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Harmonization and standardization of malnutrition screening for all adults – A systematic review initiated by the Norwegian Directorate of Health

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Abstract

**Background & Aims:** The Norwegian Directorate of Health has identified a need to harmonize and standardize the malnutrition screening practice in Norwegian hospitals and primary health care settings, in order to provide a seamless communication of malnutrition screening along the patient pathway. Our aim was to perform a systematic review of the validity and reliability of screening tools used to identify risk of malnutrition across health care settings, diagnoses or conditions and adult age groups, as a first step towards a national recommendation of one screening tool.

**Methods:** A systematic literature search for articles evaluating validity, agreement, and reliability of malnutrition screening tools, published up to August 2020, was conducted in: MEDLINE, Embase, APA PsycInfo, Cinahl, Cochrane Databases, Web of Science, Epistemonikos, SveMed+, and Norart. The systematic review was registered in PROSPERO (CRD42022300558). For critical appraisal of each included article, the Quality Criteria Checklist by The Academy of Nutrition and Dietetics was used.

**Results:** The review identified 105 articles that fulfilled the inclusion and exclusion criteria. The most frequently validated tools were Mini Nutritional Assessment short form (MNA), Malnutrition Universal Screening Tool (MUST), Malnutrition Screening Tool (MST), and Nutritional Risk Screening 2002 (NRS-2002). MNA, MST and NRS-2002 displayed overall moderate validity, and MUST low validity. All four tools displayed low agreement. MST and MUST were validated across health care settings and age groups. In general, data on reliability was limited.

**Conclusions:** The screening tools MST and NRS-2002 displayed moderate validity for the identification of malnutrition in adults, of which MST is validated across health care settings. In addition, MNA has moderate validity for the identification of malnutrition in adults 65 years or older.

**Keywords:** malnutrition screening tool, systematic reviews, MNA, MST, MUST, NRS-2002


Introduction

Malnutrition is a common condition and can be both a cause and a consequence of disease. Malnutrition also negatively affects the prognosis of disease. The Global Leadership Initiative on Malnutrition (GLIM) criteria are international consensus-based diagnostic criteria for malnutrition (1). The first step in diagnosing malnutrition in GLIM is screening to identify individuals at risk of malnutrition using a validated screening tool (1). Thus, tools used for screening are not diagnostic tools, but identifies persons at risk of becoming malnourished or persons who already are malnourished. Several malnutrition screening tools are available, but with a large variation in level of validity, reliability, and generalizability, that will affect the ability to accurately identify adults who are malnourished and in need of nutritional treatment (2).

Internationally, a wide array of screening tools are used to identify the risk of malnutrition. Since 2009, the Norwegian Directorate of Health has recommended the use of Malnutrition Universal Screening Tool (MUST), Nutritional Risk Screening 2002 (NRS-2002), Mini Nutritional Assessment Long form (Full MNA), Subjective Global Assessment (SGA) or “Ernæringsjournal” [translates to “Nutrition journal”] depending on the health care setting (3). The use of various screening tools complicates the comparison of both clinical evaluations and research results on malnutrition. Additionally, the use of several screening tools may lead to miscommunication between health care providers and may pose a risk to patient safety. Discontinuities of care in the transition between different levels in the health care systems have been identified as risk factors for increased readmission rates and adverse medical events (4). A harmonization and standardization of the screening method may lead to more accurate screening practice and comparison of the risk of malnutrition (5) during the patients' journey from one health care setting to another (6). The harmonization and standardization of the malnutrition screening may also facilitate a national overview of the burden of malnutrition and its distribution across care settings and regions (6).

The Norwegian Directorate of Health has therefore identified a need to harmonize the malnutrition screening practice across health care settings, diagnoses or conditions and adult age groups. Such a harmonization is in line with former work in other countries. The British Association for Parenteral and Enteral Nutrition (BAPEN) has since 2003 implemented MUST as the recommended screening tool (7;8) providing comparable data across care
settings (8). The American Academy of Nutrition and Dietetics (9) recommended the Malnutrition Universal Screening tool (MST) to screen adults for malnutrition regardless of their age, medical history or setting (2;10). However, one specific malnutrition screening tool with outstanding validity, reliability, and strong supportive evidence across all care settings among adults has not yet been identified.

As a first step towards a national recommendation of one screening tool for the risk of malnutrition in the entire Norwegian health care system, we conducted a systematic review as an update and extension of the systematic review performed by Skipper et al. (10), by adding more recent literature, revising the comparison standard (including GLIM), and expanding with a Scandinavian literature search. The aim of this systematic review was to summarize the validity of commonly used screening tools to identify risk of malnutrition across health care settings, diagnoses or conditions, and adult age groups.

Materials and Methods

The PRISMA (Preferred reporting Items for Systematic Reviews and Meta-Analysis) statement was used as the guideline for the review and reporting (11) to ensure objectivity, transparency, and reproducibility of the process. The systematic review has been registered in PROSPERO (CRD42022300558). For critical appraisal of each included article, the Quality Criteria Checklist (12) by The Academy of Nutrition and Dietetics (9) was used.

Research question and eligibility criteria

The research question was formed using the population, intervention, comparison intervention and outcome (PICO) format, to ensure specificity and relevance to the aim of the project (Table 1). The population criteria for eligibility of studies were adults 18 years or older, any health care settings, and any diagnoses or conditions. The inclusion criteria for studies were quantitative validation studies, published in peer-reviewed journals, written in English, Norwegian, Swedish or Danish language, and at least 20 participants for each comparison. Exclusion criteria were studies using country-specific or modified versions of a tool, tools exclusively consisting of laboratory values and studies only published as abstracts.

The intervention included the 15 common screening tools used in relevant care settings, listed in Table 1. There is no agreed upon gold standard in order to compare the validity of
screening tools (6). Therefore, a set of comparison standards for the validation of screening tools were used, as listed in Table 1. The comparison standards were defined based on well validated “semi-gold standards”, and as defined by Skipper et al. (10) in order to facilitate comparison. Furthermore, the GLIM criteria (1) were added as a “semi-gold standard” during the literature review. When used as the sole criterion, BMI was not considered an acceptable gold standard for malnutrition.

The usefulness of a malnutrition screening tool can be measured as the ability to measure the important dimensions of malnutrition in the population at quest (content validity), test-retest and inter-observer variation (reliability), and ability to measure the agreement between the screening tool and the gold-standard or semi-gold-standard (concurrent validity) (6). Concurrent validity refers to the ability of the screening tool to identify malnutrition, and can be quantified through: sensitivity (the probability of a positive screening result given that the person is malnourished), specificity (the probability of a negative screening result given that the person is not malnourished), positive predictive value (PPV) (the proportion of true positive screening tests among all positive tests), negative predictive value (NPV) (the proportion of true negative tests among all negative tests), and kappa values (the agreement between tools using Cohen’s kappa coefficient). In addition, reliability (consistency of results when using the screening tool) was included in the search. All relevant outcomes are listed in Table 1, and in the complete search strategies in Supplementary Table 1.

To be able to harmonize and standardize the malnutrition screening practice for all adults, the tool needed to be validated across adult age groups, health care settings, and diagnoses or conditions.

Systematic literature search

A systematic literature search was performed in: Ovid MEDLINE(R) and Epub Ahead of Print, Embase, APA PsycInfo, Cinahl, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Web of Science, Epistemonikos, SveMed+, and Norart. The searches were performed by a librarian (RAT) at the Library for the Healthcare Administration, Norwegian Institute of Public Health, Oslo, Norway, after peer-internal review by another librarian from the same library. The search strategies combined search terms for the screening tools and comparison standards for the validation of screening tools (in Table 1) with search terms to identify validation studies. Synonyms with appropriate
truncations and abbreviations combined with search terms for malnutrition was used for searching title, abstract, and author keywords. The search strategy was tailored to each database’s search interference. The strategies were limited to English, Swedish, Danish, and Norwegian languages. No further limits were applied. The searches were performed for articles published from the earliest published articles in the databases, and up until the search dates of the 17th-19th of August 2020. In August of 2022, an expanded search was performed where also GLIM was included among the search terms. In this expanded search, 33 additional records were identified, of which all were excluded during literature review. The complete search strategies can be found in Supplementary Table 1.

All identified records were added, sorted, screened for duplicates (using different combinations of fields in preferences), and organized in the EndNote x9 software by Clarivate Analytics, Web of Science TM. The list of records was independently screened based on title and abstract, and on eligibility criteria identified by the PICO, by two reviewers (THT, IP) blinded for each other’s decisions. In the case of disagreement on screening status, consensus was reached between the two reviewers through a third common review.

One additional record was identified through the reviews of relevant literature. The tools Nutritional Risk Index (NRI) and Prognostic Nutritional Index (PNI) were excluded during the review process (after the literature search) since both tools exclusively assess laboratory values. There were no articles validating the tool “Ernæringsjournal” (Norwegian) [translates to “Nutrition journal”].

