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Original article

Validity of nutrition screening tools for risk of malnutrition among hospitalized adult patients: A systematic review and meta-analysis

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SUMMARY

Backgrounds & aims: Malnutrition is prevalent among hospitalized patients in developed countries, contributing to negative health outcomes and increased healthcare costs. Timely identification and management of malnutrition are crucial. The lack of a universally accepted definition and standardized diagnostic criteria for malnutrition has led to the development of various screening tools, each with varying validity. This complicates early identification of malnutrition, hindering effective intervention strategies. This systematic review and meta-analysis aimed to identify the most valid and reliable nutritional screening tool for assessing the risk of malnutrition in hospitalized adults.

Methods: A systematic literature search was conducted to identify validation studies published from inception to November 2023, in the Pubmed/MEDLINE, Embase, and CINAHL databases. This systematic review was registered in INPLASY (INPLASY202090028). The risk of bias and quality of included studies were assessed using the Quality Assessment of Diagnostic Accuracy Studies version 2 (QUADAS-2). Meta-analyses were performed for screening tools accuracy using the symmetric hierarchical summary receiver operative characteristics models.

Results: Of the 1646 articles retrieved, 60 met the inclusion criteria and were included in the systematic review, and 21 were included in the meta-analysis. A total of 51 malnutrition risk screening tools and 9 reference standards were identified. The meta-analyses assessed four common malnutrition risk screening tools against two reference standards (Subjective Global Assessment [SGA] and European Society for Clinical Nutrition and Metabolism [ESPEN] criteria). The Malnutrition Universal Screening Tool (MUST) vs SGA had a sensitivity (95% Confidence Interval) of 0.84 (0.73–0.91), and specificity of 0.85 (0.75–0.91). The MUST vs ESPEN had a sensitivity of 0.97 (0.53–0.99) and specificity of 0.80 (0.50–0.94). The Malnutrition Screening Tool (MST) vs SGA had a sensitivity of 0.81 (0.67–0.90) and specificity of 0.79 (0.72–0.74). The Mini Nutritional Assessment-Short Form (MNA-SF) vs ESPEN had a sensitivity of 0.99 (0.41–0.99) and specificity of 0.60 (0.45–0.73). The Nutrition Universal Screening Tool-2002 (NRS-2002) vs SGA had a sensitivity of 0.76 (0.58–0.87) and specificity of 0.86 (0.76–0.93).

Conclusions: The MUST demonstrated high accuracy in detecting malnutrition risk in hospitalized adults. However, the quality of the studies included varied greatly, possibly introducing bias in the results. Future research should compare tools within a specific patient population using a valid and universal gold standard to ensure improved patient care and outcomes.

1. Introduction

Hospital malnutrition, typically defined as a deficiency in energy or one or more nutrients due to illness, injury, or inadequate intake [1] is commonly observed in developed countries, with estimates

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ranging from 30% to 50% [2]. This prevalent problem can negatively impact clinical outcomes, quality of life, length of hospital stay, readmission risk, and mortality rates, consequently affecting healthcare costs [3–5]. The European Society for Clinical Nutrition and Metabolism (ESPEN) estimated that, at the national level, malnutrition costs ranged between €32.8 million and €1.2 billion per year [6,7]. Early identification and management of malnutrition in hospitalized patients are critical for improving clinical outcomes and reducing healthcare costs [8–10].

Importantly, although screening for malnutrition at hospital admission has become mandatory in some European countries and strongly recommended in others, malnutrition prevalence remains high [11]. This may be attributed to the demographic shift in the population, healthcare professionals' lack of knowledge, awareness, and skills, or inadequate interprofessional communication and collaboration [12].

Screening for malnutrition using any validated risk screening tool is crucial to rapidly determine whether criteria for being “at risk” of malnutrition are fulfilled before considering diagnosis, upon hospital admission [13]. Thus, the ideal malnutrition screening tool should exhibit high validity, reliability, and agreement to ensure accurate risk identification and consistent results and minimize subjective bias. Moreover, for it to be widely used in clinical practice, it should be quick and easy to apply [8].

A significant challenge in the validation of malnutrition screening tools is identifying a suitable reference standard for assessing nutrition-related issues. Due to the absence of a universally accepted definition and standardized diagnostic criteria, many criterion validation studies have used inappropriate reference standards such as other screening tools, biochemical measures, or combined scores. For this reason, the validity of some of the tools are unclear. This has resulted in different conclusions and recommendations, and a proliferation of malnutrition screening tools [14,15].

Differences in the definitions and diagnostic criteria of malnutrition have led major clinical nutrition societies to define their own parameters. The American Society for Parenteral and Enteral Nutrition (ASPEN) [16] diagnoses malnutrition with two or more parameters such as insufficient energy intake, weight loss, loss of muscle mass or subcutaneous fat, localized or generalized fluid accumulation, and diminished functional status as measured by handgrip strength. In contrast, ESPEN requires any three of five parameters including body mass index (BMI), weight loss, recent food intake, muscle mass, and disease severity [17]. Finally, the Global Leadership Initiative on Undernutrition (GLIM) criteria [18], collaboratively developed by ASPEN, ESPEN, FELANPE (Federación Latinoamericana de Terapia Nutricional, Nutrición Clínica y Metabolismo) and PENSA (Parenteral and Enteral Nutrition Society of Asia), represents a major step forward in resolving the lack of consensus. According to GLIM, for a diagnosis to exist, it must meet one phenotypic criterion (non-volitional weight loss, low BMI, or reduced muscle mass) and one etiological criterion (reduced food intake or assimilation, or presence of inflammation or an inflammatory condition, or disease burden). Although promising, GLIM criteria are relatively new and may require further refinement and evaluation in different populations and settings [19]. The variance in gold standards utilized may result in the validation of malnutrition screening tools that might not sufficiently identify malnourished individuals. Furthermore, the gold standard itself may fail to detect all cases of malnutrition [20].

As already mentioned, a range of malnutrition screening tools have emerged over the years. Such screening tools may be used in different populations and settings, focus on various aspects of malnutrition, or be simply used based on the healthcare providers' own preferences and experience. Some screening tools, like the Subjective Global Assessment (SGA) and the Mini Nutritional Assessment (MNA) have also qualified as assessment tools because they combine data on nutritional status with clinical observations. The SGA, used primarily in hospitalized patients, includes taking a history of recent nutrient intake, weight changes, symptoms affecting oral intake, and a clinical evaluation. While it proves to be a notably swift method, proficiency and experience are essential for its effective application [21]. On the other hand, the MNA, designed for use in patients aged ≥65 years in hospitals, outpatient clinics and nursing homes, covers various aspects such as dietary intake, anthropometric measurements, cognitive function, and subjective assessment of health [22].

The malnutrition screening tools most utilized for hospital patients are the Nutrition Universal Screening Tool 2002 (NRS-2002) and the Malnutrition Universal Screening Tool (MUST) recommended by the ESPEN guidelines [23]. Other widely used tools include the Short Nutritional Assessment Questionnaire (SNAQ) [24], the Malnutrition Screening Tool (MST) [25], the patient-generated version of the SGA (PG-SGA), which can be independently used by the patient [26], and the MNA-short form (MNA-SF) [27]. While these tools share common elements, such as queries on recent and unintentional weight loss and recent changes in food intake, some also require anthropometric measures and/or clinical examinations (MST, SNAQ, MUST). Additionally, certain tools also focus on the presence of physical illness or cognitive disorders related to decreased intake or malabsorption of nutrients (MUST, NRS-2002, MNA-SF).

This diversity highlights a potential gap in research regarding the need for a single, universally accepted tool for malnutrition screening in the hospital setting.

For all the above, the research questions of interest are as follows.

1. Which nutritional screening tools are the most valid for identifying the risk of malnutrition in hospitalized adult?
2. What are the estimates of the sensitivity, specificity, and likelihood ratios between the various screening tools and the reference standards?

The latter research question is the most important to assess which nutritional screening tools are the most valid when compared to reliable reference standards. Therefore, this systematic review and meta-analysis aimed to identify the most valid and reliable nutritional screening tool for detecting malnutrition risk in hospitalized adult patients.

2. Material & methods

2.1. Protocol and registration

The protocol for this systematic review has been published [28] and registered on the International Platform of Registered Systematic Review and Meta-analysis Protocols (INSPLAY) with registration number INPLASY202090028 (https://doi.org/10.37766/inplasy2020.9.0028). The protocol was elaborated following the preferred reporting items for systematic reviews and meta-analyses protocols (PRISMA-P) statement [29,30]. It is important to mention that the original protocol was modified to include studies that utilized the GLIM criteria as a reference standard. Moreover, the age range was broadened to include adults above 18 years of age as the prevalence of malnutrition increases with age [31]. The present review and meta-analysis were reported according to the PRISMA guidelines [32,33].

