COMPARISON OF CONTENT AND PSYCHOMETRIC PROPERTIES OF MALNUTRITION OUTCOME MEASURES: A SYSTEMATIC REVIEW

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**Objective:** To determine the most-often used outcome measures for malnutrition risk and malnutrition, analyse outcome measure content, and assess psychometric properties.

**Methods:** MEDLINE, SAGE Journals, Web of Science, SCOPUS, ProQuest and Science Direct databases were searched to identify outcome measures. Outcome measure content was compared using the International Classification of Functioning Disability and Health (ICF). Psychometric properties were also systematically searched and compared. This review was prepared according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

**Results:** A total of 1,311 studies met the inclusion criteria. The most-often used outcome measures for detecting malnutrition or its risk overall were: body mass index (590), albumin (469), Mini Nutritional Assessment (312), haemoglobin (251), and Subjective Global Assessment (139). The most psychometrically sound outcome measure was Mini Nutritional Assessment, but the most comprehensive measure, covering the most ICF categories, was Patient-Generated Subjective Global Assessment, with a total of 58 meaningful concepts.

**Conclusion:** The results provide an insight into the content and psychometric quality of malnutrition risk and malnutrition outcome measures. There was some variation between the way reviewers linked meaningful concepts to ICF, and literature gaps were identified regarding psychometric properties. These results can be used to help select the most appropriate malnutrition outcome measure.

**Key words:** malnutrition; outcome measure; International Classification of Functioning Disability and Health; psychometrics; linking.

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The World Health Organization (WHO) defines malnutrition as deficiencies, excesses or imbalances in a person’s intake of energy and/or nutrients (1). The prevalence of malnutrition in the rehabilitation setting ranges from 14% to 65% worldwide, with the highest prevalence reported in Europe and Australia (2). The prevalence of malnutrition in the (acute) hospital setting has been reported to be 20–50%, depending on the patient population, the definition of malnutrition, and the outcome measures or criteria used for diagnosis (3). Keller et al. found the prevalence of malnutrition in 638 long-term care residents from 32 long-term care homes in Canada to range from 28.9% if assessed with InterRAI Long Term Care Facility undernutrition trigger, 33.4% with Patient-Generated Subjective Global Assessment (PG-SGA), and 53.7% with Mini Nutritional Assessment – Short Form (MNA-SF); hence the prevalence depends on the sensitivity and specificity of the specific malnutrition assessment tool (4).

According to the European Society for Clinical Nutrition and Metabolism (ESPEN) Consensus Statement, there are 2 methods of diagnosing malnutrition: body mass index (BMI) < 18.5 kg/m\textsuperscript{2}, or unintentional weight loss > 10% independent of time, or > 5% over the last 3 months combined with either BMI < 20 kg/m\textsuperscript{2} if < 70 years of age, or < 22 kg/m\textsuperscript{2} if 70 years of age or older, or fat-free mass index (FFMI) < 15 and 17 kg/m\textsuperscript{2} in women and men, respectively (5). These diagnostic criteria are supported by the National Institute for
Health and Care Excellence (NICE) Clinical Guideline on Nutrition Support for Adults (6) as well as the Global Leadership Initiative on Malnutrition (GLIM) approach, which updates these criteria by including both phenotypic (weight loss %, BMI and muscle mass) and aetiological criteria (reduced food intake or assimilation and inflammation) for the diagnosis of adult malnutrition (7).

According to GLIM criteria, the first step in evaluation of malnutrition is the identification of malnutrition risk, which can be done by using any validated screening tool (8). Diagnosis of malnutrition, however, consists of several additional criteria or components of qualitative or quantitative outcome measures (9). Therefore, authors searched for both malnutrition risk and malnutrition outcome measures, as both are components in the diagnostic process.

For this article, different components used for malnutrition diagnosis were each considered a separate outcome measure. Outcome measures were defined by using International Classification of Health Interventions (ICHI) as any measurements (quantitative determination of characteristics using units of measurement) or tests (review or examination using a questionnaire, rating scale or other instrument) (10).

A person’s functioning and disability is conceived as a dynamic interaction between health conditions and contextual factors, and malnutrition is no exception (11). It has many associated consequences; amongst which are a decline in physical and mental functions, causing dependency in activities of daily living, which can result in hospitalizations and longer hospital stays, poor disease outcomes and reduced quality of life (12, 13). Therefore, all healthcare professionals, and not only nutritionists and dietitians, should be knowledgeable about malnutrition and its assessment.

