates food consumed; Panel C: Similar to Panel B, but with points allocated based on the proportion of food consumed. The points are given a specific energy (kcal) and protein (g) value based on the dietary analysis of the menu served; Panel D: The use of digital technology to determine nutritional composition of food consumed. It consists of a camera to photograph the plate of food before and after consumption, a scale to weigh the food to determine gram value, a computer programme with food analysis software and a nutritional analysis printout.

point equaling 130 kcal and 5 g protein. They used a food record based on standard portion sizes as the reference method for breakfast, lunch and snacks, but with the dinner meal weighed the food before and after consumption. Ghisolphi et al. [12] used the Caloric Intake Tool (CIT) to visually estimate food consumption based on a 4-point scale, with a fixed pre-determined energy value of every one point equaling 160 kcal according to menu calculations to a total of 640 kcal. Based on total meal points, the final caloric value is calculated by the proportional consumption thereof e.g. if only 50 % of a meal scoring 4 points was consumed, total energy intake was 320 kcal [12]. In the Australian study by Tan et al. [19], the Meal Intake Points (MIP) system was used on adult hospitalized patients. Menu items were assigned points based on the nutritional value in comparison to a common denominator of 500–1000 kJ and 5–10 g protein for 1 point, up to a maximum of 4 points per meal/tray. They report results of both the original version of the MIP, as well as the adapted final version [19]. The results from the latter version are included in this scoping review. The Pictorial Dietary Assessment Tool (PDAT) [25] provides pictures of three food groups (staple food e.g. rice, porridge; animal food sources e.g. egg, chicken, and non-animal food sources e.g. tempeh, tofu). The pictures represent different proportions of food consumption with corresponding energy and protein content [25].

Digital technology was used by two studies. Dietary Intake Monitoring System (DIMS) consists of a device with a digital camera and a weighing scale to measure plate weight before and after consumption. Data is transmitted to a tablet programmed with food analysis software [21]. Schumacker et al. [16] took pictures of food trays after meal consumption and asked healthcare workers to assess intake based on a 6-point scale. Based on the pre-weight of the meals and the proportional intake, the information was converted to energy and protein intake.

Summary: A variety of measurement tools have been used for assessment of food intake, ranging from VEMs using a 10-point scale, to VEMs with plate pictorials with or without allocated predefined energy and protein values, to using photographs of meals.

3.3.2. *Validity of index methods*

The wording of the original GLIM framework requires an energy estimation to a precision of 50 % of energy requirements [1]. Please refer to Table 4 for the validation results of the included studies discussed below.

3.3.2.1. 10-point scale concept. Ingesta-VVAS defined low intake as patients consuming less than 25 kcal/kg/day and this correspond to a value of ≤7 on the 10-point scale [13]. A good sensitivity of 80.8 % accurately identified individuals having low intake, while 32.5 % were incorrectly identified as not having low intake (specificity 67.5 %). The Ingesta-VVAS had a fair correlation with energy intake (rho = 0.67, $p < 0.05$) and was considered feasible (rating of 97.7 %) [13]. Thibault et al. [14] reported a fair to good correlation between scoring and energy intake (verbal form rho = 0.66 and visual form rho = 0.74). Although most people felt comfortable providing verbal answers (98 %), the visual form provided better accuracy [14]. Van den Berg et al. [17] found higher scoring corresponded to higher intake levels, where every ascending point corresponded to a 52 kcal and 2.6 g protein increase.

3.3.2.2. Visual plate pictorials. Using cut-offs of consuming ≤50 % of meals, Bjornsdottir et al. reported good accuracy with an underestimation for energy (bias = 97 kcal/day) and protein (bias = 4.3 g/day). In general the tool overestimated slightly for energy (bias = 45 kcal) and protein (bias = 1.5 g) [24]. Husted et al. used a 5-option model (plate model) and a 4-option model (reduced plate model), and reported better results for the 5-options model, with an energy underestimation of 6 % and protein underestimation of 10 % (energy bias = 40.6 kcal and protein bias = 0.5 g) versus the 4-options tool that underestimated protein by 22 % (energy bias = 118.8 kcal and protein bias = 2.3 g) [20]. Although Palmer et al. reported good accuracy with small underestimation for both energy (bias = 55 kcal) and protein (bias = 0.5 g), only 7 % of their daily food records were complete [18].

Inadequate intake, defined as consuming ≤50 % of meals, was used as the reference in the study by Tulloch et al. [23]. The daily average intake was correctly estimated in 72 % of cases. Those with inadequate intake were correctly identified in 88 % of cases. On average, sensitivity was 81 %, however, they reported variations between the three meals of the day, with best accuracy at supper (Se 100 %, rho 0.89), followed by lunch (Se 93 %, rho = 0.77) and breakfast (Se 75 %, rho = 0.62). Accuracy decreased at the opposing ends of the scale with underestimation in the 0–25 % group and overestimation in the 75–100 % consumption groups [23].