2.2. Eligibility criteria

Inclusion criteria for trial eligibility were: 1) original validation studies of nutritional screening tools developed to identify malnutrition or risk of malnutrition; 2) conducted on hospitalized adults (males and/or females 18 years of age or older); and 3) published between January 1, 2008, and May 23, 2023. It is important to mention that an additional search on mid-November 2023 was conducted to include any relevant studies published after our initial cut-off date to ensure a more current assessment of the available literature. The outcome measures were the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios of the different malnutrition screening tools. Exclusion criteria included: 1) studies including residents of nursing homes or long-term care facilities, children and young adults (up to 18 years of age), pregnant women, terminal or palliative patients, and patients with eating disorders; 2) studies estimating sensitivity, specificity and likelihood ratios of nutritional indexes (e.g. Nutritional Risk Index [NRI], Geriatric NRI [GNRI], etc.) or diagnostic tools (MNA, SGA, GLIM, ESPEN, ASPEN), rather than screening tools; and 3) studies using BMI or subjective assessment as a reference standard.

2.3. Information sources and search

Studies were identified using MEDLINE via PubMed, Embase, and CINAHL via EBSCO. The search included controlled terms within the Medical Subject Headings (MeSH) for Medline, Embase subject headings (exp) for EMBASE, and CINAHL subject headings (MH) for CINAHL, as well as free terms. A description of the specific terms within the subject headings and the free terms employed in the electronic searches is presented in Table 1. The searches were developed and conducted by RC, NM, and MA.

2.4. Study selection and data collection

Study selection and data extraction processes were carried out using the Covidence web-based software platform (covidence.org). Initially, two reviewers (NM and MA) independently screened the titles and abstracts of all the identified studies to assess their relevance and eligibility for inclusion. Full-text articles were then retrieved for all potentially relevant studies, and the same two reviewers (NM and MA) independently assessed the eligibility of each study for inclusion based on the predefined inclusion and exclusion criteria. Any discrepancies were resolved by involving two more reviewers (RC and MBV). Data from eligible studies were then independently extracted and verified by three reviewers (NM, MA, and SF) using a pre-designed data extraction form. Any discrepancies were resolved by involving two more reviewers (RC and MBV). Letters to the editor, editorials, commentaries, conference abstracts, consensus statements, systematic reviews and meta-analyses were excluded.

The information extracted from the qualified studies included the following: name of the first author, year of publication, country where the study was performed, study setting (hospitalization ward) and/or population studied, sample size, age and percentage of female participants, malnutrition prevalence (according to the reference standard), reference standard, malnutrition screening tool, and study outcomes (i.e., sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV], reliability, agreement, and kappa values). With reference to the latter, for the sake of clarity and as part of the systematic review, validity results (sensitivity, specificity, PPV, and NPV) were rated according to the following cutoff points: >90%, excellent; 80%–90%, good; 70%–80%, fair; 60%–70%, insufficient; <60%, poor [34]. On the other hand, reliability and agreement results (kappa values) were rated as almost perfect (>0.90), strong (0.80–0.90), moderate (0.60–0.79), weak (0.40–0.59), minimal (0.21–0.39), and none (0–0.20) [35].

2.5. Risk of bias and quality assessment in individual studies

The methodological quality of the selected studies was carried out independently by two reviewers (RC and MA) and evaluated using the Quality Assessment of Diagnostic Accuracy Studies version 2 (QUADAS-2) [36] and its extension QUADA-Comparative (QUADA-C), to assess the risk of bias in comparative accuracy

Table 1
Database search strategy.

PubMed

((("Nutrition Assessment"[Mesh] OR "Nutrition Assessment"[all] OR "nutrition screening"[all] OR "nutritional assessment"[all] OR "nutritional screening"[all] OR "malnutrition screening"[all]) OR ("screening tool"[all] OR "screening tools"[all] OR "assessment screening tool"[all] OR "assessment screening tools"[all]) AND (Malnutrition[Mesh] OR Malnutrition[all] OR "protein energy malnutrition"[Mesh] OR undernutrition[all] OR "Nutritional Deficiency"[all] OR "Nutritional Deficiencies"[all] OR "protein energy malnutrition"[all]) AND (Hospitalization[Mesh] OR Inpatients[Mesh] OR Hospitals[Mesh] OR hospitalisation[all] OR Hospitalization[all] OR Hospitals[all] OR hospital[all] OR inpatient[all] OR Inpatients[all]) AND (Adult[Mesh] OR Adult[all] OR adults[all] OR Adolescent[Mesh] OR Adolescent[all] OR adolescents[all]) AND (sensitive[all] OR sensitivity[all] OR specific[all] OR specificity[all] OR "Sensitivity and Specificity"[Mesh] OR "Predictive Value of Tests"[Mesh] OR "positive predictive value"[all] OR "positive predictive values"[all] OR "negative predictive value"[all] OR "negative predictive values"[all] OR "false positive"[all] OR "false negative"[all])) NOT (Child[Mesh] OR Pediatrics[Mesh] OR Child[all] OR children[all] OR pediatric[all] OR paediatric[all] OR paediatrics[all] OR Pediatrics[all] OR infant[all] OR infant[all])) AND 2008/01/01:3000/12/31[Date – Publication]

Embase

(('Nutrition Assessment'/exp OR 'Nutrition Assessment' OR 'nutrition screening' OR 'nutritional assessment' OR 'nutritional screening' OR 'malnutrition screening' OR 'screening tool' OR 'screening tools' OR 'assessment screening tool' OR 'assessment screening tools') AND (Malnutrition/exp OR Malnutrition OR 'protein energy malnutrition'/exp OR undernutrition OR 'Nutritional Deficiency' OR 'Nutritional Deficiencies' OR 'protein energy malnutrition') AND (Hospitalization/exp OR Inpatients/exp OR Hospitals/exp OR hospitalisation OR Hospitalization OR Hospitals OR hospital OR inpatient OR Inpatients) AND (Adult/exp OR Adult OR adults OR Adolescent/exp OR Adolescent OR adolescents) AND (sensitive OR sensitivity OR specific OR specificity OR 'Sensitivity and Specificity'/exp OR 'Predictive Value of Tests'/exp OR 'positive predictive value' OR 'positive predictive values' OR 'negative predictive value' OR 'negative predictive values' OR 'false positive' OR 'false negative')) NOT (Child/exp OR Pediatrics/exp OR Child OR children OR pediatric OR paediatric OR paediatrics OR Pediatrics OR infant OR infant)) AND 2008/de

Cinahl

((((MH "Nutrition Assessment+") OR "Nutrition Assessment" OR "nutrition screening" OR "nutritional assessment" OR "nutritional screening" OR "malnutrition screening" OR "screening tool" OR "screening tools" OR "assessment screening tool" OR "assessment screening tools") AND ((MH Malnutrition+) OR Malnutrition OR (MH "protein energy malnutrition+") OR undernutrition OR "Nutritional Deficiency" OR "Nutritional Deficiencies" OR "protein energy malnutrition") AND ((MH Hospitalization+) OR (MH Inpatients+) OR (MH Hospitals+) OR hospitalisation OR Hospitalization OR Hospitals OR hospital OR inpatient OR Inpatients) AND ((MH Adult+) OR Adult OR adults OR (MH Adolescent+) OR Adolescent OR adolescents) AND (sensitive OR sensitivity OR specific OR specificity OR (MH "Sensitivity and Specificity+") OR (MH "Predictive Value of Tests+") OR "positive predictive value" OR "positive predictive values" OR "negative predictive value" OR "negative predictive values" OR "false positive" OR "false negative")) NOT ((MH Child+) OR (MH Pediatrics+) OR Child OR children OR pediatric OR paediatric OR paediatrics OR Pediatrics OR infant OR infant)) AND (MH 2008)

studies [37]. The reviewers subjectively rated the studies as having "high," "low" or "unclear" risk of bias based on four domains: patient selection, index test, reference standard, and flow and timing. Any discrepancies were resolved through consensus or by involving an additional reviewer (AY).