Review of the evidence and data extraction

The identified records that met the eligibility criteria were systematically reviewed full-text by both reviewers (independently and blinded) according to inclusion and exclusion criteria, quality of evidence, and outcome of interest. One reviewer (IP) extracted the data, and another reviewer (THT) double checked the extracted data. The following data was retrieved from each eligible research article: reference, publication year, quality of evidence, sample size, country, setting, condition/ward/diagnosis, mean/median age, lower age limit for inclusion, intervention tool, comparison tool, and relevant results of sensitivity, specificity, PPV, NPV, correlation coefficient (CC) and concordance (Cohen’s kappa values) (Table 2). Each separate performance indicator (sensitivity, specificity, PPV, NPV, agreement (Cohen’s kappa)) was evaluated based on pre-defined cut-off values as listed in Table 2 (13;14), while overall
validity of each screening tool was determined using an algorithm based on the algorithm developed by Skipper et al. (10).

**Quality of evidence**

The quality of articles was critically appraised independently by both reviewers for each of the included articles, using the Academy’s Quality Criteria Checklist of The Academy of Nutrition and Dietetics (12). The reviewers were blinded for the results of the other reviewer. The critical appraisal includes issues of inclusion/exclusion, bias, and data collection and analysis. When there was initial disagreement between the researchers on the quality assessment, consensus was reached through a third common review. Each article was graded as positive (+) indicating that the report has clearly addressed the issues, negative (-) indicating that these issues have not been adequately addressed, and neutral (ø) indicating that the report is neither exceptionally strong nor exceptionally weak in quality.

**Reliability**

Studies reporting on the reliability of Mini Nutritional Assessment Short Form (MNA), MST, MUST or NRS-2002 were summarized in Supplementary Table 2 either with test-retest or inter-rater reliability of the respective tools. One reviewer (THT) extracted the data from each eligible research article, and the other reviewer (IP) checked the extracted data. The following data were extracted: reference, publication year, sample size, country, setting, condition/ward/diagnosis, mean/median age, lower age limit for inclusion, intervention tool, observer comparison, comparison period, and relevant results of CC, intraclass correlation coefficient (ICC), and agreement coefficients (Gwet’s AC1 and Cohen’s kappa values). To summarize the evidence only agreement coefficients were comparable and were interpreted as described in Table 2.

**Results**

The inclusion of records is summarized in a PRISMA diagram (Figure 1). The literature search provided 12882 records as well as 33 additional records in an updated search including GLIM, and one record identified through other sources resulting in 7042 records after the removal of duplicates. After the exclusion of 6564 through the initial screening rounds, 485
full-text records were screened for the eligibility of inclusion. Of these, 380 records were excluded based on the given inclusion and exclusion criteria, resulting in the inclusion of 105 records for the summary of results (Supplementary Table 3).

The validity (sensitivity, specificity, PPV, and NPV) and agreement (Cohen’s kappa) is summarized in Table 3. In addition, validity, agreement, quality, and characteristics of all included studies can be found in the following tables: MNA (Table 4), MST (Table 5), MUST (Table 6), NRS-2002 (Table 7), and Nutritional Form for the Elderly (NUFFE), Nutriscore, Patient generated subjective global assessment short form (PG-SGA-SF), Short nutritional assessment questionnaire (SNAQ), and Simplified nutritional appetite questionnaire (SimplifiedNAQ) (Table 8). A list of the 105 included studies can be found in Supplementary Table 3, and the completed Quality Check List for all included studies is presented in Supplementary Table 4. For each tool a summary and a conclusion is presented in alphabetical order below:

**Mini Nutritional Assessment short form (MNA)**

MNA was validated in 34 articles and with a total of 44 comparisons of which 34 were against Full MNA, eight against SGA, and one each for Malnutrition Inflammation Score (MIS) and Patient Generated Subjective Global Assessment (PG-SGA) (Table 4). Median sample size was 250. Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement against all references, and against other references than Full MNA. The majority of comparisons (37 comparisons) were done in older adults, and the most common setting was community-dwelling (12), nursing homes (9) or inpatients (10) within a variety of conditions/wards. Risk of bias was summarized as quality of primary research in 34 articles of which 16 was graded as positive (+) and 18 was graded as neutral (ø). One article was found to report on reliability of the MNA tool, with an inter-rater reliability of 0.31 (15). In conclusion, MNA obtained moderate validity, low agreement and validation studies limited to the older adult population across health care settings and conditions or wards. The quality of research was positive in 47% of the articles, and data on reliability was limited.

**Malnutrition Screening Tool (MST)**

MST was validated in 26 articles and with a total of 31 comparisons, of which 16 against SGA, nine against PG-SGA, three against Full MNA, two against GLIM, and one against
McWhrter (Table 5). Median sample size was 134. Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement. Of the comparisons, 15 were in populations of 18 years or above, and seven in older adults. The most common comparison setting was inpatients (15), outpatients (12), within a variety of conditions or wards. The quality of primary research was graded as positive (+) in 17 of the articles and neutral (ø) in nine articles. Six articles were found to report on reliability of MST (16;18-22), with a total of 10 comparisons. The mean inter-rater reliability between comparisons was 0.64 (0.28-0.93) measured in kappa values and 0.8 (0.6-0.9) with Gwet’s AC1. In conclusion, MST obtained moderate validity, low agreement, and validated across age groups, health care settings, and conditions or wards. The quality of research was positive in 65% of the articles, and data on reliability was moderate.

**Malnutrition Universal Screening tool (MUST)**

MUST was validated in 35 articles with a total of 41 comparisons of which 21 against SGA, six against PG-SGA, 11 against Full MNA, two against GLIM, and one against a nutrition assessment including body composition and change in body weight over time (Table 6). Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement. Most of the comparisons were performed in inpatients (26) or outpatients (9), within a variety of conditions or wards. Of the comparisons, 19 were in adult populations, and 15 in older adults. Quality of primary research was graded as positive (+) in 19 articles and neutral (ø) in 16 articles. Reliability was reported in three studies (16-18), with a mean inter-rater reliability between two studies of 0.68 (0.58-0.78). In conclusion, MUST obtained low validity, low agreement, and validity across age groups, health care settings, and conditions or wards. The quality of research was positive in 56% in of the articles, and data on reliability was limited.

**Nutritional Form for the Elderly (NUFFE)**

NUFFE was validated in one article and with one comparison against Full MNA with a sensitivity of 70, specificity of 76, PPV of 81, and NPV of 30 (Table 3, Table 8). The validation was performed in 97 older adults in a nursing home setting. Quality of primary research was graded as positive (+) in the included article.
Nutritional Risk Screening 2002 (NRS-2002)

NRS-2002 was validated in 36 articles and with a total of 46 comparisons of which 26 against SGA, three against PG-SGA, 12 against Full MNA, three against GLIM, one against McWhriter, and one nutrition assessment including body composition and change in body weight over time (Table 7). Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement. Median sample size was 210, and the majority of comparisons (23 comparisons) were done in populations 18 years or above and in older adults (14 comparisons). Most of the comparisons were performed in inpatients (42), within a variety of conditions or wards. Quality of primary research was graded as positive (+) in 27 articles and neutral (ø) in nine articles. Reliability was reported in three studies with five comparisons (23-25). The median inter-rater reliability between comparisons was 0.78 (0.65-0.96). In conclusion, NRS-2002 obtained moderate validity, low agreement, and validation studies limited to inpatients within a variety of wards. The quality of research was positive in 75% of the articles, and data on reliability was moderate.

Nutriscore

Nutriscore was validated in one article and with comparison against PG-SGA, with a sensitivity of 97, specificity 96, PPV 85, NPV 99, and kappa 0.88 (Table 3, Table 8). The validation was performed in a population of 394 oncology outpatients. Quality of primary research was graded as positive (+) in the included article.

Patient generated subjective global assessment short form (PG-SGA-SF)

PG-SGA-SF was validated in three articles and with a total of five comparisons, all against PG-SGA (Table 8). The median sample size was 246, of which all validations were performed in populations 18 years or above. Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement. The setting for four comparisons were in oncology and one nephrology ward. It should be noted that three of the comparisons were performed with different cut-off values for risk of malnutrition in the same population. Quality of primary research was graded as positive (+) in all three articles.

Short nutritional assessment questionnaire (SNAQ)
SNAQ was validated in five articles and with a total of six comparisons of which four against SGA, one against GLIM, and one against Full MNA (Table 8). The median sample size was 170, and four validations were performed in inpatients, and one in outpatients. Four of the comparisons were in populations 18 years or above, and two in populations 65 years or above. Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement. Quality of primary research was graded as positive (+) in three articles and neutral (ø) in two articles.

Simplified nutritional appetite questionnaire (SimplifiedNAQ)

SimplifiedNAQ was validated in six articles and with a total of eight comparisons of which six against Full MNA and two against SGA (Table 8). Median sample size was 180, and all validations were performed in populations above 55, 60 or 65 years of age within different health care settings. Table 3 lists the median sensitivity, specificity, PPV, NPV, and agreement. Quality of primary research was graded as positive (+) in three articles and neutral (ø) in three articles.