Information on the psychometric properties and content of the most-often used malnutrition and malnutrition risk outcome measures needs to be systematically reviewed in order to improve evidence-based practice. The latest available evidence on this topic includes Xu & Vincent’s 2020 article on the measurement properties of malnutrition assessment tools for use in hospitals. The authors concluded that the use of the Subjective Global Assessment (SGA), PG-SGA and Mini Nutritional Assessment (MNA) can be supported, but that more studies with sound methodology are needed to assess their responsiveness to change (14). Miller et al. published an article in 2018 about the lack of validated screening tools for simultaneously assessing cachexia, sarcopenia and malnutrition (15). Marshall et al., in a 2018 systematic review and meta-analysis, concluded that, other than MNA, there is insufficient evidence to recommend a particular assessment tool (16). Zhang et al.’s 2017 study systematically reviewed and evaluated many different malnutrition biomarkers, and showed that BMI, haemoglobin and total cholesterol are useful biomarkers of malnutrition in older adults (17). However, to our knowledge, there is no evidence on the comprehensive comparison of the content of the outcome measures used according to the International Classification of Functioning, Disability and Health (ICF) (11). The aims of this systematic review were therefore to determine the most-often used outcome measures for malnutrition risk or malnutrition, to analyse the content of outcome measures by linking meaningful concepts with the ICF, and to assess the psychometric properties of outcome measures.

**METHODS**

This review was prepared and reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (18).

MEDLINE, SAGE Journals, Web of Science, SCOPUS, ProQuest and Science Direct databases were searched for studies published up to October 2019. Search strategies were created using the keyword “malnutrition” and MeSH terms (if available in the database) and adding Boolean operators. The search strategies used in each database are shown in Appendix 1. Appropriate search filters were then added: “language (articles in English)”; “article type (randomized controlled trial, clinical trial)”; “publication date (2010–2019)”; “species (human)”; and “age (18+)”.

Inclusion criteria for this systematic review were: (i) research design (randomized controlled trial, observational studies, cross-sectional studies, qualitative studies); (ii) at least 1 outcome measure is reported as an outcome variable within the article (screening, clinical assessment, subjective (healthcare personnel and caretakers’ perspective) and/or quality-of-life outcome measures); (iii) article published between 2010 and October 2019; (iv) article in English; (v) research with human subjects; and (vi) study participants aged 18 years or older. Exclusion criteria were: (i) laboratory or genetic studies; and (ii) retracted articles.

One reviewer reviewed the titles and abstracts of studies to determine their eligibility for inclusion. Studies that clearly did not meet the inclusion criteria were excluded at this point. Those that could not be clearly assessed were included and analysed in full text. Studies that met the inclusion criteria were included and further analysed. Data on study design, participant group and amount, as well as outcome measures used in the studies were then extracted from all included studies. Information on frequency of clinical assessments (clinical signs and medical history) was not included in this study, as they do not represent a form of standardized outcome measures. The cut-off for the most-often used outcome
measures that were included in further analysis in each group was 5%. To obtain more objective and realistic results and to include a larger selection of research articles, representing as many patient groups as possible, lower levels of evidence (e.g. case reports) were also included. Therefore, the methodological quality of the included studies was not assessed.

ICF linking process
The most commonly used functional outcome measures were selected for the linking process. Two reviewers with prior knowledge of the ICF and linking procedure performed the linking process independently, based on the ICF linking rules described by Cieza et al. (19, 20). Meaningful concepts were first identified, then linked to the most precise ICF category. Wherever possible, consensus between reviewers was reached, either with a discussion or with an opinion from a third reviewer. Agreement between reviewers was determined by calculation of Cohen’s kappa coefficient (κ). Values were interpreted according to Cohen’s 1960 study, where ≤0 = no agreement, 0.01–0.20 = none to slight agreement, 0.21–0.40 = fair agreement, 0.41–0.60 = moderate agreement, 0.61–0.80 = substantial agreement, and 0.81–1.00 = almost perfect agreement (21).