2.6. Statistical analysis for the meta-analysis

Available data on sensitivity, specificity, prevalence, and sample size were entered in an online calculator (available from http://araw.mede.uic.edu/cgi-bin/testcalc.pl) to calculate false positive (FP), false negative (FN), true positive (TP) and true negative (TN) values. These data were then entered into Review Manager (RevMan) software (version 5.4, Copenhagen, Denmark: The Nordic Cochrane Centre, the Cochrane Collaboration 2014) for analysis. The RevMan 5.4 software generates forest plots for each screening tool category. To compute test performance indicators, such as the sensitivity, specificity, positive and negative likelihood ratios, and the diagnostic odds ratio (DOR), symmetric hierarchical summary receiver operative characteristic (HSROC) models were used in STATA Statistical Software, version 17 (StataCorp, College Station, TX). Of note, HSROC models are multivariate approaches that evaluate sensitivity and specificity. These models use the within-study binomial structure to account for both within and between-study variability, making them the most statistically robust and recommended strategy for dealing with threshold effects. They generate a HSROC curve and summary points for sensitivity, specificity, confidence, and prediction area. Through HSROC models we can compare the pooled point values of sensitivity and specificity between different tools in meta-analysis studies [38]. If there were fewer than four validation analyses that compared the same malnutrition screening tool with the same reference standard, combining the estimates was not viable. In such cases, data were exclusively presented in forest plots.

3. Results

3.1. Study selection

The first databases search (Medline via PubMed, Embase, and Cinahl via EBSCO) and manual search (reference-list scanning) performed on May 23, 2023, yielded a total of 1497 citations. The additional search (databases and manual) performed on November 13, 2023, yielded a further 149 citations. A total of 1646 publications were identified. After eliminating 341 duplicates, 1306 titles and abstracts were screened for inclusion. During this phase, 1118 citations were deemed irrelevant and 188 proceeded to full-text screening and were assessed in more detail against the inclusion and exclusion criteria. Studies on diagnostic concordance between screening and diagnostic tools, and thus not defining a reference standard, were excluded. After full-text screening, 131 citations were further excluded. Reasons for excluding studies at this stage were recorded (missing data, wrong setting, wrong outcomes, wrong comparator, wrong study design, conference abstract, and wrong patient population). The remaining 60 studies met the eligibility criteria and were included in this systematic review. The PRISMA flow diagram in Fig. 1 illustrates the selection process. Under the condition that a minimum of four comparisons should be made between the same malnutrition screening tool and reference standard, 21 studies were included in the meta-analysis.

3.2. Studies characteristics

The descriptive characteristics of the included studies are presented in Table 2. The total number of participants was 62,702. One trial contributed to more than half of the total participants with 34,071 included subjects [39]. The pooled mean age was 62 (standard deviation ± 14) years. In 6 studies, the mean nor median age was reported; however, according to inclusion criteria, the included participants were either adults above the age of 18 years [39–43] or elderly people aged 65 years and older [44]. Six studies exclusively included geriatric patients or subjects aged 65 years or older. The mean percentage of female individuals was 49.2% (±11.3); however, 6 studies did not report the prevalence of female/male sex. The mean prevalence of malnutrition, as determined using the reference standard, was 38.7% (±18.2). The included participants were heterogeneous regarding their medical condition or the ward to which they were admitted (17 different medical specialties).

A total of 138 comparisons were made across the selected studies. Among the 9 identified reference standards, the most frequently used was the SGA [39–41,43,45–67]. The other reference standards used were: NRS-2002 [68–74], MNA [42,75–77], MUST [42,74,78–80], ESPEN [81–85], GLIM [84,86–90], Global Indicator of Malnutrition (GIM) [91], a combined index (SGA, NRI, the Gassull classification, and Instant Nutritional Assessment [INA]) [92], and the Spanish tool Valoración Nutricional Completa (VNC) [93]. As for the malnutrition screening tools, a total of 51 were identified. The most frequently validated tool was the MUST; other malnutrition screening tools were: 3-Minute Nutrition Screening (3-MinNS), 3-MinNS with cut-off points at 3 and 5, Adult Nutrition Tool (ANT), Cardona, Canadian Nutrition Screening Tool (CNST), Controlling NUTritional Status (CONUT), Eating Validation Scheme (EVS), Glasgow Nutritional Screening Tool (Glasgow NST), Graz Malnutrition Screening (GMS), Herramienta de Evaluación de la Malnutrición Hospitalaria (HEMAN), Imperial Nutritional Screening System (INSYST) I and II, MNA, MNA (≥65 y), MNA-short form (MNA-SF), MNA-SF (≥65 y), MNA-SF-Body Mass Index (MNA-SF-BMI), MNA-SF-Calf Circumference (MNA-SF-CC), modified-MNA (m-MNA), reduced-MNA (r-MNA), abridged SGA (without physical examination), abridged PG-SGA, modified PG-SGA, modified MUST (Mod-MUST), malnutrition risk screening tool-hospital (MRST-H), Malnutrition Screening Tool (MST), malnutrition screening tool for hospitalized cancer patients (MSTC), MUST (<65 y), MUST (≥65 y), Nutritional Risk in Emergency-2017 (NRE-2017) with cut-off points at 1 and 1.5, NRS-2002, NRS-2002 (<65 y), NRS-2002 (≥65 y), NRS-2002 nutritional status only (NRSstat), NUTRISCORE, Nutritional Pre-screening (PTS), Rapid screen, Renal Inpatient Nutrition Screening Tool (Renal iNUT), Royal Marsden Nutrition Screening Tool (RMNST), Renal Nutrition Screening Tool (R-NST), SNAQ, Simplified SNAQ, and Tamizaje Nutricional de la Unidad Médica de Alta Especialidad 1 (TN-UMAE1).

Eight studies [57,58,60,63,76,82,89,92] conducted comparisons between reference standard tools and malnutrition screening tools as well as indices. While we did not exclude these studies from the analysis, the comparisons including nutritional indices were not taken into consideration.

A total of 25 studies were conducted in Europe (nine in Spain [57,58,61,64,73,75,77,79,93], six in the United Kingdom [40,42,46,49,59,78], two in Greece [81,92], and one in Austria [70], Denmark [94], Finland [95], Poland [53], Portugal [68], Russia [60], the Netherlands [83], and Turkey [71]); sixteen were conducted in Asia (seven in China [39,55,69,82,87–89], three in Malaysia [52,56,91], two in Singapore [50,51], and one in India [85], Republic of Korea [96], Taiwan [63] and Japan [90]); ten were conducted in Australia (nine in Australia [41,43,44,54,65–67,84,97]; and one in New Zealand [48]); five were conducted in Brazil, South America [47,72,74,86,98]; and three were conducted in North America (two in the USA [76,80], one in Canada [45], and one in Mexico [62]).