Kawasaki et al. [26] interpreted whole trays using an 11-point scale, and reported that 61 % of trays were categorized with 90–100 % accuracy. They did report a difference in the accuracy of measurements performed by nursing assistants and dietitians, with more accurate assessments performed by the latter group (energy bias = 36.4 kcal; protein bias = 1.0 g) versus the nursing assistants (energy bias = 41.4 kcal; protein bias = 2.1 g). Dietitians performed even better when scoring individual foods (energy bias = 23 kcal; protein bias = 1.0 g). Intake of certain food groups (dairy and grains) and consumption of modified textured foods (minced meals) affected the accuracy of the data [26].

3.3.2.3. Visual plate pictorials with associated predefined nutritional value. Dekker et al. [15] reported different accuracy results for the research assistants and dietitians, with less bias reported for the latter group. Energy was underestimated by 2.3 % (bias = 37 kcal) versus 7 % (bias = −109 kcal) and protein underestimation by 1.5 % (bias = 0.9 g) versus 6 % (bias = −3.7 g) (dietitians versus research assistants respectively). A good interclass correlation (ICC) of 0.79–0.96 between energy and protein was reported for both groups [15]. Ghisolfi et al. [12] reported good ICC between nursing staff trained to complete the tool, with an energy bias = 35 kcal. Items with larger caloric content produced a slight energy underestimation with the CIT compared to weighed plate waste [12]. A cut-off point for poor intake per meal, which corresponded to 50 % of the nutritional value of the meals provided, was set at ≤ 1000 kJ and ≤10 g protein by Tan et al. [19]. Both the original and revised versions of MIP produced 100 % sensitivity for both energy and protein. Specificity improved in the revised version to 80 % for energy and 75.9 % for protein, but it showed lower accuracy to correctly identify higher intakes. They stated a priori that good agreement would be achieved if the index method scored within 250 kJ and 2.5 g protein compared to the reference test. This was achieved for 58.97 % of meals for energy and 44.4 % of meals for protein. If the limits of agreement were extended to within 450 kJ and 4.5 g protein, it was achieved in 77.8 % (energy) and 62.2 % (protein) of meals. Good correlation was achieved between food weighing and the MIP (energy: r = 0.85; protein: r = 0.83) [19]. Budiningsari et al. [25] reported accuracy within 15 % of the true value for more than 90 % of cases for both energy (bias = 6.2 kcal/day) and protein (bias = 10 g/day). Different staff assessors agreed with each other with an ICC of 0.96 (energy) and 0.91 (protein). A very good correlation between weighing and PDAT was reported for energy (r = 0.929) and protein (r = 0.859). The percentage of individuals with inadequate food intake and identified by PDAT as at risk for intakes ≤50 %, were good for all food groups (sensitivity for staple food 97 %, animal foods 98.2 % and non-animal foods 93.9 %).

3.3.2.4. Digital technology. Very small underestimation of energy (bias = 13.49 kJ) and protein (bias = 0.04 g) consumption, with good agreement (ICC 0.99 for both energy and protein) and excellent correlation (r = 0.99 for energy and r = 0.98 for protein) was reported using digital camera technology [21]. Similarly, good accuracy was reported by Schumacker et al. [16] with an overestimation of food intake <5 % using photography (bias = 4.7 %) or food record charts (bias = 3.2 %). The actual impact on energy and protein intake was negligible with < 5 kJ and 0.2 g protein difference from weighed records. Overestimation of intake was more prevalent when overall consumption was less than 50 %, or in the case of consumption of liquids or semi-solid foods [16].

Summary: The 10-point Ingesta-VVAS missed 32.5 % of individuals with inadequate intake. This decreased to 12 % using visual plate pictorials. Tools tend to be less accurate at opposing ends of intake levels, also when assessing different food consistencies, food groups, different meals and therapeutic diets versus regular meals. Using digital technology proves to provide accurate data, however, the human component is still required to estimate proportional intake and preprogramme the device with nutritional values of menu items.