Table I. Most commonly used malnutrition outcome measures

| Outcome measure                                      | Number of times mentioned in studies | %   | Type of measure                  |
|------------------------------------------------------|--------------------------------------|-----|----------------------------------|
|                                                      |                                      |     | Functional | Laboratory | Instrumental | Anthropometric |
| Body mass index (BMI)                                 | 590                                  | 45  | ✓         | ✓          |             |               |
| Albumin                                              | 469                                  | 35  | ✓         | ✓          |             |               |
| Mini Nutritional Assessment (MNA)                    | 312                                  | 23  | ✓         | ✓          |             |               |
| Haemoglobin                                          | 251                                  | 19  | ✓         | ✓          |             |               |
| Subjective Global Assessment (SGA)                   | 139                                  | 10  | ✓         | ✓          |             |               |
| Bioelectrical impedance analysis (BIA)               | 135                                  | 10  | ✓         | ✓          |             |               |
| Dual energy X-ray absorptiometry (DEXA)              | 17                                   | 10  | ✓         | ✓          |             |               |
| Cholesterol                                          | 109                                  | 8   | ✓         | ✓          |             |               |
| Indirect calorimetry                                 | 13                                   | 8   | ✓         | ✓          |             |               |
| Vitamin B12/cobalamin                                 | 102                                  | 7   | ✓         | ✓          |             |               |
| Pre-albumin/transferritin                             | 99                                   | 7   | ✓         | ✓          |             |               |
| Arm circumference                                    | 96                                   | 7   | ✓         | ✓          |             |               |
| Nutritional Risk Screening 2002 (NRS-2002)           | 96                                   | 7   | ✓         | ✓          |             |               |
| Malnutrition Universal Screening Tool (MUST)         | 83                                   | 6   | ✓         | ✓          |             |               |
| Weight loss percentage                               | 74                                   | 5   | ✓         | ✓          |             |               |
| Arm muscle circumference                              | 69                                   | 5   | ✓         | ✓          |             |               |
| Triceps skinfold thickness                            | 68                                   | 5   | ✓         | ✓          |             |               |
| Waist circumference                                  | 58                                   | 5   | ✓         | ✓          |             |               |
| Patient-Generated Subjective Global Assessment (PG-SGA)| 47                                   | 5   | ✓         | ✓          |             |               |

RESULTS
A total of 11,225 studies were identified through the databases. Of these, 3,923 duplicates were excluded. After removal of duplicates and the screening process, 1,631 full-text articles were reviewed for eligibility. Of these, 320 did not meet inclusion criteria, and 1,311 studies were included in qualitative synthesis. Fig. 1 shows the flow of study selection.

Outcome measures
Out of 215 identified outcome measures, 92 were functional assessments, 59 were laboratory tests, 3 were instrumental assessments, and 61 were anthropometric indicators. Nineteen of the instruments identified were subject to further analysis. The most commonly used outcome measures from all groups are shown in Table I.
arm circumference, arm muscle circumference, bioelectrical impedance analysis (BIA), dual-energy X-ray absorptiometry (DEXA), triceps skinfold thickness, and waist circumference.

Functional assessments (standardized assessment tools) (PG-SGA, NRS-2002, MNA, MUST and SGA) are the most comprehensive of the outcome measures, covering the most components of the ICF. The majority of outcome measures were predominantly covered by Body Function and Activity and Participation components. Three PG-SGA concepts (5%) were found to not be covered by the ICF.

All laboratory tests covered 1 category from the Body Structure component—structure of cardiovascular system (s410). Indirect calorimetry also only covered 1 category, which is from the Body Function component (general metabolic functions (b540)). BIA and DEXA contain concepts, which were not covered by the ICF.

Tables II–III show the results of anthropometric and functional outcome measure linking with ICF. The agreement between reviewers regarding the linking of most commonly used malnutrition outcome measures with ICF is summarized in Table IV.

**Analysis of psychometric properties**

Psychometric property analysis was performed for all functional outcome measures (MNA, SGA, NRS-2002, MUST and PG-SGA). Overall, 42 studies that described psychometric properties were included. A summary of the measurement properties in different study populations is shown in Table V.