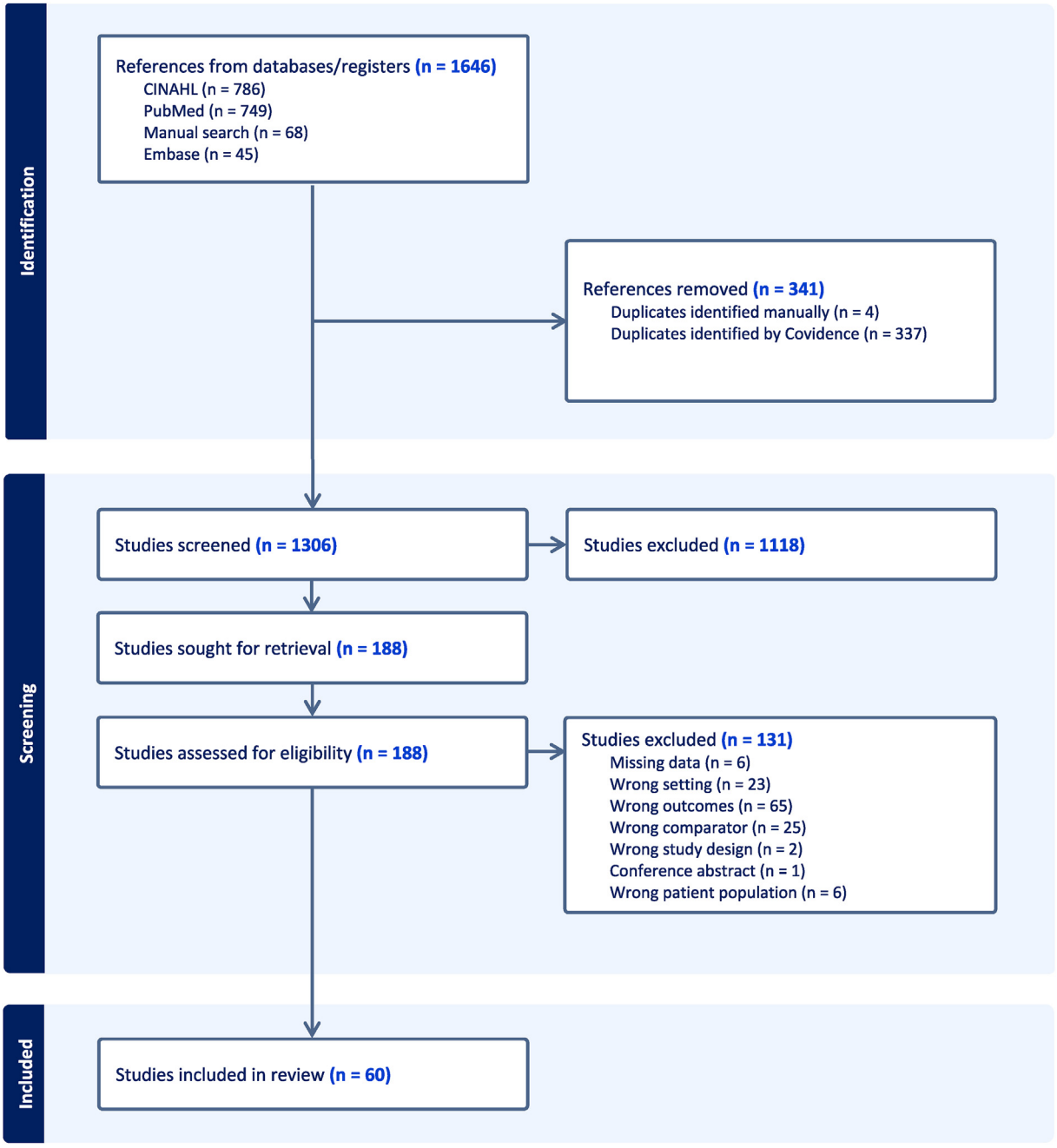

Fig. 1. PRISMA flowchart of the study selection process for the systematic review.

As for study design, the majority were defined as "validation" or "comparison" studies. The rest of the studies were either observational cross-sectional, prospective or retrospective cohort studies.

3.3. Quality assessment and risk of bias within studies

The results of the methodological quality assessment are shown in Fig. 2. A significant proportion of the articles (43%) did not specify how the sampling of patients was carried out, and many (22%) relied on convenience sampling. Only 35% of the studies explicitly mentioned that the patient sampling method was consecutive or random. Therefore, the risk of bias for the selection of patients was often unclear and highly likely to have introduced bias in the comparison. It was also often unclear whether the index test and reference standard were conducted and interpreted blindly. In 48% of cases, the risk of bias for the conduct or interpretation of the index test was unclear, and for the reference standard, it was high in 52% of studies, potentially introducing a high-risk bias into the comparison as well. Importantly, almost half of the studies (47%) employed nutrition screening tools such as NRS-2002 [68–74], MUST [42,74,78–80], GIM [91], a combined index [92], and VNC [93] as the reference standard. These tools are unlikely to be 100% sensitive in identifying malnutrition, thus influencing the reliability of the sensitivity and specificity measurements for the index tests.

3.4. Synthesis of results based on the systematic review

The sensitivity and specificity values of each malnutrition screening tool compared against the reference standard are shown in Table 2. Their visual representation is shown in Fig. 3. The overall

Table 2
Descriptive characteristics of study populations and malnutrition screening tools included in the systematic review.

Lead author, year	Country	Hospital ward(s)/ population	n (analyzed)	Age (y) (mean ± SD)	Female (%)	Malnutrition prevalence (ref std.) (%)	Screening tool	Ref std.	Sensitivity % (95% CI)[a]	Specificity % (95% CI)[a]	PPV % (95% CI)[a]	NPV % (95% CI)[a]	Reliability % (95% CI)	Agreement % (95% CI)	Kappa (95% CI)[b]
MUST															
Azian, 2014	Malaysia	Medical, surgical	151	45.2 ± 13.7	60	19.9	MUST	SGA	96.6 (E)	80.9 (G)	55.7 (P)	98.8 (E)	NR	NR	0.78 (Mod)
Calleja Fernández, 2015	Spain	Medical, general surgery, orthopedic, other surgical, oncology-hematology	201	71.6 (21.4)[d]	51	62.1	MUST	SGA	82.40 (75.32 −89.48) (G)	93.42 (87.19 −99.65) (E)	29.7 (P)	76.34 (67.17 −85.52) (F)	NR	NR	NR
Olivares, 2014	Spain	Medical, surgical	537	61.3 ± 17.7	44	19.5	MUST	SGA	64.1 (54.5−72.7) (I)	91.9 (89−94.1) (E)	95.37 (90.94 −99.80) (E)	91.5 (88.5 −93.8) (E)	NR	NR	0.564 (W)
Gibson, 2012	Australia	Medical, surgical	262	70.8 ± 16.3	52	26.7	MUST	SGA	80 (G)	85 (G)	65.3 (55.7 −73.9) (I)	NR	NR	NR	NR
Guerra-Sánchez, 2015	Spain	Internal medicine, cardiology/patients admitted with decompensated chronic heart failure	242	75 ± 9	50	49.2	MUST	SGA	95.8 (93.3−99.4) (E)	42.2 (33.8−51.4) (P)	NR	91.2 (83.9 −98.6) (E)	NR	NR	0.197 (N)
Jackson, 2019	UK	Nephrology	141	64 (52−74)[d]	41	44.7	MUST	SGA	44.4 (P)	100 (E)	61.9 (54.9 −69) (I)	69 (I)	NR	NR	0.47 (0.34 −0.60) (W)
Lawson, 2012	UK	Nephrology	190	NR	NR	52.6	MUST	SGA	53.8 (46.6−60) (P)	78.3 (70.1 −85.2) (F)	100 (E)	60 (53.7 −65.3) (I)	NR	NR	0.31 (0.16 −0.44) (Min)
Lomivorotov, 2013	Russia	Patients scheduled for cardiothoracic surgery with CPB	894	59 (53−64)[d]	37	5.2	MUST	SGA	97.9 (E)	87.1 (G)	73.7 (63.8 −82.1) (F)	99.9 (E)	NR	NR	NR
Padilla-Romo, 2015	Mexico	Internal medicine, nephrology	100	49	49	72	MUST	SGA	91.6 (E)	60.7 (I)	85.7 (G)	73.9 (F)	NR	83	0.554 (W)
Tu, 2012	Taiwan	Patients with colorectal cancer (diagnosis based on colonoscopy and pathological examinations)	45	62.1 ± 11.5	44	36	MUST	SGA	96 (80.5 −99.3) (E)	75 (53.1 −88.8) (F)	82.8 (G)	93.8 (E)	NR	NR	0.7 (0.5 −0.9) (Mod)
Velasco, 2011	Spain	Internal medicine, surgical	400	67.3 ± 16.1	40	35.3	MUST	SGA	71.6 (63.8−79.4) (F)	90.3 (86.5 −94.1) (E)	80.1 (72.8 −87.5) (G)	85.4 (81 −89.7) (G)	NR	75.3	0.635 (Mod)
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	MUST	SGA	87.1 (76.6−93.3) (G)	86.1 (76.3 −92.3) (G)	84.4 (73.6 −91.3) (G)	88.6 (79 −94.1) (G)	NR	NR	NR
Olivares, 2014	Spain	Medical, surgical	265	NR	NR	NR	MUST (<65 y)	SGA	60.0 (42.3−75.4) (I)	91.8 (87.6 −94.6) (E)	47.4 (32.5 −62.7) (P)	94.4 (91.3 −97.1) (E)	NR	NR	0.464 (W)
Olivares, 2014	Spain	Medical, surgical	272	NR	NR	NR	MUST (≥65 y)	SGA	65.8 (54.3−75.6) (I)	92.1 (87.4 −95.2) (E)	76.2 (64.4 −85.0) (F)	87.6 (82.3 −91.4) (G)	NR	NR	0.605 (Mod)
Sharma, 2017	Australia	Acute care, general medicine	132	79.5 ± 8.6	63	51.6	MUST	PG-SGA	69.7 (I)	75.8 (F)	75.4 (F)	70.1 (F)	NR	72.7	0.49 (W)
Poulia, 2017	Greece	Internal medicine and surgical	362	62 (46−75)[d]	49	11.3	MUST	ESPEN	100 (E)	96 (E)	75.9 (F)	100 (E)	NR	NR	0.843 (S)
Wang, 2020	China	Patients with cystic echinococcosis	232/396	41.0 ± 14.6 (for the whole sample)	57 (over the whole sample)	28.8	MUST	ESPEN	91.1 (E)	64.8 (I)	51.7 (P)	94.6 (E)	NR	NR	0.457 (W)
Wang, 2020	China	Patients with alveolar echinococcosis	164/396	41.0 ± 14.6 (for the whole sample)	57 (over the whole sample)	31.7	MUST	ESPEN	84.3 (G)	74.1 (F)	59.7 (P)	91.2 (E)	NR	NR	0.525 (W)
Srinivasaraghavan, 2022	India	Surgical oncology	206	54.7 ± 11	37	28.6	MUST	ESPEN	100 (E)	69.4 (I)	56.7 (P)	100 (E)	NR	NR	0.565 (W)
Aloy Dos Santos, 2023	Brazil	Surgical or clinical admissions	5270	59 ± 16	49	17.1	MUST	GLIM	100 (E)	56 (P)	31.8 (P)	100 (E)	NR	NR	0.303 (Min)