Overall validity

For each screening tool, the overall validity was based on the algorithm as shown in Figure 2.

Discussion

In this systematic review, we summarized the validation of malnutrition screening tools for adults (18 years or older) in any setting and independent of medical diagnoses or conditions. The four screening tools MNA, MST, MUST, and NRS-2002 were the most frequently validated against “semi-gold standards” for malnutrition screening.

This systematic review was initiated by the Norwegian Directorate of Health as a first step towards choosing one malnutrition screening tool to be used in the entire health care system. The main objective for choosing one tool was to facilitate seamless communication of malnutrition screening along the patient pathway.

Screening for malnutrition is the first step in the approach of diagnosing malnutrition suggested in the GLIM framework (1). Thus, it is of great importance that the screening tool used can identify those at risk of malnutrition in an accurate and timely manner. The
European Society of Parenteral and Enteral Nutrition (ESPEN) guidelines for nutrition screening states that the purpose of nutritional screening is to “predict the probability of a better or worse outcome due to nutritional factors, and whether nutritional treatment is likely to influence this” (26). The screening tools MNA, MST, and NRS-2002 all displayed overall moderate validity for the identification of malnutrition. MUST had low validity due to a sensitivity below the cut-off value of 70% sensitivity, however, the sensitivity of MST and NRS-2002 was only slightly higher. Of the four most validated screening tools, the NRS-2002 had the highest, while the MNA had the lowest percentage of high-quality studies.

The validation across age groups, settings and diagnoses or conditions varied for MNA, MST, MUST, and NRS-2002. The tools MNA, MST, and MUST were validated in a broader variety of settings as compared to NRS-2002, which was almost exclusively validated in hospital settings. MST, MUST, and NRS-2002 were validated in both all adults (18 years or older) and separately for older adults, while the MNA was mostly validated for the use in older adults (65 years and older) reflecting the target population of the MNA.

According to national quality indicators in Norway, malnutrition screening is inadequate among older adults in the primary health and care service (27). Lack of time, resources and knowledge are identified as barriers to malnutrition screening and follow-up by community nurses (28) and in hospitals (29-30). Given the same validity, it will therefore be of interest if the screening tool is quick and easy to carry out in order to meet some of the barriers to conduct screening. The four tools MNA, MST, MUST, and NRS-2002 differ in time for completion and ease of use as the number of items range from two (MST) to fourteen (MNA) for initial screening, and time to complete varies from less than two minutes to about 10 minutes (31-32).

In total, our systematic review and the systematic review by Skipper et al. (10) includes 126 studies of which only 47 are included in both reviews. Even with a substantially different selection of articles, our findings are in line with the results presented in the systematic review performed by Skipper et al. (10), which summarized the findings from 67 studies published until July of 2017. We identified 58 additional studies included in our summary of which 30 were published after July of 2017. Thus, our review includes 156% more studies as compared to the review published by Skipper et al. (10). The main reason for exclusion of studies in our review, of those included in the review by Skipper et al. (10), was the use of BMI as the sole reference standard for malnutrition. We do not consider BMI alone as sufficient and adequate to identify disease-related malnutrition in adults. This decision is supported by the fact that
BMI is only one of three possible phenotypic criteria in the recently proposed GLIM diagnostic criteria for malnutrition (1), and in the diagnostic criteria for malnutrition by American Society for Parenteral and Enteral Nutrition (ASPEN) BMI is not even included (33). In addition, if BMI alone was appropriate for the diagnosis of malnutrition, we do not see the need for a screening tool.

Strengths of this publication is the ability to update and extend on previous work in the field, by including the GLIM criteria as a comparison standard, by adding articles from the Scandinavian countries (databases) and by adding additional years of publications. The literature search identified records that were in correspondence to previous work. Additionally, 30 of the included validation studies were published after July of 2017. The present review used systematically methods to ensure objectivity, transparency, and reproducibility of the process.

Possible limitations of the review process are related to the ability to select relevant inclusion and exclusion criteria, as well as relevant reference standards. Such bias may have been reduced by involving a working group appointed by the Norwegian Directorate of Health in discussing the selected inclusion and exclusion criteria. This systematic review is an extension to previous reviews in the field. Although most of the selected screening tools reported in relevant literature were included, there is a possibility that unidentified instruments capable of accurately predicting malnutrition have been excluded. Reference standards for the validation of screening tools were chosen on the basis of previous work (10), the newly introduced GLIM criteria for diagnosing malnutrition, as well as well-known validated tools for identification of malnutrition. Missing available data in the included studies may have excluded some studies from comparison with others, however the extension of such is not known.

Comparison between subgroups were limited due to lack of standardization in the reported description of age (range), setting, diagnosis or condition. In order to recommend one screening tool across health care settings, the instrument should be validated within different age groups, settings and/or conditions/wards where the tool will be implemented. This was only true in a reasonable range for two of the screening tools – MST and MUST.

Risk of bias was considered for all the included studies, of which 44 studies scored neutral indicating neither exceptionally strong nor weak data. None of the included studies were scored as negative. The reminding 61 studies scored positive, indicating clearly addressing risk of bias related issues. The most frequent negative scores were related to the lack in
description of handling withdraws of study participants. The most unclear scores were related
to whether blinding was used to prevent introduction of bias, as well as some uncertainty
regarding the likelihood of bias due to relevant funding or sponsorship. Reports on the inter-
rater reliability were available for MNA, MST, MUST, and NRS-2002, although only one
article reported reliability for the MNA tool.

This systematic review was not able to identify one outstanding screening tool for
malnutrition with high validity, agreement, and reliability for use across health care settings,
diagnoses or conditions, and adult age groups. The MST was supported by a considerable
amount of evidence, had a moderate ability to predict malnutrition in the adult population, had
supportive evidence of reliable results, was validated across health care settings, and a limited
risk of bias. This evidence may guide decision-making for the choice of one tool for screening
of malnutrition in all levels of the health care system in order to minimize discontinuities of
care in the transition between them. The Norwegian Directorate of Health utilized the results
of this review in the process of revising the Norwegian guideline for prevention and treatment
of malnutrition from 2009. The revised guideline was published in 2022 (34). The decision-
making process for the screening recommendation is co-published in this number of Clinical
Nutrition ESPEN (REF).

As such, these results have the potential to improve communication and optimalization of
nutritional care along the patient pathway, and thus ultimately reduce the burden of
malnutrition. The results can contribute to the process of establishing a national overview of
the burden and distribution of malnutrition across health care settings and regions, and may
set an example for a standardized, systematic malnutrition screening practice as the first step
in the implementation of GLIM in clinical practice. This may be a starting point towards a
harmonization of screening and diagnosing for malnutrition also in other countries.

Conclusions

The screening tools MST and NRS-2002 display moderate concurrent validity for the
identification of malnutrition in adults, of which MST is validated across health care settings.
In addition, MNA has moderate validity for the identification of malnutrition in adults 65
years or older.

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**Statement of Authorship**

THT: Methodology, Investigation, Validation, Formal analysis, Writing original draft, Writing review & editing. HWK: Conceptualization, Methodology, Writing review & editing, Project administration. GBS: Conceptualization, Methodology, Writing review & editing. RAT: Methodology, Data Curation, Writing review & editing. AB: Conceptualization, Methodology, Writing review & editing. IP: Conceptualization, Methodology, Investigation, Validation, Formal analysis, Visualization, Supervision, Writing original draft, Writing review & editing.

**Conflict of Interest Statement**

The authors declare no conflicts of interest.

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Tables and Figures Legends

Figure 1 PRISMA flow chart

Figure 2 Summary of overall validity for MNA, MST, MUST, and NRS-2002.

The figure is based on the algorithm developed by Skipper et al. (10). The overall validity is given as the median for all validation studies for the respective malnutrition screening tools.