MNA proved to have positive content validity for its original population, elderly patients (23). Internal consistency was positive for patients with Parkinson’s disease, institutionalized Spanish elderly people, Turkish geriatric outpatients, Ethiopian elderly patients, and Norwegian acute geriatric patients (24–28). Criterion validity was positive only in Norwegian geriatric nursing home patients (29). Agreement was positive in Chinese stroke patients and test-retest reliability was positive in institutionalized Spanish elderly people (27, 30). Responsiveness was positive in all populations tested, except for Iranian elderly people (24, 26, 28, 31, 32). No floor or ceiling effect was found for MNA (25). Interpretability was lacking clear description in older Australian patients undergoing rehabilitation (33). Construct validity for the
Table II. Results of anthropometric outcome measure meaningful concept linked with International Classification of Functioning, Disability and Health (ICF) 2nd level categories

| ICF category code and title | BMI | Arm circumference | Weight loss % | Arm muscle circumference | Handgrip strength | Triceps skinfold thickness | Waist circumference |
|----------------------------|-----|------------------|---------------|-------------------------|------------------|-------------------------|-------------------|
| b530 Weight maintenance functions | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| b730 Muscle power functions | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| s730 Structure of upper extremity | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| s760 Structure of trunk | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| s810 Structure of areas of skin | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

BMI: body mass index.

This review identified 215 outcome measures that have been used in research as components to measure malnutrition risk or malnutrition. While authors agree that the concepts “malnutrition” and “risk of malnutrition” differ, outcome measures that are components for diagnosis of malnutrition are stand-alone assessments for malnutrition risk; for example, MNA, MUST, and NRS-2002. Perhaps the issue is one of terminology: malnutrition, risk of malnutrition and malnutrition diagnosis. GLIM combines diagnostic criteria for diagnosis of malnutrition. Validated tools are considered malnutrition screenings only in the context of GLIM, because within the outcome measures themselves, they score the patient as “malnourished” all the same. The issue is that, within the tools, the term “malnutrition” is still being used, even if, alone, it does not determine the diagnosis of malnutrition.

The identified outcome measures are diverse and can be categorized into 4 types: (i) functional assessment tools, (ii) laboratory tests, (iii) instrumental assessments, and (iv) anthropometric indicators. The 19 most commonly used tools covered 47 categories when linked to the ICF. An extensive systematic search of the literature was also performed in order to identify and compare the psychometric properties of functional assessment tools. The available evidence was related mostly to responsiveness, reliability and internal consistency of the instruments.

Body mass index (BMI) has been established in this review as, overall, the most commonly used component in malnutrition diagnostics. BMI is a useful measurement for the majority of adults; however, it is flawed if used alone, because it is dependent only on height and weight. It fails to account for any other personal factors that are important in the diagnosis of malnutrition, such as age, ethnicity, sex, physical activity and body composition. Standards of good clinical practice include complex malnutrition assessment to obtain a diagnosis of malnutrition, consisting of several components, such as the GLIM model, however, research articles show that these components are often also used separately, as is the case for BMI.

Therefore, for accurate diagnosis of malnutrition it is necessary to use BMI in addition to other...
outcome measures. For example, waist circumference can provide additional information on visceral adiposity. Due to its ease of use, BMI is included in many functional assessment tools, such as MNA, NRS-2002 and MUST. BMI parameters do measure nutritional status, but have been supplemented by other important items, making such functional assessment tools accurate in diagnosing risk of malnutrition, compared with BMI alone, as shown in 2016 in a study by Miranda et al. (57). The other most commonly used anthropometric indicators for nutritional assessment in this review were arm circumference, weight loss percentage, arm muscle circumference, triceps skinfold thickness and waist circumference. These are cost-effective, simple and quick, and the results can be compared with the values for a general population. However, other anthropometric indicators have similar issues to BMI; the results, by themselves, are not reliable for all patient groups. For example, assessing only arm circumference or arm muscle circumference in patients with upper extremity oedema would not correctly portray quantity of fat and muscle mass; hence the addition of other assessments is necessary.

Anthropometric indicator content in itself is not very comprehensive and covers only the Body Structure and Body Function components of the ICF. Categories from component Body Structures that were most often linked to were “s730 Structure of upper extremity”, indicating an item construct assessing arm circumference or arm muscle circumference and “b530 Weight maintenance functions”.