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Table 2 (*continued*)

Lead author, year	Country	Hospital ward(s)/ population	n (analyzed)	Age (y) (mean ± SD)	Female (%)	Malnutrition prevalence (ref std.) (%)	Screening tool	Ref std.	Sensitivity % (95% CI)[a]	Specificity % (95% CI)[a]	PPV % (95% CI)[a]	NPV % (95% CI)[a]	Reliability % (95% CI)	Agreement % (95% CI)	Kappa (95% CI)[b]
Zhang, 2021	China	Patients diagnosed with cancer and due to receive radiation therapy	637	56.8 ± 14.4	40	28	MUST	GLIM	52.2 (P)	99.1 (E)	95.9 (E)	84 (G)	NR	NR	0.596 (W)
Zhou, 2022	China	Patients diagnosed with gastrointestinal stromal tumor	269	57 ± 12.2	52	32	MUST	GLIM	91.9 (E)	83.1 (G)	71.8 (F)	95.6 (E)	NR	NR	0.70 (0.61 −0.79) (Mod)
Amaral, 2008	Portugal	Oncology	130	57.1 ± 13.5	69	28.5	MUST	NRS-2002	97.3 (E)	77.4 (F)	63.2 (I)	98.6 (E)	NR	83.1	0.64 (Mod)
Ma, 2020	China	Laryngeal cancer patients admitted for surgery	197	61.8 ± 8.8	8	4.6	MUST	NRS-2002	82.8 (G)	88.1 (G)	54.5 (P)	96.7 (E)	NR	87.3	0.584 (W)
Rabito, 2017	Brazil	Emergency	752	53.6 ± 15.5	55	29.3	MUST	NRS-2002	82.6 (G)	84.5 (G)	NR	NR	NR	NR	0.581 (W)
Castro-Vega, 2018	Spain	Patients admitted to hospital	285	64 ± 16.2	NR	30.2	MUST	VNC	80.2 (G)	93.5 (E)	84.1 (G)	91.6 (E)	NR	NR	0.747 (Mod)
Poulia, 2012	Greece	Patients admitted through emergency	248	75.2 ± 8.5	48	66.9	MUST	Combined index	87.3 (G)	76.8 (F)	88.4 (G)	75 (F)	NR	NR	0.638 (Mod)
Gibson, 2012	Australia	Medical, surgical	262	70.8 ± 16.3	52	26.7	Mod-MUST	SGA	77 (F)	83 (G)	NR	NR	NR	NR	NR
MUST-Plus															
Timsina, 2021	USA	Patients admitted to the Hospital who had a nutritional evaluation	5064	NR	50	26.9	MUST-Plus	MUST	73.5 (70−76.8) (F)	76.9 (75.6 −78.1) (F)	32.8 (30.5 −35.3) (P)	NR	NR	NR	NR
MST															
Morris, 2018	Australia	Medical	608	NR	NR	41.1	MST	SGA	84 (78.9−88.3) (G)	70.7 (65.7 −75.3) (F)	66.7 (61.2 −71.9) (I)	86.3 (81.9 −90.1) (G)	NR	NR	NR
Wu, 2012	Australia	Hospitalized patients at high risk of readmission	157	77.6 ± 6.4	77	20.6	MST	SGA	94 (E)	89 (G)	70 (F)	98 (E)	77.8	NR	0.74 (0.62 −0.86) (Mod)
Azian, 2014	Malaysia	Medical, surgical	151	45.2 ± 13.7	60	19.9	MST	SGA	93.3 (E)	80.9 (G)	54.9 (P)	98 (E)	NR	NR	0.52 (W)
Lawson, 2012	UK	Nephrology	190	NR	NR	52.6	MST	SGA	48.7 (41.7−54) (P)	85.5 (77.9 −91.3) (G)	78.7 (67.5 −87.3) (F)	60.2 (54.8 −64.3) (I)	NR	NR	0.33 (0.19 −0.44) (Min)
Ulltang, 2013	Australia	Medical assessment and planning	153	62 ± 17.4	50	16.9	MST	SGA	73 (47−99) (F)	76 (65−87) (F)	38 (17−59) (P)	93 (85−100) (E)	NR	NR	NR
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	MST	SGA	90.3 (80.5−95.5) (E)	84.7 (74.7 −91.2) (G)	83.6 (72.9 −90.6) (G)	91 (81.8 −95.8) (E)	NR	NR	NR
Kang, 2022	China	Cancer patients from thoracic surgery, gastroenterology, oncology	1000	55.9 ± 11.8	52	45	MST	SGA	50.9 (46.2−55.9) (P)	74.9 (71 −78.4) (F)	62.4 (57.2 −67.3) (I)	65.1 (61.2 −68.8) (I)	NR	NR	0.262 (Min)
Shaw, 2015	UK	Oncology	126	59 (19−81)[c]	54	71	MST	PG-SGA	66 (55−75) (I)	83 (67−94) (G)	91 (E)	49 (P)	NR	NR	NR
Byrnes, 2018	Australia	General surgical/ people aged 65 years and older	75	74 ± 6.7	60	19	MST	PG-SGA	86 (57−98) (G)	80 (68−89) (G)	50 (37−63) (P)	96 (87−99) (E)	NR	NR	NR
Clark, 2020	Australia	Subacute geriatric rehabilitation	444	82.4 ± 8.01	57	12.6	MST	ESPEN	60.7 (I)	58 (P)	17.2 (P)	91 (E)	NR	NR	0.09 (N)
Aloy Dos Santos, 2023	Brazil	Surgical or clinical admissions	5270	59 ± 16	49	17.1	MST	GLIM	75.4 (F)	89.9 (G)	60.4 (I)	94.6 (E)	NR	NR	0.591 (W)
Clark, 2020	Australia	Subacute geriatric rehabilitation	444	82.4 ± 8.01	57	52	MST	GLIM	56.7 (P)	69 (I)	66.5 (I)	59.5 (P)	NR	NR	0.26 (Min)
Amaral, 2008	Portugal	Oncology	130	57.1 ± 13.5	69	28.5	MST	NRS-2002	48.7 (P)	94.6 (E)	78.3 (F)	82.2 (G)	NR	81.5	0.49 (W)
Ma, 2020	China	Laryngeal cancer patients admitted for surgery	197	61.8 ± 8.8	8	4.6	MST	NRS-2002	17.3 (P)	97.6 (E)	55.6 (P)	87.2 (G)	NR	85.8	0.208 (N)