*MNA against other comparisons than Full MNA
### Table 1 PICO

| Population                                                                 | Intervention                                                                 | Comparison                                                                 | Outcome                                      |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------|
| • Patients admitted to hospitals or other health institutions within      | • Malnutrition Screening Tool (MST)                                          | • Mini Nutritional Assessment Long form (Full MNA) (35)                    | • sensitivity                                 |
| secondary care                                                             | • Malnutrition Universal Screening tool (MUST)                               | • Subjective Global Assessment (SGA) (36, 37)                             | • specificity                                 |
| • Persons living in nursing home or long term care facilities within the   | • Mini Nutritional Assessment short form (MNA)                               | • Patient-Generated Subjective Global Assessment (PG-SGA) (38, 39)        | • validity                                    |
| primary health care                                                        | • Nutritional Form for the Elderly (NUFFE)                                   | • McWhirter and Pennington Criteria (40)                                   | • reliability                                 |
| • Persons receiving home based care within the primary health care system  | • Nutritional Risk Index (NRI)                                               | • A nutrition assessment including at least body composition and change    | • agreement                                    |
| • Persons with high risk of malnutrition who are in contact with the      | • Nutritional Risk Screening 2002 (NRS-2002)                                 | in body weight over time (10)                                             | • generalization                               |
| primary health care system                                                 | • Patient generated subjective global assessment short form (PG-SGA-SF)     | • Malnutrition Inflammation Score (MIS) (when used for nutrition assessment)|(10, 41)                                      |
|                                                                           | • Prognostic Nutritional Index (PNI)                                         | • The GLIM criteria (1) (added after the original search)                 |                                              |
|                                                                           | • Short nutritional assessment questionnaire (SNAQ)                          |                                                                            |                                              |
|                                                                           | • Simplified nutrition appetite questionnaire (SimplifiedNAQ)                |                                                                            |                                              |
|                                                                           | • Subjective global assessment (SGA)                                         |                                                                            |                                              |
|                                                                           | • Nutriscore                                                                  |                                                                            |                                              |
|                                                                           | • Ernæringsjournal [Nutrition journal]                                       |                                                                            |                                              |

### Table 2 Interpretation of performance indicators for overall validity and reliability of screening tools based on Neelemaat et al. and McHugh et al. (13, 14)

| Validity                        | High  | Moderate | Low   |
|---------------------------------|-------|----------|-------|
| Sensitivity                     | ≥ 90 %| 70 % - 89 %| <70 % |
| Specificity                     | ≥ 90 %| 70 % - 89 %| <70 % |
| Negative predictive value       | ≥ 90 %| 70 % - 89 %| <70 % |
| Positive predictive value       | ≥ 90 %| 70 % - 89 %| <70 % |
| Agreement (Cohen’s kappa)       | ≥ 0.8 | 0.6-0.79 | < 0.6 |

**Reliability**

- Correlation coefficient: ≥ 0.8, 0.6-0.79, < 0.6
- Reliability (Cohen’s kappa): ≥ 0.8, 0.6-0.79, < 0.6
- Gwet’s AC1: ≥ 0.8, 0.6-0.79, < 0.6
Table 3 Summary of validity

|                      | Sensitivity | Specificity | PPV  | NPV  | Agreement |
|----------------------|-------------|-------------|------|------|-----------|
|                      | Median (range) | Median (range) | Median (range) | Median (range) | (Cohen’s kappa) Median (range) |
| MNA (n=34)           |             |             |      |      |           |
| Against all comparisons | 85.9 (64-100) | 86.3 (44-100) | 77.7 (16-100) | 90.5 (58-100) | 0.62 (0.14-0.92) |
| Against other comparisons than Full-MNA | 84.3 (70-100) | 77.9 (53-95) | 57.0 (20-76) | 98.4 (93-100) | 0.52 (0.14-0.92) |
| MST (n=26)           | 72.9 (32-100) | 84.4 (25-98) | 69.9 (36-98) | 87.1 (49-100) | 0.59 (0.23-0.9) |
| MUST (n=35)          | 69.7 (16-100) | 87.3 (45-100) | 80.5 (30-100) | 88.7 (34-100) | 0.52 (0.16-0.91) |
| NUFFE (n=1)          | 69.8         | 75.7        | 80.8 | 30.3 | -         |
| NRS-2002 (n=35)      | 70.4 (37-97) | 90.1 (30-98) | 85.0 (32-99) | 77.5 (35-100) | 0.53 (0.13-0.89) |
| Nutriscore (n=1)     | 97.3         | 95.6        | 84.8 | 99.0 | 0.88      |
| PG-SGA-SF (n=3)      | 89.0 (78-94) | 72.3 (62-94) | 41 (31-91) | 98.0 (84-98) | 0.39 (0.31-0.49) |
| SNAQ (n=5)           | 79.0 (51-92) | 90.3 (81-100) | 80.0 (29-100) | 86.9 (56-100) | -         |
| SimplifiedNAQ (n=6)  | 69.3 (28-87) | 78.9 (77-94) | 89.0 (78-90) | 57.1 (44-88) | 0.27 (0.18-0.36) |

Abbreviations: MNA: Mini Nutritional Assessment (short form); MST: Malnutrition Screening Tool; MUST: Malnutrition Universal Screening Tool; NRS-2002: NPV: negative predictive value; Nutritional Risk Screening 2002; (PG)-SGA(-SF): (Patient Generated) Subjective Global Assessment (short form); PPV: positive predictive value; SimplifiedNAQ: Simplified nutrition appetite questionnaire; SNAQ: Short nutritional assessment questionnaire
## Table 4 Validation of MNA

| Reference                 | Quality | Publication year | Sample size | Country     | Setting                                      | Condition/ward/diagnosis | Mean/Median age | Lower age limit for inclusion | Validated tool | Comparison | Sensitivity | Specificity | PPV | NPV | AUC | CC | Kappa |
|---------------------------|---------|------------------|-------------|-------------|-----------------------------------------------|--------------------------|-----------------|-------------------------------|----------------|------------|-------------|-------------|-----|-----|-----|----|-------|
| Albay VB, et al. (42)     | Ø       | 2020             | 75          | Turkey      | Outpatient                                    | Parkinson’s Disease       | 67              | 45                            | MNA            | Full MNA   | 87.1        | 70.5        | 88.6| 77.3|     |     |       |
| Borowiak E, et al. (43)   | Ø       | 2003             | 160         | Poland      | Community-dwelling                            | Older adults              | 74              | 65                            | MNA            | Full MNA   | 73.6        | 93          | 82  |     |     |     |       |
|                           |         | 2003             | 151         | Poland      | nursing home                                  | Older adults              | 79              | 65                            | MNA            | Full MNA   | 64.4        | 100         | 58  |     |     |     |       |
| Charlton KE, et al. (44)  | Ø       | 2007             | 220         | South Africa| community-dwelling and nursing home           | Older adults              | 72              | 60                            | MNA            | Full MNA   | 100.0       | 94.6        | 16.3| 62.9|     |     |       |
| Charlton KE, et al (45)   | +       | 2010             | 1615        | Australia   | rehabilitation                                 | rehabilitation            | 81              | 65                            | MNA            | Full MNA   | 77          | 44          | 72.8| 77.5| 0.532|     |       |
| Christner S, et al. (46)  | +       | 2016             | 201         | Germany     | Inpatient                                     | geriatric                 | 83              | 65                            | MNA            | Full MNA   |                     |             |     |     | 0.7 |     |       |
| Cohendy R, et al. (47)    | Ø       | 2001             | 408         | France      | day care                                      | surgery                   | 70              | 60                            | MNA            | Full MNA   | 89          | 86          | 79  | 93  |     |     |       |
| Cuervo, M., et al. (48)   | +       | 2009             | 22007       | Spain       | community-dwelling                            | Older adults              | 75              | 65                            | MNA            | Full MNA   | 85.2        | 76.4        | 93.4| 0.942|     |     |       |
| De La Montana I, et al (49)| Ø     | 2011             | 728         | Spain       | community-dwelling                            | Older adults              | 81              | 65                            | MNA            | Full MNA   | 81          | 93          | 96  | 68  |     |     |       |
| Dent E, et al. (50)       | +       | 2017             | 100         | Australia   | inpatients                                    | Geriatric                 | 85              | 70                            | MNA            | Full MNA   |                     |             |     |     | 0.93| 0.87|       |
| Domini LM, et al. (51)    | Ø       | 2016             | 246         | Italy       | nursing home                                  | Older adults women 82, men 77 | 60              | MNA            | Full MNA | 96.4        | 55.8        | 89          | 80.6| 0.588|     |     |       |
| Duran Alert P, et al. (52)| Ø       | 2012             | 40          | Spain       | inpatients                                    | geriatric                 | Female: 85, male 83 | MNA            | Full MNA |                     |             |     |     | 0.81|     |       |
| Reference | Year | Country | Setting | Group | Age | Method | Full MNA | PG-SGA | p value |
|-----------|------|---------|---------|-------|-----|--------|---------|--------|---------|
| Garcia-Meseguer, M. J., et al. (53) | 2013 | Spain | nursing home | Older adults | 82 | 65 | MNA | Full MNA | 86.1 | 87.9 | 82.6 | 90.4 | 0.95 | 0.685 |
| Holvoet E, et al. (54) | 2020 | Belgium | dialysis | 67 | 18 | MNA | Full MNA | 0.909 |
| Isenring EA, et al. (55) | 2012 | Australia | nursing home | 83 | 53 | MNA | Full MNA | 100 | 56.4 | 0.257 |
| Joaquin C, et al. (56) | 2019 | Spain | Outpatient | heart failure | 69 | adult | MNA | Full MNA | 71 | 93.8 | 79.4 | 90.5 | 0.67 |
| Kaiser MJ, et al (57) | 2011 | Germany | community-dwelling | Older adults | 81 | MNA | Full MNA | 0.586 |
| Keller H, et al (58) | 2019 | Canada | nursing home | Older adults | 7 | 65 | MNA | PG-SGA | 83.99 | 70.22 |
| Kiesswetter E, et al (59) | 2014 | Germany | community-dwelling | home care | 81 | 65 | MNA | Full MNA | 0.62 |
| Kostka, J., et al. (60) | 2014 | Poland | community-dwelling | Older adults | 72 | 65 | MNA | Full MNA | 82.7 | 88.9 |
| Lei Z, et al. (61) | 2009 | China | inpatients | 68 | 60 | MNA | Full MNA | 89.6 | 88 | 0.932 |
| Lilamand M, et al. (62) | 2015 | France | day care | frail | 82 | 65 | MNA | Full MNA | 0.954 |
| Lomivorotov VV et al (63) | 2013a | Russia | inpatients | Cardiovascular disease | 58 | 18 | MNA | SGA | 84.6 | 77.9 | 27.1 | 98.1 |
| Authors           | Year | Country | Setting       | Disease                  | Sample Size | Gender | MNA   | SGA   | Z-Score | p-value |
|-------------------|------|---------|---------------|--------------------------|-------------|--------|-------|-------|---------|----------|
| Lomivorotov VV et al. (64) | 2013b | Russia | inpatients    | Cardiovascular disease   | 59          | 18     | MNA   | SGA   | 81.8    | 20.4     | 98.6     |
| Martin A, et al. (65) | 2016 | Spain  | inpatients    | diabetes                 | 78          | 65     | MNA   | Full MNA | 90.6   | 85.1     |
| Montejano Lozoya, R et al. (66) | 2017 | Spain  | community-dwelling | Older adults             | 74          | 65     | MNA   | Full MNA | 73.4   | 86.6     | 62.4     | 91.4     | 0.88     | 0.78     | 0.54     |
| Olivares J, et al. (67) | 2014 | Spain  | inpatients    | medical and surgery      | 61          | adult  | MNA   | SGA   | 69.9    | 94.7     | 75.8     | 93       | 0.666    |
| Rubenstein, L. Z., et al. (68) | 2001 | France | inpatients and community-dwelling | Older adults             | 79          |        | MNA   | Full MNA | 98     | 100      | 0.961    |
| Santin FG, et al (69) | 2016 | Brazil | dialysis      | day care                 | 70          | 60     | MNA   | MIS    |         |          | 0.14     |
| Schrader, E., et al. (70) | 2016 | Germany | day care                  | geriatric                | 80          | 65     | MNA   | Full MNA |         |          | 0.53     |
| Sheard JM, et al. (71) | 2013 | Australia | community-dwelling | Parkinson’s disease     | 70          | 18     | MNA   | SGA   | 94.7    | 78.3     | 58.1     | 98.8     | 0.92     |
| Sheean PM, et al. (72) | 2013 | USA    | ICU            | medical and surgery      | 65          |        | MNA   | Full MNA | 72     | 98       | 0.76     |
| Simsek, H., et al. (73) | 2014 | Turkey | community-dwelling | Older adults             | 74          | 65     | MNA   | Full MNA | 88.7   | 0.87     | 0.63     |
| Wikby, K., et al. (74) | 2008 | Sweden | nursing home   | Older adults             | 65          |        | MNA   | Full MNA | 89.00  | 82.00    | 92.00    |
| Young AM, et al. (75) | 2013 | 134 | Australia | inpatients | medical | 80 | 65 | MNA | Full MNA | 95.6 | 79.1 | 90.5 | 89.5 | 0.96 |
|----------------------|------|-----|-----------|------------|---------|----|----|-----|----------|------|------|------|------|-----|
| 2013                 | 134  | Australia | inpatients | medical | 80 | 65 | MNA | SGA | 100 | 52.8 | 64.6 | 100 | 0.95 |