### Table III. Results of functional measure meaningful concept linked with International Classification of Functioning, Disability and Health (ICF) 2nd level categories

| ICF category code and title | MNA | SGA | NRS-2002 | MUST | PG-SGA |
|-----------------------------|-----|-----|----------|------|--------|
| Body Functions              |     |     |          |      |        |
| b117 Intellectual functions | 1   |     |          |      |        |
| b122 Global psychosocial functions |     | 1   |          |      |        |
| b130 Energy and drive functions | 1   |     |          |      |        |
| b152 Emotional functions    |     | 1   |          |      |        |
| b180 Experience of self and time functions |     |     | 1      |      |        |
| b250 Taste function         | 1   |     |          |      |        |
| b255 Smell function         |     | 1   |          |      |        |
| b280 Sensation of pain      |     | 1   |          |      |        |
| b455 Exercise tolerance functions | 1   |     |          |      |        |
| b510 Ingestion functions    | 5   | 5   | 4        | 3    | 4      |
| b515 Digestive functions    | 1   | 1   |          |      |        |
| b525 Defecation functions   |     | 2   |          |      |        |
| b530 Weight maintenance functions | 3   | 6   | 8        | 7    | 2      |
| b535 Sensations associated with the digestive system | 1   |     |          |      |        |
| b540 General metabolic functions | 1   | 1   |          |      |        |
| b545 Water, mineral and electrolyte balance | 1   | 1   |          |      |        |
| b550 Thermoregulatory functions |     |     |        |      |        |
| b810 Protective functions of the skin | 1   |     |          |      |        |
| Body Structures             |     |     |          |      |        |
| s230 Structures around eye  |     |     |          |      |        |
| s320 Structure of mouth     |     |     |          |      |        |
| s710 Structure of head and neck region | 1   |     |          |      |        |
| s720 Structure of shoulder region | 2   |     |          |      |        |
| s730 Structure of upper extremity |     |     | 1      |      |        |
| s750 Structure of lower extremity | 1   |     | 2      |      |        |
| s770 Additional musculoskeletal structures related to movement | 1   |     | 1      |      |        |
| s810 Structure of areas of skin | 1   |     |          |      |        |
| Activities and Participation|     |     |          |      |        |
| d230 Carrying out daily routine |     |     |          |      |        |
| d240 Handling stress and other psychological demands | 2   |     |          |      |        |
| d410 Changing basic body position | 2   | 2   |          | 3    |        |
| d420 Transferring oneself   | 1   | 1   |          |      |        |
| d450 Walking                | 1   |     |          |      |        |
| d550 Eating                 | 2   | 1   | 1        | 1    |        |
| d560 Drinking               |     |     |          |      |        |
| d570 Looking after one’s health | 1   | 1   |          |      |        |
| d710 Basic interpersonal interactions |     |     | 1      |      |        |
| Environmental Factors       |     |     |          |      |        |
| e110 Products or substances for personal consumption | 5   | 1   | 2      | 6    |        |
| e115 Products and technology for personal use in daily living | 1   |     |          |      |        |
| e165 Assets                 |     |     |          |      |        |
| e355 Health professionals   | 1   |     |          |      |        |
| e580 Health services, systems and policies | 7   |     | 6      |      |        |
| Not covered by ICF categories |     |     |          |      |        |
| Personal factors (pf)       | 5   | 1   | 1      | 3    | 3      |
| Health condition (hc)       | 13  | 2   | 9      |      |        |
| Not covered (nc)            | 1   |     | 3      |      |        |

MNA: Mini Nutritional Assessment; MUST: Malnutrition Universal Screening Tool; NRS-2002: Nutritional Risk Screening 2002; PG-SGA: Patient-generated Subjective Global Assessment; SGA: Subjective Global Assessment.
Malnutrition outcome measures

Table IV. Agreement between reviewers on linking

| Outcome measure | Agreement (Cohen’s kappa coefficient (κ)) |
|-----------------|------------------------------------------|
| BMI             | 1.00                                     |
| Albumin         | 1.00                                     |
| MNA             | 0.79                                     |
| Haemoglobin     | 1.00                                     |
| SGA             | 0.92                                     |
| NRS-2002        | 0.88                                     |
| MUST            | 0.86                                     |
| PG-SGA          | 0.81                                     |
| Cholesterol     | 1.00                                     |
| BIA             | 1.00                                     |
| DEXA            | 1.00                                     |
| Indirect calorimetry | 1.00                                 |
| Arm circumference| 1.00                                     |
| Body weight loss %| 1.00                                     |
| Arm muscle circumference | 1.00                               |
| Handgrip strength | 1.00                                   |
| Triceps skinfold thickness | 1.00                               |
| Waist circumference | 1.00                                   |

BIA: bioelectrical impedance analysis; BMI: body mass index; DEXA: dual-energy X-ray absorptiometry; MNA: Mini Nutritional Assessment; MUST: Malnutrition Universal Screening Tool; NRS-2002: Nutritional Risk Screening 2002; PG-SGA: Patient-generated Subjective Global Assessment; SGA: Subjective Global Assessment.

maintenace functions”, measured by BMI and body weight loss percentage.