3.3.3. Accuracy of the index tools used by various healthcare professionals in estimating food intake

Both studies using VEM based on a 1–10 point scale found that 98 % of participants could answer the verbal form completed by the patients themselves or dietitians, indicating good agreement [13,14]. The 4-option VEM plate models of Bjornsdottir et al. [24] and Palmer et al. [18] showed good accuracy for nursing staff completing the tools with an underestimation of energy of less than 100 kcal (bias of 97 kcal and 55 kcal respectively). Similarly, Ghisolfi et al. [12] reported an energy bias of 35 kcal for nursing staff trained to complete the tools. These differences are relatively small and should not influence the outcome of using these tools in dietary assessment. The study by Palmer et al. [18] did, however, report differences between the meals of the day, with the biggest underestimation of both energy and protein intake noted for breakfast. This aspect could be considered during the training of the staff. Even though it is part of their routine clinical practice, nursing assistants, not trained in the method being tested, had significantly lower accuracy in estimating food intake using an 11-point scale compared to dietitians, without specific training in completion of the tools [26]. In the case of Tulloch et al. [23] food service workers adequately trained to complete the tools could correctly determine daily intake of patients in 72 % of cases and could correctly identify patients with inadequate intakes (≤50 % of intake) in 88 % of cases. The results of this study have important clinical implications, as it showed that adequately trained food service workers can accurately assess patients' intake quickly when removing trays. Nutrition assistants could accurately determine energy and protein for 61 % of cases, and underestimated intakes in up to a third of cases using the Rate-the-Plate method [15]. In the same study, adequately trained researchers reached the same level of accuracy for energy (61 %), but could determine protein with higher accuracy (79 %) [15]. Using the PDAT, dietitians, nurses and serving assistants showed that staff from different backgrounds could accurately complete the tool with a good agreement amongst them (ICC of more than 0.90) [25]. It is also clear that employing digital technology resulted in good agreement between assessors without receiving specific training (ICC of 0.99) [21].

Summary: Good results are shown when the various tools were completed by patients themselves, nursing staff, food service workers and dietitians. It is also clear that adequate training on the completion of the tools enhances accuracy.

4. Discussion

This scoping review appraised measures for food intake of adult patients in healthcare settings and reports on their validity, reliability and potential for application for determining the food

intake criteria of GLIM. Determination of the food intake variable within GLIM should be easy to complete by most healthcare professionals with limited nutrition training. For this reason, we limited our search to tools that take less than 5 min to complete (e.g. less than 20 items), with minimal participant burden. Common dietary intake assessment methods (e.g. 24-hour recall, food frequency questionnaire) were thus not considered. Our focus was also to identify tools that could extrapolate data to percentage energy intake, as the original GLIM framework operationalized reduced food intake as $\leq$ 50 % of intake [1,2].

Assessment of food intake is essential for the diagnosis of malnutrition. Various techniques for dietary assessment are available with different levels of ease and time required for completion, analysis and interpretation [28,29]. In general, most techniques require a certain amount of training and skills to implement. Weighed records are considered to provide the most accurate results [30] and were used as the reference method in many studies included in this scoping review. Interestingly, only four studies conducted food weighing before and after consumption [12,20,21,23,27], while the remaining studies compared post-meal weights to an assumed standard portion of food served [18,19,24,25,31].

We found various visual estimation methods reported, with different levels of accuracy and sophistication. These ranged from a 1–10-point scale without any visuals, to visuals of various plate options, with and without pre-determined nutritional value, to digital technology. A VEM is defined as "a method or tool that aids a rater to estimate the proportion or amount of food and fluids consumed during eating and drinking occasions, subsequently allowing for nutrient analysis" [8].

Comparing the accuracy of the plate model with 5 options versus the one with 4 options, Husted et al. [20] reported smaller bias for both energy and protein with the 5-options [20]. Keller et al. also noted that factors affecting accuracy of VEM include portion-controlled meals (smaller portion sizes) and adding additional food items to trays. The latter resulted in a 3.8 times higher chance of misclassification (OR = 3.85) [31].

Visuals with associated energy and protein values attached, accurately reflected nutritional intake. These methods, however, require significant effort at the food production end (food service unit) to ensure use of standardized menus and nutritional analysis, as it restricts menu flexibility. But it does save time at the user-end (ward level). This need for accurate menu analysis was stressed by a few studies [12,15].

Incorporating intake analysis by means of pre-programmed nutritional analysis, can assist with identifying at-risk individuals at the ward level. This was also reported by Budiningsari et al. [25] who found very good accuracy in predicting individuals at risk of $\leq$50 % intake. They stated that the use of a system with pre-programmed nutritional analysis for every menu item saves time and assists in the calculation of nutritional content. It does require standardized meals and detailed menu analysis beforehand. This was emphasized in the study by Palmer et al. [18]. These authors reported that researchers were unable to determine daily intake in 93 % of the food intake charts, due to missing data in the pre-programmed nutritional analysis, or due to inadequate supplier information, resulting in the inability to determine up to 450 kcal and 24 g protein at meals. This led to an inability to determine agreement between the index and reference methods [18]. The problem was therefore not with using the VEM, but the accuracy of the data available in food intake charts [18].