Abbreviations: AUC: area under the curve; CC: correlation coefficient; Full MNA: Full Mini Nutritional Assessment; ICU: Intensive Care Unit; MIS: Malnutrition Inflammation Score; MNA: Mini Nutritional Assessment (short form); NPV: negative predictive value; (PG-)SGA: (Patient Generated) Subjective Global Assessment; PPV: positive predictive value.
| Reference | Quality | Publication year | Sample size | Country | Setting | Condition/ ward/ diagnosis | Mean/ Median age | Lower age limit for inclusion | Validated tool | Comparison | Sensitivity | Specificity | PPV | NPV | AUC | CC | Kappa |
|-----------|---------|------------------|-------------|---------|---------|-----------------------------|-----------------|-----------------------------|----------------|------------|------------|------------|-----|-----|-----|-----|-------|
| Abboit J, et al. (101) | Ø | 2014 | 300 | Australia | Outpatient | Oncology | 59/18 | MST | PG-SGA | 70.6 | 69.5 | 0.77 |
| Abe Vicente M, et al. (76) | Ø | 2013 | 75 | Brazil | Outpatient | Oncology | 60 | MST | PG-SGA | 52 | 84 | |
|  | 2013 | 62 | Brazil | Outpatient | Oncology | 61 | MST | PG-SGA | 61.5 | 91.8 | |
| Arribas L, et al. (102) | + | 2017 | 394 | Spain | Outpatient | Oncology | 62/18 | MST | PG-SGA | 84 | 85.6 | 57.7 | 95.7 | 0.84 | 0.59 |
| Byrnes A, et al. (103) | + | 2018 | 75 | Australia | Inpatient surgery | 74/65 | MST | PG-SGA | 86 | 80 | 50 | 96 | 0.83 |
| Clark, A.B., et al. (104) | + | 2020 | 444 | Australia | Hospital Geriatric rehabilitation | 82 | MST | GLIM | 56.7 | 69 | 66.5 | 59.5 | 0.63 | 0.26 |
| De Groot LM et al. (105) | + | 2020 | 246 | Australia | Oncology | 62/18 | MST | PG-SGA | 100 | 90 | |
| Ferguson M, et al. (19) | + | 1999 | 408 | Australia | Inpatients medical and surgery | 58/18 | MST | SGA | 93 | 93 | 98.4 | 72.7 | |
| Ferguson, M. L., et al. (106) | + | 1999 | 106 | Australia | Outpatient Oncology | 60/7 | MST | SGA | 100.00 | 81.00 | 40 | 100 | |
| Fiol-Martinez L, et al. (82) | + | 2017 | 73 | Spain | Inpatients hematology | 64/18 | MST | SGA | 72.7 | 65.4 | 72.70 | 90.9 | 0.691 |
| Fiorindi, C., et al. (83) | Ø | 2020 | 53 | Italy | Inpatients GI surgery | 51 | MST | GLIM | 63.6 | 96.8 | |
| Gabrielson, D. K., et al. (107) | + | 2013 | 90 | Canada | Outpatient Oncology | 55/18 | MST | PG-SGA | 81.3 | 72.4 | |
| Georgiou A, et al. (84) | + | 2019 | 170 | Greece | Outpatient Hepatology | 59/18 | MST | SGA | 51.3 | 97.7 | 87 | 87.1 | 0.814 |
| Study                                      | Year | Country   | Setting                        | Disease/Condition | Measure | MNA Score | SGA Score | MNA Gain | SGA Gain | p-value |
|-------------------------------------------|------|-----------|--------------------------------|-------------------|---------|-----------|-----------|----------|----------|---------|
| Hogan D, et al. (108)                     | 2017 | Vietnam   | Outpatient pulmonary disease   | 70                | MST     | 38        | 94        | 83       | 65       |         |
| Isenring E, et al. (109)                  | 2006 | Australia | Outpatient oncology            | 59                | MST     | PG-SGA    | 100.00    | 92.00    | 80.00    | 100.00  |
| Isenring EA, et al. (55)                  | 2012 | Australia | Nursing home                   | 83                | MST     | Full MNA  | 94.1      | 80.9     |          | 0.501   |
| Isenring EA, et al. (110)                 | 2009 | Australia | Nursing home                   | 84                | MST     | SGA       | 88.6      | 93.5     |          | 0.806   |
| Joaquin C, et al. (56)                    | 2019 | Spain     | Outpatient heart failure adult | 69                | MST     | Full MNA  | 31.5      | 91.1     | 54.5     | 79.8    | 0.26    |
| Leipold CE, et al. (111)                  | 2012 | UK        | Inpatients rehabilitation      | 74                | MST     | SGA       | 48.7      | 85.5     | 78.7     | 60.2    | 0.335   |
| Morris NF, et al. (112)                   | 2018 | Australia | Inpatients medical            | 62                | MST     | SGA       | 72.2      | 83.8     | 69.6     | 85.4    |         |
| Mourão F, et al. (113)                    | 2004 | Portugal  | Inpatients surgery             | 55                | MST     | McWhirter |           |          |          | 0.72    |
| Nor Azian MZ et al. (18)                  | 2014 | Malaysia  | Inpatients and outpatient     | 45                | MST     | SGA       | 93.3      | 80.9     | 54.9     | 98      |         |
| Shaw C et al. (114)                       | 2015 | UK        | Inpatients oncology            | 59                | MST     | PG-SGA    | 66        | 83       | 91.00    | 49.00   | 0.83    |
| Ulhâng M, et al. (115)                    | 2013 | Australia | Inpatients medical            | 62                | MST     | SGA       | 73        | 76       | 38       | 93      |         |
| Wu ML, et al. (116)                       | 2012 | Australia | Inpatients rehabilitation     | 78                | MST     | SGA       | 94.00     | 89       | 70       | 98      | 0.74    |
| Young AM, et al. (75) | + | 2013 | 134 | Australia | inpatients | medical | 80 | 65 | MST | Full MNA | 67.7 | 88.3 | 92.4 | 56.7 | 0.87 |
|----------------------|---|------|-----|-----------|------------|---------|----|----|-----|----------|------|------|------|------|-----|
| 2013 | 134 | Australia | inpatients | medical | 80 | 65 | MST | SGA | 90.3 | 84.7 | 83.6 | 91 | 0.92 |