Since anthropometric measurements on their own do not give enough information about body composition and are subject to measurement variability, instrumental assessments can be useful, offering accurate results. Three commonly used instrumental assessments were identified in this review, with 2 of them being body composition assessments (BIA and DEXA) and 1 being a measurement of energy expenditure (indirect calorimetry). BIA was identified as the most-often used body composition instrumental assessment. It is a quick non-invasive method, but requires strict adherence to certain procedures beforehand, such as, fasting for 2 h (58). DEXA is considered an even more accurate method and is consistent with anthropometric measurements (59). DEXA is a reliable and easy-to-perform method, which can help quickly detect early malnutrition and monitor changes in nutritional status (58, 59). However, even though the radiation dose of a single DEXA measurement is low, it is not recommended for pregnant women (58), and DEXA requires specialized, expensive radiology equipment, therefore it is not as feasible in clinical practice as BIA, which is a low-cost device. If no devices are available, combinations of other assessment methods (anthropometrics and laboratory tests) can be used for the assessment of body composition; however, they will be less accurate than instrumental assessments.

Indirect calorimetry was reported as an outcome measure used in 8% of studies included in this review. Indirect calorimetry determines energy expenditure by measuring pulmonary gas exchanges, which allows clinicians to determine the requirements for patients’ energy intake and is a non-invasive technique (60, 61). For calculating energy expenditure, validated equations can be used as well, however, within the scope of this review, indirect calorimetry remains the only method mentioned. Overall, it is the most accurate assessment of energy expenditure and remains the gold standard (60).

Content of body composition instrumental measurements (BIA and DEXA) was found to not be covered in detail by the ICF. Aspects such as body water or fat mass could potentially be linked to Body structure category s598 “Structures related to the digestive, metabolic and endocrine systems, other specified”. However, updated linking rules advise against using “other specified” categories if the content of a meaningful concept is not explicitly named (13); therefore, they were marked as “not covered”.

The first step towards diagnosis of malnutrition is screening for malnutrition risk with a valid tool (8). The most-often used functional assessment tools were MNA, SGA, NRS-2002, MUST and PG-SGA.

MNA, designed for use in elderly patients, shows overall positive psychometric properties, with the only exception being poor construct validity and indeterminate interpretability, where further studies with clearly described minimal important change are necessary. MNA was also the second most comprehensive functional assessment tool, covering 19 ICF categories from all components, including Personal Factors (9 Body Functions, 2 Body Structures, 7 Activities and Participation, 1 Environmental Factors, and 5 Personal Factors). Ten out of 14 identified studies on psychometric properties of MNA were performed with a geriatric population. Therefore, based on our analysis of the available data, MNA can be recommended for use in elderly patients; however, there are insufficient studies available to be able to draw conclusions regarding other patient groups.

SGA and NRS-2002 were originally both validated for hospitalized patients. Despite several studies being available for this patient group, SGA does not clearly demonstrate positive psychometric properties. Content validity was indeterminate, responsiveness was poor, and criterion validity with BMI was also poor. However, internal consistency, agreement and reliability were scored positively. SGA content covers 15 ICF categories over components Body Functions (9 categories) and Activities and Participation (6 categories) and Personal Factor (1 category). Of all the functional assessment tools, NRS-2002, however, had the largest literature gap. No studies could be found on NRS-2002 internal consistency, among other properties, which is in agreement with Millers 2018 systematic review (9), even though first validation studies on the outcome measure were published in early 2000s. Similarly to SGA, NRS-2002 also received a positive rating on
Table V. Summary of the measurement properties of malnutrition functional assessments