Rabito, 2017	Brazil	Emergency	752	53.6 ± 15.5	55	29.3	MST	NRS-2002	76.8 (F)	84.7 (G)	NR	NR	NR	NR	0.592 (W)
Castro-Vega, 2018	Spain	Patients admitted to hospital	285	64 ± 16.2	NR	30.2	MST	VNC	75.6 (F)	95 (E)	86.7 (G)	90 (E)	NR	NR	0.73 (Mod)
NRS-2002															
Olivares, 2014	Spain	Medical, surgical	537	61.3 ± 17.7	44	19.5	NRS-2002	SGA	68.9 (59.4−77.1) (I)	90.1 (86.9 −92.6) (E)	62.3 (53.1 −70.6) (I)	92.4 (89.5 −94.6) (E)	NR	NR	0.567 (W)
Calleja Fernández, 2015	Spain	Medical, general surgery, orthopedic, other surgical, oncology-hematology	201	71.6 (21.4)[d]	51	62.1	NRS-2002	SGA	56 (46.90−65.10) (P)	97.37 (93.11 −100) (E)	97.22 (92.73 −100) (E)	57.36 (48.44 −66.29) (P)	NR	NR	NR
Guerra-Sánchez, 2015	Spain	Internal medicine, cardiology/patients admitted with decompensated chronic heart failure	242	75 ± 9	50	49.2	NRS-2002	SGA	95.8 (93.3−99.4) (E)	52.8 (44 −61.7) (P)	66.3 (59.2 −73.3) (I)	92.8 (86.8 −98.9) (E)	NR	NR	0.483 (W)
Kroc, 2021	Poland	Geriatric acute care	622	81.7 ± 7.8	69	15	NRS-2002	SGA	77.4 (F)	87.7 (G)	NR	NR	NR	NR	NR
Lomivorotov, 2013	Russia	Patients scheduled for cardiothoracic surgery with CPB	894	59 (53−64)[d]	37	5.2	NRS-2002	SGA	38.3 (P)	95.4 (E)	31.6 (P)	96.5 (E)	NR	NR	NR
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	NRS-2002	SGA	90.3 (80.5−95.5) (E)	83.3 (73.1 −90.2) (G)	82.4 (71.6 −89.6) (G)	90.9 (81.6 −95.8) (E)	NR	NR	NR
Velasco, 2011	Spain	Internal medicine, surgical	400	67.3 ± 16.1	40	35.3	NRS-2002	SGA	74.4 (66.9−82) (F)	87.2 (83 −91.5) (G)	76.1 (68.6 −83.5) (F)	86.2 (81.9 −90.6) (G)	NR	82.8	0.62 (Mod)
Olivares, 2014	Spain	Medical, surgical	265	NR	NR	NR	NRS-2002 (<65 y)	SGA	56.7 (39.2−72.6) (P)	97.9 (95.3 −99.1) (E)	77.3 (56.6 −89.9) (F)	94.8 (91.3 −96.9) (E)	NR	NR	0.618 (Mod)
Olivares, 2014	Spain	Medical, surgical	272	NR	NR	NR	NRS-2002 (≥65 y)	SGA	72.6 (61.4−81.5) (F)	90.1 (85 −93.5) (E)	73.6 (62.4 −82.4) (F)	89.6 (84.5 −93.2) (G)	NR	NR	0.629 (Mod)
Poulia, 2017	Greece	Internal medicine and surgical	362	62 (46−75)[d]	49	11.3	NRS-2002	ESPEN	61 (I)	76.3 (F)	24.8 (P)	93.9 (E)	NR	NR	0.228 (Min)
Wang, 2020	China	Patients with cystic echinococcosis	232/396	41.0 ± 14.6 (for the whole sample)	57 (over the whole sample)	28.8	NRS-2002	ESPEN	79.4 (F)	75.8 (F)	57.4 (P)	89.9 (G)	NR	NR	0.496 (W)
Wang, 2020	China	Patients with alveolar echinococcosis	164/396	41.0 ± 14.6 (for the whole sample)	57 (over the whole sample)	31.7	NRS-2002	ESPEN	68.6 (I)	86.6 (G)	70 (F)	85.8 (G)	NR	NR	0.555 (W)
Huang, 2022	China	Patients diagnosed with gastrointestinal cancer	488	71.5 (11.35)[d]	35	28.27	NRS-2002	GLIM	78 (F)	73 (F)	54 (P)	90 (E)	NR	NR	NR
Zhang, 2021	China	Patients diagnosed with cancer and due to receive radiation therapy	637	56.8 ± 14.4	40	28	NRS-2002	GLIM	81.7 (G)	97.6 (E)	93 (E)	93.1 (E)	NR	NR	0.823 (S)
Zhou, 2022	China	Patients diagnosed with gastrointestinal stromal tumor	269	57 ± 12.2	52	32	NRS-2002	GLIM	65.1 (I)	90.7 (E)	56.9 (P)	89 (G)	NR	NR	0.47 (0.37 −0.57) (W)
Sheean, 2013	USA (IL)	Surgical, Medical/ people aged 65 years and older	260	73.8 ± 6.4	51	34	NRS-2002	MNA	87 (G)	44 (P)	NR	NR	NR	NR	NR
Poulia, 2012	Greece	Patients admitted through emergency	248	75.2 ± 8.5	48	66.9	NRS-2002	Combined index	99.4 (E)	6.1 (P)	68.2 (I)	83.3 (G)	NR	NR	0.088 (N)
Orell-Kotikangas, 2015	Finland	Head and neck cancer patients	65	61 (33−77)[c]	23	34	NRS-2002 (cutoff 3)	PG-SGA	77.3 (57−90) (F)	97.7 (88 −100) (E)	94.4 (E)	89.4 (G)	NR	NR	0.784 (Mod)
MNA-SF and variations of the MNA															
Olivares, 2014	Spain	Medical, surgical	537	61.3 ± 17.7	44	19.5	MNA-SF	SGA	69.9 (60.5−77.9) (I)	94.7 (92.2 −96.4) (E)	75.8 (66.3 −83.3) (F)	93 (90.2−95) (E)	NR	NR	0.666 (Mod)
Guerra-Sánchez, 2015	Spain	Internal medicine, cardiology/patients admitted with decompensated chronic heart failure	242	75 ± 9	50	49.2	MNA-SF	SGA	96.6 (94.4−99.9) (E)	59.3 (50.7 −68) (P)	69.7 (62.7 −76.7) (I)	94.8 (89.8 −99.8) (E)	NR	NR	0.556 (W)

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Table 2 (*continued*)

Lead author, year	Country	Hospital ward(s)/ population	n (analyzed)	Age (y) (mean ± SD)	Female (%)	Malnutrition prevalence (ref std.) (%)	Screening tool	Ref std.	Sensitivity % (95% CI)[a]	Specificity % (95% CI)[a]	PPV % (95% CI)[a]	NPV % (95% CI)[a]	Reliability % (95% CI)	Agreement % (95% CI)	Kappa (95% CI)[b]
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	MNA-SF	SGA	100 (92.8–100) (E)	52.8 (41.4–63.8) (P)	64.6 (54.5–73.2) (I)	100 (88.8–100) (E)	NR	NR	NR
Olivares, 2014	Spain	Medical, surgical	265	NR	NR	NR	MNA-SF (<65 y)	SGA	70.0 (52.1–83.3) (F)	95.1 (91.6–97.2) (E)	63.6 (46.6–77.8) (I)	96.3 (93.0–98.0) (E)	NR	NR	0.623 (Mod)
Olivares, 2014	Spain	Medical, surgical	272	NR	NR	NR	MNA-SF (≥65 y)	SGA	69.9 (58.6–79.2) (I)	94.2 (90.0–96.8) (E)	89.1 (84.1–92.7) (G)	82.3 (71.0–89.8) (G)	NR	NR	0.672 (Mod)
van der Sijp, 2018	the Netherlands	Patients admitted with a proximal femoral fracture	437	79.2 ± 12.8	69	16.9	MNA-SF	ESPEN	100 (E)	62.8 (I)	35.4 (P)	100 (E)	NR	NR	NR
Srinivasaraghavan, 2022	India	Surgical oncology	206	54.7 ± 11	37	28.6	MNA-SF	ESPEN	100 (E)	34 (P)	37.8 (P)	100 (E)	NR	NR	0.228 (Min)
Wang, 2020	China	Patients with cystic echinococcosis	232/396	41.0 ± 14.6 (for the whole sample)	57 (over the whole sample)	28.8	MNA-SF (≥65 y)	ESPEN	89.7 (G)	70.9 (F)	55.9 (P)	94.3 (E)	NR	NR	0.515 (W)
Wang, 2020	China	Patients with alveolar echinococcosis	164/396	41.0 ± 14.6 (for the whole sample)	57 (over the whole sample)	31.7	MNA-SF (≥65 y)	ESPEN	86.2 (G)	65.1 (I)	53 (P)	91.2 (E)	NR	NR	0.439 (W)
Huang, 2022	China	Patients diagnosed with gastrointestinal cancer	488	71.5 (11.35)[d]	35	28.27	MNA-SF	GLIM	81 (G)	67 (I)	49 (P)	90 (E)	NR	NR	NR
Matsumoto, 2020	Japan	Acute care	490	69.5 ± 16	45	33	MNA-SF	GLIM	93.4 (E)	69.3 (I)	60.8 (I)	95.3 (E)	NR	NR	NR
Andersen, 2021	Denmark	Emergency/people aged 65 years and older	127	77.6 (72.3–85.2)[d]	56	59	MNA-SF	NRS-2002 (baseline)	79 (F)	82 (G)	NR	NR	NR	80	0.57 (0.42–0.72) (W)
Andersen, 2021	Denmark	Emergency/people aged 65 years and older	127	77.6 (72.3–85.2)[d]	56	NR	MNA-SF	NRS-2002 (follow-up)	42 (P)	100 (E)	NR	NR	NR	60	0.31 (0.18–0.44) (Min)
Calvo, 2012	Spain	Internal medicine/ people aged 65 years and older	106	79.4	45.3	22	MNA-SF	MNA	95 (E)	64 (I)	80 (G)	86 (G)	NR	NR	NR
Sheean, 2013	USA (IL)	Surgical, Medical/ people aged 65 years and older	260	73.8 ± 6.4	51	34	MNA-SF	MNA	72 (F)	98 (E)	NR	NR	NR	NR	NR
Poulia, 2012	Greece	Patients admitted through emergency	248	75.2 ± 8.5	48	66.9	MNA-SF	Combined index	98.1 (E)	50 (P)	79.9 (F)	93.2 (E)	NR	NR	0.545 (W)
Castro-Vega, 2018	Spain	Patients admitted to hospital	285	64 ± 16.2	NR	30.2	MNA-SF (≥65 y)	VNC	94.3 (E)	57.4 (P)	47.6 (P)	96.1 (E)	NR	NR	0.401 (W)
Martín, 2016	Spain	Internal medicine	591	77.7 ± 7.3	50	70	m-MNA (≥65 y)	MNA	95.7 (93.6–97.8) (E)	65.1 (57.8–72.5) (I)	NR	NR	NR	NR	0.75 (0.72–0.79) (Mod)
Martín, 2016	Spain	Internal medicine	591	77.7 ± 7.3	50	70	r-MNA (≥65 y)	MNA	87.7 (84.5–91) (G)	78.3 (71.9–84.7) (F)	NR	NR	NR	NR	0.72 (0.68–0.76) (Mod)
Martín, 2016	Spain	Internal medicine	591	77.7 ± 7.3	50	70	MNA-SF-BMI (≥65 y)	MNA	90.6 (87.7–93.6) (E)	85.1 (76.6–90.7) (G)	NR	NR	NR	NR	0.81 (0.77–0.84) (S)
Martín, 2016	Spain	Internal medicine	591	77.7 ± 7.3	50	70	MNA-SF-CC (≥65 y)	MNA	92.6 (89.9–95.2) (E)	71.4 (64.5–78.4) (F)	NR	NR	NR	NR	0.75 (0.72–0.79) (Mod)