Abbreviations: AUC: area under the curve; CC: correlation coefficient; Full MNA: Full Mini Nutritional Assessment; GI: Gastrointestinal; GLIM: Global Leadership Initiative on Malnutrition; MST: Malnutrition Screening Tool; NPV: negative predictive value; (PG-)SGA: (Patient Generated) Subjective Global Assessment; PPV: positive predictive value
### Table 6 Validation of MUST

| Reference                  | Quality | Publication year | Sample size | Country        | Setting            | Condition/ward/diagnosis | Mean/ Median age | Lower age limit for inclusion | Validated tool | Comparison | Sensitivity | Specificity | PPV | NPV | AUC | CC | Kappa |
|---------------------------|---------|------------------|-------------|----------------|--------------------|--------------------------|-------------------|-----------------------------|----------------|------------|-------------|-------------|-----|-----|-----|----|-------|
| Abe Vicente M, et al. (76) | Ø       | 2013             | 75          | Brazil         | Outpatient         | Oncology                | 60                |                            | MUST           | PG-SGA     | 72          | 48.9        |     |     |     |    |       |
|                           |         | 2013             | 62          | Brazil         | Outpatient         | Oncology                | 61                |                            | MUST           | PG-SGA     | 72          | 73.4        |     |     |     |    |       |
| Almeida AL, et al. (77)   | +       | 2012             | 300         | Portugal       | Inpatient          | surgery                 | 60                | 18                          | MUST           | SGA        | 85          | 93          | 89  | 99  | 0.912| 0.912|       |
| Bellanti, F., et al. (78) | +       | 2020             | 152         | Italy          | Hospital           | Internal and aging medicine | 78/79            | 65                          | MUST           | GLIM       | 64.3        | 81.7        | 75  | 72.8 | 0.89 |     |       |
| Boběíková K, et al. (79) | Ø       | 2020             | 103         | Czech Republic | Inpatient          | Cardiovascular disease  | 76                | 65                          | MUST           | Full MNA   |            |             |     |     | 0.44 |     |       |
| Boleo-Tome C, et al. (80) | +       | 2012             | 450         | Portugal       | Outpatient          | Oncology                | 62                |                            | MUST           | PG-SGA     | 80          | 89          | 87  | 100 | 0.86 |     |       |
| Diekmann R et al. (81)    | +       | 2013             | 200         | Germany        | Nursing home       | Older adults            | 86                | 65                          | MUST           | Full MNA   |            |             |     |     | 0.16 |     |       |
| Domini LM, et al. (51)    | Ø       | 2016             | 246         | Italy          | Nursing home       | Older adults            | women            | 60                          | MUST           | Full MNA   | 47.9        | 98.1        | 98.8| 33.6| 0.27 |     |       |
| Fiol-Martinez L, et al. (82) | +      | 2017             | 73          | Spain          | Inpatients         | Hematology             | 64                | 18                          | MUST           | SGA        | 90.9        | 75          | 43.5| 97.5| 0.83 |     |       |
| Fiorindi, C., et al. (83) | Ø       | 2020             | 53          | Italy          | Inpatients         | GI surgery              | 51                |                            | MUST           | GLIM       | 63.6        | 96.8        |     |     | 0.878|     |       |
| Georgiou A, et al. (84)   | +       | 2019             | 170         | Greece         | Outpatient         | Hepatology              | 59                | 18                          | MUST           | SGA        | 59          | 96.9        | 85.2| 88.8| 0.777|     |       |
| Gibson S, et al. (85)     | Ø       | 2012             | 262         | Australia      | Inpatients         | Medical                 | 71                | 7                           | MUST           | SGA        | 80          | 85          |     |     |     |     |       |
| Hettiarachchi J, et al. (86) | Ø     | 2018             | 100         | Sri Lanka      | Outpatient         | Oncology                | 59                | 18                          | MUST           | PG-SGA     | 86.7        | 94.5        | 92.9| 89.7| 0.79 |     |       |
| Source                          | Year | Country | Setting     | Diagnosis                  | Gender | Age | MUST | Full MNA | SGA | 95% CI | P value |
|--------------------------------|------|---------|-------------|----------------------------|--------|-----|------|----------|-----|--------|---------|
| Holst M et al. (87)            | 2013 | Denmark and Sweden | inpatients | Gastroenterology and Geriatric | 81     | 65  | MUST | Full MNA | 0.38 |
| Isenring EA, et al. (55)       | 2012 | Australia | nursing home | 83 | 55 | MUST | Full MNA | 0.51 |
| Jackson HS, et al. (88)        | 2019 | UK      | inpatients | nephrology               | 64     | 18  | MUST | SGA      | 0.47 |
| Joaquin C, et al. (56)         | 2019 | Spain   | Outpatient | heart failure, adult      | 69     | 69  | MUST | Full MNA | 0.36 |
| Kosters CM, et al. (89)        | 2020 | Netherlands | inpatients and outpatients | nephrology | 18 | MUST | PG-SGA | 0.65 |
| Kozakova R, et al. (90)        | 2014 | Czech Republic | community y-dwelling | home care | 77 | 65 | MUST | Full MNA | 0.451 |
| Kyle UG, et al. (91)           | 2006 | Switzerland | inpatients | medical and surgery | LOS 1-10  | 61 | 76 | 65 | 76 | 0.26 |
| Lawson CS, et al. (16)         | 2012 | UK      | inpatients | nephrology                | 65     | 7   | MUST | SGA      | 0.316 |
| Lomivorotov VV, et al. (63)    | 2013 | Russia  | inpatients | cardiovascuar disease     | 58     | 18  | MUST | SGA      | 100 |
| Lomivorotov VV, et al. (64)    | 2013 | Russia  | inpatients | cardiovascuar disease     | 59     | 18  | MUST | SGA      | 99.9 |

Note: MUST, Full MNA, SGA, PG-SGA, and LOS stand for different assessment methods and lengths of stay, respectively.
| Author(s) and Year | Country | Setting | Age | Domain | Measure | SGA Score | Weight Loss | P-value |
|--------------------|---------|---------|-----|--------|---------|-----------|-------------|---------|
| Martin Palmero A, et al. (92) | Spain | Inpatients | 65 | Medical and Surgery | MUST | | | 0.422 |
| Naik R, et al. (93) | India | Outpatient | Older adults | | MUST | | | |
| Nor Azian MZ et al. (18) | Malaysia | Inpatients and Outpatient | Medical | | MUST | SGA | | |
| Olivares J et al. (67) | Spain | Inpatients | Adult | Medical and Surgery | MUST | SGA | | 0.564 |
| Pereira Borges N, et al. (94) | Brazil | Inpatients | Oncology | | MUST | SGA | | 0.799 |
| Raupp D, et al. (95) | Brazil | Inpatients | Emergency | | MUST | SGA | | 0.67 |
| Sharma Y, et al. (96) | Australia | Inpatients | Medical | | MUST | PG-SGA | 69.70 75.80 75.40 70.10 | 0.73 | 0.45 |
| Stratton RJ, et al. (7) | UK | Inpatients | Medical | Under 65 | MUST | SGA | | 0.783 |
| Tripathy S, et al. (97) | India | ICU | Medical and Surgery | | MUST | ’Standard’ based on low BMI AND unplanned weight loss | 96.5 72.3 80.9 94.4 | 0.65 |
| Tu MY, et al. (98) | Taiwan | Inpatients | Oncology | | MUST | SGA | 96 75 82.7 93.8 | 0.724 |
| Vallen C, et al. (99) | Sweden | Inpatients | Orthopedics, Cardiovascular Disease | | MUST | Full MNA | 57.00 93.00 86 75 | |
| Velasco C, et al. (100) | Spain | Inpatients | Medical and Surgery | | MUST | Full MNA | | 0.388 |
| | Spain | Inpatients | Medical and Surgery | | MUST | SGA | 71.6 90.3 80.1 85.4 | 0.635 |
| Young AM, et al (75) | + | 2013 | 134 | Australia | inpatients | medical | 80 | 65 | MUST | Full MNA | 87.1 | 86.1 | 84.4 | 88.6 | 0.89 |