| Measurement | Content validity | Criterion validity | Construct validity | Internal consistency | Agreement | Reliability | Responsiveness | Floor or ceiling effect | Interpretability | Study population |
|-------------|------------------|--------------------|--------------------|---------------------|------------|-------------|---------------|---------------------|----------------|------------------|
| MNA         | ?                | -                  | -                  | -                   | 0          | 0           | +             | 0                   | 0              | Elderly          |
|             | +                | -                  | +                  | -                   | 0          | 0           | +             | 0                   | 0              | Hospitalized elderly |
|             | -                | -                  | -                  | -                   | 0          | 0           | +             | 0                   | 0              | Healthy individuals |
|             | -                | -                  | +                  | +                   | 0          | 0           | +             | 0                   | 0              | Parkinson’s disease patients |
|             | -                | -                  | +                  | 0                   | 0          | 0           | +             | 0                   | 0              | Institutional elderly |
|             | +                | +                  | 0                  | +                   | 0          | +           | 0             | 0                   | 0              | Elderly rehabilitation patients |
|             | +                | 0                  | -                  | -                   | +          | 0           | +             | 0                   | 0              | Elderly outpatients |
|             | 0                | 0                  | 0                  | +                   | 0          | 0           | 0             | 0                   | 0              | Stroke patients |
|             | 0                | 0                  | 0                  | +                   | 0          | 0           | 0             | 0                   | 0              | Peritoneal dialysis patients |
| SGA         | 0                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Liver-transplant candidates |
|             | 0                | 0                  | 0                  | +                   | 0          | 0           | 0             | 0                   | 0              | Surgical patients |
|             | ?                | 0                  | 0                  | 0                   | 0          | 0           | +             | 0                   | 0              | Hospitalized patients before gastrointestinal surgery |
|             | 0                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Hemodialysis patients |
|             | 0                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Patients with end stage renal disease |
| NRS-2002    | +                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Various diagnostic groups |
|             | 0                | 0                  | 0                  | 0                   | 0          | 0           | +             | 0                   | 0              | Surgical patients |
|             | 0                | 0                  | 0                  | 0                   | 0          | +           | 0             | 0                   | 0              | Hospitalized patients |
|             | 0                | 0                  | 0                  | 0                   | 0          | +           | 0             | 0                   | 0              | Hemodilysis patients |
|             | +                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Hospitalized patients |
| MUST        | +                | -                  | -                  | +                   | 0          | +           | 0             | 0                   | 0              | Surgical patients |
|             | -                | -                  | -                  | -                   | +          | +           | +             | +                   | +              | Hospitalized patients |
| PG-SGA      | +                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Hospital and outpatient clinic participants |
|             | ?                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Hospitalized patients |
|             | ?                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Elderly rehabilitation patients |
|             | ?                | 0                  | 0                  | 0                   | 0          | 0           | 0             | 0                   | 0              | Stroke patients |

Rating: +: positive; -: poor; ?: lacking clear description or doubtful design or methods; 0: no information available (22).

MNA: Mini Nutritional Assessment; MUST: Malnutrition Universal Screening Tool; NRS-2002: Nutritional Risk Screening 2002; PG-SGA: Patient-generated Subjective Global Assessment; SGA: Subjective Global Assessment.
3 different measurement properties: however, it lacks too much overall information to receive a strong recommendation from the authors of this review for use in hospitalized patients. Content analysis revealed that it is also less comprehensive, compared with SGA, covering only 2 categories of Body Functions, 2 contextual factors, and several health conditions.

MUST is intended to be a universal screening tool. However, the available studies mostly tested measurement properties in hospitalized patients, to enable comparison with SGA and NRS-2002. This review shows that, overall, MUST has more available evidence and receives a positive rating for more measurement properties, based on criteria by Terwee et al. (22). Information is lacking for other care settings. Content analysis shows MUST covers 4 Body Function categories, 2 Body Structure categories, 2 Activities and Participation categories, and 4 Environmental Factors categories. It also includes some Personal Factors and Health Conditions. Based on the available evidence, perhaps MUST is a more suitable assessment tool for use in hospitalized patients, compared with SGA and NRS-2002.

PG-SGA is a comprehensive outcome measure, including both patients’ and physicians’ perspectives. Studies are available on different patient groups besides oncological patients, such as outpatients, hospitalized stroke patients and elderly patients. PG-SGA shows several good properties, however, there is a lack of strong evidence on responsiveness, to provide context for clinically meaningful changes in results, which was also established by Xu et al. (2020)’s systematic review, making it clear that further research is necessary (14). PG-SGA is the most comprehensive of all functional outcome measures, covering 25 different ICF categories of all components and Health Conditions. The majority of meaningful concepts were linked to the Body Function categories; however, some were not covered by the ICF. Those meaningful concepts were body structures in conjunction with body composition, which were not described clearly enough to link to a specific category, such as, fat and fluid, similarly to meaningful concepts identified with BIA and DEXA.