SNAQ and simplified SNAQ														
Lomivorotov, 2013	Russia	Patients scheduled for cardiothoracic surgery with CPB	894	59 (53–64)[d]	37	5.2	SNAQ	SGA	91.5 (E)	87.5 (G)	28.9 (P)	99.5 (E)	NR	NR	NR
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	SNAQ	SGA	79 (67.4–87.3) (F)	90.3 (81.3 –95.3) (E)	87.5 (76.4 –93.8) (G)	83.3 (73.5 –90) (G)	NR	NR	NR
van der Sijp, 2018	the Netherlands	Patients admitted with a proximal femoral fracture	437	79.2 ± 12.8	69	16.9	SNAQ	ESPEN	71.6 (F)	90.4 (E)	60.2 (I)	94 (E)	NR	NR	NR
Rabito, 2017	Brazil	Emergency	752	53.6 ± 15.5	55	29.3	SNAQ	NRS-2002	73.2 (F)	87.4 (G)	NR	NR	NR	NR	0.599 (W)
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	Simplified SNAQ	SGA	86.9 (76.2–93.2) (G)	78.9 (68 –86.8) (F)	77.9 (66.7 –86.2) (F)	87.5 (77.2 –93.5) (G)	NR	NR	NR
PG-SGA, variations of the PG-SGA and variations of the SGA														
Zhang, 2021	China	Patients diagnosed with cancer and due to receive radiation therapy	637	56.8 ± 14.4	40	28	PG-SGA	GLIM	81.1 (G)	71.6 (F)	52.9 (P)	90.6 (E)	NR	NR	0.453 (W)
Fu, 2022	China	Patients diagnosed with cancer and due to receive radiation therapy	34,071	NR	45	58.3	Modified PG-SGA	PG-SGA	94.5 (E)	93 (E)	NR	NR	NR	NR	0.88 (S)
Fu, 2022	China	Patients diagnosed with cancer and due to receive radiation therapy	34,071	NR	45	58.3	Modified PG-SGA-Box 1	SGA	78 (F)	81 (G)	NR	NR	NR	NR	0.73 (Mod)
Fu, 2022	China	Patients diagnosed with cancer and due to receive radiation therapy	34,071	NR	45	58.3	Modified PG-SGA-Box 1 + worksheet	SGA	85 (G)	77 (F)	NR	NR	NR	NR	0.77 (Mod)
Fu, 2022	China	Patients diagnosed with cancer and due to receive radiation therapy	34,071	NR	45	58.3	Abridged PG-SGA	SGA	90 (E)	94 (E)	NR	NR	NR	NR	0.83 (S)
Vivanti, 2021	Australia	Adult patients with available SGA history and meeting inclusion criteria	489	NR	NR	15.95	Abridged SGA (without physical examination)	SGA	87.2 (G)	98.9 (E)	91.9 (E)	97.6 (E)	99	NR	0.967 (S)
GMS														
Roller, 2016	Austria	Internal medicine, surgical, orthopedic	404	61 (18–93)[c]	45	24.5	GMS	NRS-2002	94 (E)	77 (F)	76 (F)	95 (E)	NR	NR	NR
Sahin, 2022	Turkey	Internal medicine, surgical	348	57	48	35.6	GMS	NRS-2002	95.16 (E)	78.57 (F)	71.08 (F)	96.7 (E)	NR	NR	0.686 (Mod)
Lima, 2018	Brazil	Elderly patients diagnosed with cancer or admitted to general surgical and reparatory	60	NR	NR	49.4	GSM	MNA-SF	86 (G)	75 (F)	88 (G)	71 (F)	NR	NR	0.602 (Mod)
Lima, 2018	Brazil	Adult cancer patients	60	NR	NR	47.1	GSM	PG-SGA	90 (E)	73 (F)	88 (G)	77 (F)	NR	NR	0.648 (Mod)
Sahin, 2022	Turkey	Internal medicine, surgical	348	57	48	47.1	GSM	SNAQ	91.59 (E)	75.11 (F)	74.7 (F)	78.02 (F)	NR	NR	0.609 (Mod)
EVS														
Andersen, 2021	Denmark	Emergency/people aged 65 years and older	127	77.6 (72.3 –85.2)[d]	56	68	EVS (at baseline)	MNA- SF	69 (I)	100 (E)	NR	NR	NR	70	0.1 (−0.01-0.21) (N)
Andersen, 2021	Denmark	Emergency/people aged 65 years and older	127	77.6 (72.3 –85.2)[d]	56	59	EVS (at baseline)	NRS-2002	61 (I)	100 (E)	NR	NR	NR	62	0.07 (0.01 −0.15) (N)

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Table 2 (*continued*)

Lead author, year	Country	Hospital ward(s)/ population	n (analyzed)	Age (y) (mean ± SD)	Female (%)	Malnutrition prevalence (ref std.) (%)	Screening tool	Ref std.	Sensitivity % (95% CI)[a]	Specificity % (95% CI)[a]	PPV % (95% CI)[a]	NPV % (95% CI)[a]	Reliability % (95% CI)	Agreement % (95% CI)	Kappa (95% CI)[b]
Andersen, 2021	Denmark	Emergency/people aged 65 years and older	127	77.6 (72.3 −85.2)[d]	56	NR	EVS (at follow-up)	MNA-SF	74 (F)	64 (I)	NR	NR	NR	73	0.21 (0.06 −0.47) (Min)
Andersen, 2021	Denmark	Emergency/people aged 65 years and older	127	77.6 (72.3 −85.2)[d]	56	NR	EVS (at follow-up)	NRS-2002	35 (P)	100 (E)	NR	NR	NR	45	0.14 (0.06 −0.22) (N)
INSYST I and II															
Tammam, 2009	UK	Medical, surgical, oncology	61	NR	NR	34	INSYST I	MNA	100 (E)	83 (G)	NR	NR	NR	NR	0.76 (0.60 −0.92) (Mod)
Tammam, 2009	UK	Medical, surgical, oncology	61	NR	NR	34	INSYST I	MUST	95 (E)	80 (G)	NR	NR	NR	NR	0.73 (0.56 −0.92) (Mod)
Tammam, 2009	UK	Medical, surgical, oncology	61	NR	NR	34	INSYST II	MNA	95 (E)	65 (I)	NR	NR	NR	NR	0.53 (0.34 −0.72) (W)
Tammam, 2009	UK	Medical, surgical, oncology	61	NR	NR	34	INSYST II	MUST	95 (E)	65 (I)	NR	NR	NR	NR	0.53 (0.34 −0.72) (W)
3-MinNS, 3-MinNS (cutoff 3) and 3-MinNS (cutoff 5)															
Tah, 2020	Malaysia	Medical, surgical, nephrology, rheumatology, endocrinology, hematology	350	54.5 ± 16.1	45	36.3	3-MinNS	SGA	68.5 (I)	95.1 (E)	88.8 (G)	84.1 (G)	NR	NR	NR
Lim, 2009	Singapore	General medicine, surgical, cardiology, orthopedic, gastroenterology, nephrology, oncology, neurology, respiratory, endocrinology, cardiothoracic and vascular surgery, neurosurgery, others	818	51.9 ± 15.4	41	29	3-MinNS (cutoff 3)	SGA	86 (G)	83 (G)	NR	NR	NR	NR	NR
Lim, 2013	Singapore	Surgical, oncology	121	59 ± 16	48	46	3-MinNS (cutoff 3)	SGA	89.3 (G)	87.7 (G)	NR	NR	NR	NR	NR
Lim, 2009	Singapore	General medicine, surgical, cardiology, orthopedic, gastroenterology, nephrology, oncology, neurology, respiratory, endocrinology, cardiothoracic and vascular surgery, neurosurgery, others	818	51.9 ± 15.4	41	29	3-MinNS (cutoff 5)	SGA	93 (E)	86 (G)	NR	NR	NR	NR	NR