Abbreviations: AUC: area under the curve; BMI: Body Mass Index; CC: correlation coefficient; Full MNA: Full Mini Nutritional Assessment; GLIM: Global Leadership Initiative on Malnutrition; ICU: Intensive Care Unit; GI: Gastrointestinal; LOS: Length of stay; MUST: Malnutrition Universal Screening Tool; NPV: negative predictive value; (PG-)SGA: (Patient Generated) Subjective Global Assessment; PPV: positive predictive value
| Reference          | Quality | Publication year | Sample size | Country | Setting                  | Condition/ward/diagnosis                                      | Mean/ Median age | Lower age limit for inclusion | Validated tool | Comparison | Sensitivity | Specificity | PPV | NPV | AUC | CC | Kappa |
|--------------------|---------|------------------|-------------|---------|--------------------------|----------------------------------------------------------------|------------------|-----------------------------|----------------|------------|-------------|-------------|-----|-----|-----|----|------|
| Almeida AI et al. (77) | +       | 2012             | 300         | Portugal | Inpatient                | surgery                                                            | 60               | 18                          | NRS-2002       | SGA        | 80          | 89          | 87  | 100 | 0.854 | 0.853 |        |
| Badia-Tahull MB, et al. (117) | +       | 2014             | 45          | Spain    | Inpatient                | digestive surgery patients on parenteral nutrition               | 65               | 18                          | NRS-2002       | PG-SGA     | 0.31        |            |     |     |      |      |      |
|                     |         | 2014             | 45          | Spain    | Inpatient                | digestive surgery patients on parenteral nutrition               | 65               | 18                          | NRS-2002       | SGA        | 0.53        |            |     |     |      |      |      |
| Bauer JM, et al. (118) | +       | 2005             | 121         | Germany  | Inpatient                | geriatric                                                          | 80               | 65                          | NRS-2002       | Full MNA   | 39.3        | 83.3        | 84.6 | 37  |      |      |      |
|                     |         | 2005             | 121         | Germany  | Inpatient                | geriatric                                                          | 80               | 65                          | NRS-2002       | SGA        | 70.4        | 84.6        | 79.2 | 77.5|      |      |      |
| Bellanti, F., et al. (78) | +       | 2020             | 152         | Italy    | Inpatient                | Internal and Aging Medicine clinic Malnourished 78, not malnourished 80 | 58               | 18                          | NRS-2002       | GLIM       | 54.7        | 91          | 90  | 60  | 0.62 |      |      |
| Boulhosa, R., et al. (119) | +       | 2020             | 166         | Brazil   | Inpatient                | advanced chronic liver disease                                     | 58               | 18                          | NRS-2002       | GLIM       | 54.7        | 91          | 90  | 60  | 0.43 |      |      |
| Chavez-Tostado M, et al. (120) | +       | 2020             | 196         | Mexico   | Inpatient                | Gastroenterology                                                   | 46               | 18                          | NRS-2002       | SGA        | 0.53        |            |     |     |      |      |      |
| Cunha CD, et al. (32) | Ø       | 2015             | 173         | Brazil   | Inpatient                | oncology                                                          | 70               | 18                          | NRS-2002       | PG-SGA     | 0.322       |            |     |     |      |      |      |
|                     |         | 2015             | 173         | Brazil   | Inpatient                | oncology                                                          | 70               | 18                          | NRS-2002       | SGA        | 0.345       |            |     |     |      |      |      |
| Demirel B, et al. (121)  | +  | 2018 | 124 | Turkey | Inpatient and outpatients | Oncology | 52 | ? | NRS-2002 | Full MNA | 96.5 | 92.1 | 96.5 | 92.1 | 0.886 |
|------------------------|----|-------|-----|--------|---------------------------|----------|----|---|-------------|----------|-------|-------|-------|-------|-------|
| Diekmann R, et al (81) | +  | 2013 | 200 | Germany | Nursing home | Older adults | 86 | 65 | NRS-2002 | Full MNA | 0.13 |
| Donni LM, et al (51)   | Ø  | 2016 | 246 | Italy   | Nursing home | Older adults men | 77 | 60 | NRS-2002 | Full MNA | 0.291 |
| Fiorindi, C., et al. (83) | Ø   | 2020 | 53  | Italy   | Inpatients | GI surgery | 51  | 18 | NRS-2002 | GLIM | 0.919 |
| Georgiou A, et al. (84) | +  | 2019 | 170 | Greece  | Outpatient | Hepatology | 59  | 18 | NRS-2002 | SGA | 0.747 |
| Hartz LLK, et al. (122) | +  | 2019 | 594 | USA    | Inpatients | Medical and surgery | 63  | 18 | NRS-2002 | Assessment incl. NFPE | 0.56 |
| Holst M, et al. (87)   | +  | 2013 | 233 | Denmark and Sweden | Inpatients | Gastroenterology and geriatric | 81  | 65 | NRS-2002 | Full MNA | 0.52 |
| Javid Mishamandani Z, et al. (123) | Ø   | 2018 | 1311 | Iran   | ICU | ? | 16 | NRS-2002 | SGA | 0.226 |
| Juntao Chi, J., et al. (124) | +  | 2017 | 280 | China  | Inpatients | Oncology | 63  | 18 | NRS-2002 | SGA | 0.54 |
| Kyle UG, et al. (91)   | +  | 2006 | 995 | Switzerland | Inpatients | Medical and surgery | LOS 1-10 days 51; LOS >11d 65; LOS unknown 44 | Adult | NRS-2002 | SGA | 0.48 |
| Leandro-Merhi VA, et al. (125) | +  | 2015 | 210 | Brazil  | Inpatients | Gastroenterology | ? | 20 | NRS-2002 | SGA | 0.461 |
|                          |    | 2015 | 290 | Brazil  | Inpatients | Oncology | ? | 20 | NRS-2002 | SGA | 0.526 |
| Reference                          | Year | Country | Setting            | Diagnosis                  | NRS-2002 | SGA     | Full MNA | SGA     | PG-SGA | MNA     | Prevalence |
|-----------------------------------|------|---------|--------------------|----------------------------|----------|---------|----------|---------|--------|---------|------------|
| Leandro-Merhi VA, et al. (126)    | 2017 | Brazil  | inpatients         | oncology                   | 72       | 65      | NRS-2002 | SGA     |        |         | 0.528      |
|                                   | 2017 | Brazil  | inpatients         | oncology                   | 72       | 65      | NRS-2002 | SGA     |        |         | 0.239      |
| Lomivorotov VV, et al. (63)       | 2013 | Russia  | inpatients         | cardiovascular disease     | 58       | 18      | NRS-2002 | SGA     | 43.6   | 93.5   | 39.5   | 94.5   | 0.784      |
| Lomivorotov VV, et al. (64)       | 2013 | Russia  | inpatients         | cardiovascular disease     | 59       | 18      | NRS-2002 | SGA     | 38.3   | 93.4   | 31.6   | 96.5   | 0.567      |
| Martin Palmero A et al (92)       | 2017 | Spain   | inpatients         | medical and surgery        | 65       | 18      | NRS-2002 | SGA     |        |         | 0.758      |
| Martins CP, et al. (127)          | 2005 | Portugal| inpatients         | orthopedic                 | 74       | 65      | NRS-2002 | Full MNA| 81.7   | 84.6   | 92.1   | 67.9   | 0.62       |
|                                   | 2005 | Portugal| inpatients         | orthopedic                 | 74       | 65      | NRS-2002 | SGA     | 85.9   | 69.2   | 85.9   | 69.2   | 0.55       |
| Mereles MS, et al (128)           | 2012 | Brazil  | inpatients         | surgery                    | 52       | 19      | NRS-2002 | SGA     |        |         | 0.49       |
| Miao JP, et al. (129)             | 2019 | China   | inpatients         | geriatric                  | 81       | 70      | NRS-2002 | Full MNA|        |         | 0.521      |
| Mourão F, et al. (113)            | 2004 | Portugal| inpatients         | surgery                    | 55       | 18      | NRS-2002 | McWhirter|        |         | 0.29       |
|                                   | 2004 | Portugal| inpatients         | surgery                    | 55       | 18      | NRS-2002 | SGA     | 96     | 30     |        |         | 0.39       |
| Olivares J, et al. (67)           | 2014 | Spain   | inpatients         | medical and surgery        | 61       | adult   | NRS-2002 | SGA     | 68.9   | 90.1   | 62.3   | 92.4   | 0.567      |
| Orell-Kotikangas H, et al. (130)  | 2015 | Finland | outpatient         | oncology                   | 61       | ?       | NRS-2002 | PG-SGA  | 77.3   | 97.7   | 94.4   | 89.4   | 0.784      |
| Raslan M, et al. (131)            | 2011 | Brazil  | inpatients         | medical and surgery        | 57       | 18      | NRS-2002 | SGA     |        |         | 0.56       |
| Raupp D, et al. (95)              | 2018 | Brazil  | inpatients         | emergency                  | 54       | 18      | NRS-2002 | SGA     |        |         | 0.62       |
| Authors | Year | Country | Setting | N | Nutritional Test | Score N | Score SGA | p_value |
|---------|------|---------|---------|---|-----------------|---------|-----------|---------|
| Ryu SW, et al. (132) | 2010 | South Korea | inpatients oncology subtotal gastrectomy: 58.5; total gastrectomy: 56.5 | 80 | NRS-2002 | 80 | 96 | 0.685 |
| Sheean PM, et al (72) | 2013 | USA | ICU medical and surgery Medical ICU 75; surgical ICU 74 | 232 | NRS-2002 Full MNA | 87 | 44 | 0.78 |
| Velasco C, et al. (100) | 2011 | Spain | inpatients medical and surgery | 400 | NRS-2002 Full MNA | 74.4 | 87.2 | 76.1 | 86.2 | 0.392 |
| 2011 | Spain | inpatients medical and surgery | 67 | NRS-2002 SGA | 76.1 | 86.2 | 0.62 |
| Wang F, et al. (133) | 2016 | China | inpatients gastroenterology | 332 | NRS-2002 SGA | 90.3 | 83.3 | 82.4 | 90.9 | 0.514 |
| Westergren, A., et al (134) | 2011 | Sweden | inpatients medical and surgery | 85 | NRS-2002 Full MNA | 72.2 | 95.3 | 97 | 62.1 | 0.9 |
| Young AM et al. (75) | 2013 | Australia | inpatients medical | 134 | NRS-2002 Full MNA | 90.3 | 83.3 | 82.4 | 90.9 | 0.89 |