Digital technology provided the most accurate estimation of food intake, however, the clinical application and usability in current resource-constrained environments are questioned. In general, image-based methods (digital) can affect intake and result in bias associated with the knowledge that an image will be taken before and after meals, as this process can affect behavior. Using technology is also dependent on the availability and tech-savviness of participants [29]. A positive component of digital methodology, is that memory is not an issue and portion sizes can be more accurately captured [29] and digital technology can be implemented with minimal interruptions during meal times [32]. Currently, a human component is still required to assess proportional intake based on the photographs taken and further analysis for nutritional composition. It therefore saves time at the ward level but requires the same detailed processes for the analysis as for other tools.

In general, various factors affect participants' ability to rate their food intake. This can include the type of meals received, where differences were reported in the accuracy of estimating regular diets compared to therapeutic diets, with regular diets being less accurate [27]. Food consistency also impacts accuracy of assessment, with a lower sensitivity reported for fluids compared to solids [22]. Variations were also found in the accuracy of reporting specific meals, where Palmer et al. reported accuracy of especially lunch and supper to be very poor [18], to Tulloch et al. reporting the opposite, with best results at supper [23].

Barriers to reporting accurate intake are more commonly reported in women [29,33,34], younger participants [33], those consuming less than 50 % of a meal [33], underweight individuals [33,34], overweight individuals [14], those suffering comorbidities [33] and mental issues (depression and anxiety) [34]. Other components that influence accuracy of reporting include types of meals (therapeutic versus regular diets), as mentioned above [27], and setting (outpatients versus in-patients) [14].

Most tools reviewed have the ability to accurately identify those individuals with inadequate intake, however, the ability to extrapolate the data for determination of actual energy requirements to comply with the original GLIM variable, is challenging. Using a VEM with more options, for instance 11 options [26], provides estimations to an accuracy levels of 10 %, whereas the more commonly used 4 or 5 option VEMs, can only provide data to an accuracy level of 20–25 % of actual intake [18,20,24]. These tools can more easily identify percentage meal intake than percentage actual energy requirements.

Dietary intake tools can be completed by various health care professionals. However, adequate training of staff, especially non-dietetic professionals, is needed to improve the accuracy of results [8,15]. Among staff members (nurses and nursing assistants), those who received training in completing VEM demonstrated greater knowledge, paid more attention to detail (e.g., removing dish covers), and showed improved understanding of portion sizes [35].

All tools should be supported by nutrition support protocols to ensure that at-risk cases are escalated for appropriate treatment. Such protocols must define the number of inadequate meals permitted and the intake thresholds that trigger intervention.

4.1. Strengths and limitations

Strengths in this study are the use of multiple databases for the search, the use of standard procedures and double-blind review of included references. Only publications written in English, and those that estimated energy and protein were included. Another limitation is that references focused on healthy individuals, athletes, individuals with overweight or with noncommunicable diseases, and pregnancy were excluded, but appropriately limiting the generalizability to the clinical setting.

4.2. Conclusions

Different index methods were used primarily in hospital settings to determine food intake and specifically energy intake.

These methods were generally accurate as compared to a reference method, and more specifically individuals with reduced food intake can be identified. These brief food intake measures can be completed by various members of the health care team, as well as participants themselves, with training improving accuracy. Although the tools can identify inadequate intake, which is required for the GLIM criteria, they do not identify sufficiency of this intake relative to the individual patient's energy requirement. This component of the GLIM framework needs reconsideration, as establishing an individual energy requirement in clinical settings requires specialist skills. Clinicians can use the various methods of visual estimation found in this scoping review with confidence to determine food intake in clinical settings.

Author contributions

Renée Blaauw: Conceptualization; Project administration; Literature searches; Methodology; Screened all relevant articles for eligibility; Full article evaluation; Writing - original draft; Writing - review & editing; **Gert Bischoff:** Screened all relevant articles for eligibility; Writing - review & editing; **Marian de van der Schueren:** Screened all relevant articles for eligibility; Writing - review & editing; **Charlene Compher:** Screened all relevant articles for eligibility; Writing - review & editing; **Krista Haines:** Screened all relevant articles for eligibility; Writing - review & editing; **Nicole Kiss:** Screened all relevant articles for eligibility; Writing - review & editing; **Charles Lew:** Screened all relevant articles for eligibility; Writing - review & editing; **Ainsley Malone:** Screened all relevant articles for eligibility; Writing - review & editing; **Claudia Maza:** Screened all relevant articles for eligibility; Writing - review & editing; **Nancy Stoner:** Screened all relevant articles for eligibility; Writing - review & editing; **Heather Keller:** Screened all relevant articles for eligibility; Software; Full article evaluation; Writing - review & editing. Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work ChatGPT was used to generate Fig. 2. The authors reviewed the content for factual correctness and take full responsibility for the content of the published article.

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Conflict of interest

The authors declare no conflict of interest related to this work.

Appendix A. Supplementary data

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