Most functional assessment tool constructs, assessing malnutrition, were linked to ICF categories “b510 Ingestion functions” and “b530 Weight maintenance functions”. Those include aspects connected with swallowing and digestion of food, as well as functions of maintenance of acceptable BMI, which is a construct measured in many functional assessment tools. The impact of malnutrition on everyday activities, based on outcome measure content, seems mainly to be related to mobility and self-care. The ability to perform activities, such as “changing basic body position” or “eating”, were assessed in MNA, NRS-2002 and PG-SGA. The most-often covered Environmental Factor category was e110 Products or substances for personal consumption. Outcome measures that included constructs linked to this category were assessing aspects such as meals eaten daily and products consumed, consistency of diet, and necessity for special diets or drugs. Regarding Personal Factors, weight and height were mostly included as separate items to determine a patient’s BMI. Health conditions mentioned in outcome measures were used as an additional factor that increases risk of malnutrition. For example, NRS-2002, MUST and PG-SGA included kidney failure, oncological diseases and intensive care patients as such.

Kappa coefficient values show that the functional outcome measure content has less agreement between reviewers (Table IV). Since functional outcome measure content has more meaningful concepts that can be linked to the ICF, compared with instrumental assessments or anthropometric indicators, interpretations of those concepts tend to differ between reviewers, based on how the item has been phrased. Instrumental assessments and laboratory tests, each with only 1 meaningful concept, had almost perfect reviewer linking agreement.

The most commonly used laboratory tests in the process of malnutrition diagnostics, in this review, were albumin, haemoglobin, cholesterol, vitamin B12 and pre-albumin. Content analysis showed that laboratory tests cover only 1 ICF category. While not being comprehensive, laboratory tests are designed to answer specific clinical questions. According to ESPEN guidelines on definitions and terminology of clinical nutrition, biochemical markers should not be used as indicators of a patient’s overall nutritional status (58). Albumin might be useful for measuring degree of catabolism/inflammation (62). With careful interpretation, under some circumstances, albumin and pre-albumin may be monitored for long- and short-term effects (58, 63). The British Association for Parenteral and Enteral Nutrition advises assessing haemoglobin levels for iron status and indication of anaemia; micronutrients, including vitamins, could be affected if inflammation or infection is present, so should be measured when C-reactive protein is low (62). Therefore, not all laboratory tests are components of currently accepted malnutrition definition; rather, they can be associated with nutrition risk, not malnutrition itself (64).

Nutritional status is determined as a result of the nutritional intake, absorption and influence of other factors, such as the presence of disease. A single measure cannot provide a comprehensive assessment. In the absence of 1 gold standard assessment, different groups of nutrition assessments are combined, as
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Conclusions

This review identified BMI as the most commonly used component for assessment of malnutrition. No overall quality score was given, so there is no single objective answer as to which might be the psychometrically best, validated assessment tool in all cases. In conclusion, within the scope of this study, for elderly people, the best, validated assessment tool might be the MNA and, for hospitalized patients, the MUST.

However, the most comprehensive outcome measure, covering the most ICF categories, is the PG-SGA, with 58 meaningful concepts in total.

In clinical practice, malnutrition diagnostics are complex, including several outcome measures; hence careful consideration is necessary and other factors, mainly the aim of the measurement, the time-frame for administering and interpreting it, and cost, must be taken into account.

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Appendix 1. Search strategies used in databases for the outcome measure literature search.

- **Science Direct, SAGE Journals, SCOPUS**: Malnutrition OR “Nutritional deficiency” OR Undernutrition OR Undernourishment
- **Web of Science**: TI=(Malnutrition OR “Nutritional deficiency” OR Undernutrition OR Undernourishment)
- **MEDLINE (PubMed)**: “Protein-Energy Malnutrition”[MeSH]
- **ProQuest**: MeSH (protein-energy malnutrition)

Appendix 2. Search algorithm used in databases for the outcome measure properties literature search.

- **MEDLINE (PubMed)**: (“Mini Nutritional Assessment”) AND (psychometrics); (“Subjective global assessment”) AND (psychometrics); (“patient generated subjective global assessment”) AND (psychometrics); (“nutritional risk screening 2002”) AND (psychometrics); (“malnutrition universal screening tool”) AND (psychometrics).