Abbreviations: AUC: area under the curve; CC: correlation coefficient; Full MNA: Full Mini Nutritional Assessment; GLIM: Global Leadership Initiative on Malnutrition; ICU: Intensive Care Unit; LOS: Length of stay; NFPE: Nutritional Focused Physical Exam; NPV: negative predictive value; NRS-2002: Nutritional Risk Screening 2002; (PG-)SGA: (Patient Generated) Subjective Global Assessment; PPV: positive predictive value
| Reference                                  | Quality | Publication year | Sample size | Country | Setting               | Condition/ ward/ diagnosis | Mean/ Median age | Lower age limit for inclusion | Validated tool | Comparison | Sensitivity | Specificity | PPV | NPV | AUC | CC | Kappa |
|-------------------------------------------|---------|------------------|-------------|---------|-----------------------|-----------------------------|----------------------|-----------------------------|----------------|------------|-------------|-------------|-----|-----|-----|-----|-------|
| Sharifi F, et al. (135)                   | +       | 2018             | 97          | Iran    | nursing home          | Older adults                | 74/60               |                             | NUFFE          | Full MNA   | 69.8        | 75.7        | 80.8| 30.30| 0.796|     |       |
| Arribas L, et al. (102)                   | +       | 2017             | 394         | Spain   | Outpatient            | oncology                    | 62/18               |                             | Nutriscore      | PG-SGA    | 97.3        | 95.6        | 84.8| 99  | 0.95 | 0.88|       |
| De Groot LM, et al. (105)                 | +       | 2020             | 246         | Australia| ?                      | oncology                    | 62/18               |                             | PG-SGA- SF (≥3) | PG-SGA    | 94          | 62          | 31  | 98  | 0.311|     |       |
|                                            |         |                  |             |         |                       |                             |                     |                             | PG-SGA- SF (≥4) | PG-SGA    | 92          | 71          | 37  | 98  | 0.387|     |       |
|                                            |         |                  |             |         |                       |                             |                     |                             | PG-SGA- SF (≥5) | PG-SGA    | 89          | 80          | 45  | 98  | 0.493|     |       |
| Abbott, J., et al. (136)                  | +       | 2016             | 300         | Australia| Outpatient            | Oncology                    | 59                  |                             | PG-SGA-SF       | PG-SGA    | 80.4        | 72.3        |     |     | 0.85 |     |       |
| Kosters CM, et al. (89)                   | +       | 2020             | 123         | Netherlands| inpatients and outpatients | nephrology                  | ?/18                |                             | PG-SGA-SF (≥6) | PG-SGA    | 78          | 94          | 91  | 84  |      |     |       |
| Yaxley, A., et al. (137)                  | +       | 2015             | 185         | Australia| community-dwelling    | rehabilitation              | 78/60               |                             | Simplified NAQ  | Full MNA   | 28          | 94          | 89  | 44  | 0.176|     |       |
| Akin S, et al. (138)                      | Ø       | 2019             | 871         | Turkey   | community-dwelling    | Older adults                | 71/65               |                             | Simplified NAQ  | Full MNA   |             |             |     |     | 0.725|     |       |
| Young AM, et al. (75)                     | +       | 2013             | 134         | Australia| inpatients            | medical                     | 80/65               |                             | Simplified NAQ  | Full MNA   | 69.3        | 83.7        | 89.7| 57.1| 0.83 |     |       |
|                                            |         |                  |             |         |                       |                             |                     |                             | Simplified NAQ  | SGA       | 86.9        | 78.9        | 77.9| 87.5| 0.87 |     |       |
| Rolland Y, et al. (139)                   | Ø       | 2012             | 175         | France   | inpatients and outpatients | Older adults                | 78/65               |                             | Simplified NAQ  | Full MNA   |             |             |     |     | 0.767| 0.48|       |
| Isenring EA, et al. (55)                  | Ø       | 2012             | 127         | Australia| nursing home          |                             | 83/55               |                             | Simplified NAQ  | Full MNA   | 70.6        | 77.3        |     |     | 0.32 |     |       |
| Year | Country | Setting | Age Group | Age | Survey | Short NAQ | Simplified NAQ | SGA | GLIM | CC | AUC |
|------|---------|---------|-----------|-----|--------|-----------|---------------|-----|------|----|-----|
| 2012 | Australia | nursing home | 83 | 55 | Simplified NAQ | SGA | 45.7 | 77.2 | 0.225 |
| 2018 | Turkey | Outpatient | Older adults | 77 | 60 | Simplified NAQ | Full MNA | 0.355 |
| 2013 | Australia | inpatients | medical | 80 | 65 | Short NAQ | Full MNA | 62.2 | 100 | 100 | 55.8 | 0.89 |
| 2013 | Australia | inpatients | medical | 80 | 65 | Short NAQ | SGA | 79 | 90.3 | 87.5 | 83.3 | 0.93 |
| 2013 | Russia | inpatients | Cardiovascular disease | 58 | 18 | Short NAQ | SGA | 92.3 | 81.3 | 32.4 | 99.1 |
| 2013 | Russia | inpatients | cardiovasculardisease | 59 | 18 | Short NAQ | SGA | 91.5 | 87.5 | 28.9 | 99.5 |
| 2019 | Greece | Outpatient | hepatology | 59 | 18 | Short NAQ | SGA | 51.3 | 96.2 | 80 | 86.9 | 0.81 |
| 2020 | Poland | Systemic sclerosis | 54 | 18 | Short NAQ | GLIM | 0.52 |

Abbreviations: AUC: area under the curve; CC: correlation coefficient; Full MNA: Full Mini Nutritional Assessment; GLIM: Global Leadership Initiative on Malnutrition; MNA: Mini Nutritional Assessment (short form); NUFFE: Nutritional Form for the Elderly; NPV: negative predictive value; (PG-)SGA: (Patient Generated) Subjective Global Assessment; SNAQ: Short nutritional assessment questionnaire; SimplifiedNAQ: Simplified nutrition appetite questionnaire; PPV: positive predictive value
List of Supplementary material

Supplementary Table 1 Complete search

Supplementary Table 2 Reliability

Supplementary Table 3 List of included references

Supplementary Table 4 Quality Check List for all included studies
PRISMA 2009 Flow Diagram

Records identified through database searching (n = 12882)

Additional records identified through other sources (n = 1)

Additional records identified through updated database searching (n = 33)

Records after duplicates removed (n = 7009)

Records screened (n = 7042)

Records excluded (n = 6564)

Full-text articles assessed for eligibility (n = 478)

Studies included in qualitative synthesis (n = 105)

Full-text articles excluded (n = 373) with reasons:
- Local tool (n = 10)
- Abstracts (n = 186)
- Duplicates (n = 1)
- Not relevant tool (n = 8)
- Not relevant comparison (n = 122)
- Participants under 18 years (n = 1)
- Less than 20 participants (n = 1)
- Reviews (n = 27)
- Language other than those included (n = 1)
- Not relevant outcome (n = 16)