NRE-2017 (cutoff ≥ 1.0) and NRE-2017 (cutoff ≥ 1.5)														
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	33.3	NRE-2017 ≥ 1.0	MST	89.6 (G)	69.6 (I)	89.6 (G)	69.6 (I)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	37.1	NRE-2017 ≥ 1.0	MUST	83.7 (G)	69.6 (I)	83.7 (G)	69.6 (I)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	29.3	NRE-2017 ≥ 1.0	NRS-2002	91.7 (E)	63.3 (I)	91.7 (E)	67.3 (I)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	31.6	NRE-2017 ≥ 1.0	SNAQ	91.6 (E)	68 (I)	91.6 (E)	68 (I)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	33.3	NRE-2017 ≥ 1.5	MST	80.7 (G)	82.6 (G)	80.7 (G)	82.6 (G)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	37.1	NRE-2017 ≥ 1.5	MUST	79.2 (F)	81.8 (G)	73.2 (F)	81.8 (G)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	29.3	NRE-2017 ≥ 1.5	NRS-2002	81.2 (G)	79.4 (F)	81.2 (G)	79.4 (F)	NR	NR	NR
Marcadenti, 2018	Brazil	Emergency	748	53.6 ± 15.5	46	31.6	NRE-2017 ≥ 1.5	SNAQ	84.1 (G)	81.4 (G)	84.1 (G)	81.4 (G)	NR	NR	NR
NUTRISCORE															
Vidal-Casariego, 2021	Spain	Oncology	93	65.1 ± 15.3	49	69.9	NUTRISCORE	MUST	58.6 (45.7–71.2) (P)	89.3 (76–100) (G)	92.7 (83.5–100) (E)	48.1 (33.5–62.6) (P)	NR	NR	0.38 (0.23–0.54) (Min)
Kang, 2022	China	Cancer patients from thoracic surgery, gastroenterology, oncology	1000	55.9 ± 11.8	52	45	NUTRISCORE	PG-SGA	6.2 (4.2–8.9) (P)	99.8 (98.8–100) (E)	96.6 (80.4–99.8) (E)	56.5 (53.4–59.7) (P)	NR	NR	0.066 (N)
Other screening tools															
Morris, 2018	Australia	Medical	608	NR	NR	41.1	ANT	SGA	96 (92.8–98.7) (E)	59.5 (54.2–64.6) (P)	62.3 (57.3–67.2) (I)	95.5 (91.9–97.8) (E)	NR	NR	NR
Guerra-Sánchez, 2015	Spain	Internal medicine, cardiology/patients admitted with decompensated chronic heart failure	242	75 ± 9	50	49.2	Cardona	SGA	52.1 (45.8–61.1) (P)	66.7 (58.3–75)	60.2 (50.7–69.6) (I)	58.9 (50.8–67.2) (P)	NR	NR	0.188 (N)
Laporte, 2015	Canada	Medical, surgical	1014	66 (18–98)[c]	48	45	CNST	SGA	91.7 (E)	74.8 (F)	74.9 (F)	91.6 (E)	NR	NR	NR
Guerra-Sánchez, 2015	Spain	Internal medicine, cardiology/patients admitted with decompensated chronic heart failure	242	75 ± 9	50	49.2	CONUT	SGA	87.4 (83.2–93.4) (G)	20.3 (13.2–27.4) (P)	51.5 (44.6–58.4) (P)	62.5 (47.5–77.5) (I)	NR	NR	0.076 (N)
Gerasimidis, 2007	UK	Medical, orthopedic, general surgical, plastic surgery including head and neck burns, geriatric, oncology	202	64 (18–95)[c]	55	42.1	Glasgow NST	MUST	95.3 (E)	64.9 (I)	95 (E)	66.4 (I)	NR	NR	0.57 (W)
Alfonso García, 2012	Spain	Internal Medicine, Oncology	112	73.1 ± 14.4	65	72	HEMAN	NRS-2002	100 (100-100) (E)	80 (68–92) (G)	90 (84–97) (E)	100 (100-100) (E)	NR	NR	NR
Sakinah, 2012	Malaysia	Geriatric/people aged 65 years and older	100	73.11 ± 6.03	63	10.5	MRST-H	GIM	66.7 (I)	96.2 (E)	82.4 (G)	NR	NR	NR	NR
Kim, 2011	Republic of Korea	Patients with gastric, colon, lung, liver (pancreas and gallbladder), breast, prostate, uterus, brain and spinal cord, head and neck, or urinary organ cancer	257	59.6 ± 11.3	37	26.1	MSTC	PG-SGA	94 (85.4–98.3) (E)	84.2 (78.2–89.1) (G)	67.8 (57.3–77.1) (I)	97.6 (93.9–99.3) (E)	NR	NR	0.7 (Mod)
MacLaughlin, 2018	UK	Nephrology	143	57.9 ± 15.9	37	38	NIS	SGA	89 (G)	65 (I)	NR	NR	NR	NR	NR
Sheean, 2013	USA (IL)	Surgical, Medical/ people aged 65 years and older	260	73.8 ± 6.4	51	34	NRSstat	MNA	81 (G)	96 (E)	NR	NR	NR	NR	NR
Lima, 2012	Brazil	Emergency	196	57 ± 18	39	66	PTS	SGA	96.9 (E)	80 (G)	90.65 (E)	92.98 (E)	NR	NR	0.95 (S)
Young, 2013	Australia	Medical	133	80 ± 8	50	46.6	Rapid screen	SGA	29 (19.7–41.8) (P)	100 (93.8–100) (E)	100 (79.1–100) (E)	62.1 (53.2–70.5) (I)	NR	NR	NR
Jackson, 2019	UK	Nephrology	141	64 (52–74)[d]	41	44.7	Renal iNUT	SGA	69.8 (I)	92.3 (E)	88 (G)	79.1 (F)	NR	NR	0.63 (0.51–0.76) (Mod)
Shaw, 2015	UK	Oncology	126	59 (19–81)[c]	54	71	RMNST	SGA	93 (86–98) (E)	53 (36–70) (P)	83 (G)	76 (F)	NR	NR	NR

(continued on next page)

Table 2 (*continued*)

Lead author, year	Country	Hospital ward(s)/ population	n (analyzed)	Age (y) (mean ± SD)	Female (%)	Malnutrition prevalence (ref std.) (%)	Screening tool	Ref std.	Sensitivity % (95% CI)[a]	Specificity % (95% CI)[a]	PPV % (95% CI)[a]	NPV % (95% CI)[a]	Reliability % (95% CI)	Agreement % (95% CI)	Kappa (95% CI)[b]
Xia, 2016	New Zealand	Patients admitted with acute kidney injury, chronic kidney disease, and dialysis	122	57.1 ± 14.1	48	53.3	R-NST	SGA	97.3 (90.7–99.1) (E)	74.4 (57.9–87) (F)	88 (79–94.1) (G)	93.6 (78.6–99.2) (E)	NR	NR	NR
Padilla-Romo, 2015	Mexico	Internal medicine, nephrology	100	49	49	72	TN-UMAE1	SGA	70 (F)	53.5 (P)	79.6 (F)	41.6 (P)	NR	66	0.224 (Min)

Abbreviations: 3-MinNS = 3-Minute Nutrition Screening; ANT = Adult Nutrition Tool; CI = confidence interval; CNST = Canadian Nutrition Screening Tool; CONUT = Controlling NUTritional Status; ESPEN = European Society for Clinical Nutrition and Metabolism; EVS = Eating Validation Scheme; GIM = Global Indicator of Malnutrition; Glasgow NST = Glasgow Nutritional Screening Tool; GLIM = Global Leadership Initiative on Undernutrition; GMS = Graz Malnutrition Screening; HEMAN = Herramienta de Evaluación de la Malnutrición Hospitalaria; INSYST = Imperial Nutritional Screening System; MNA = Mini Nutritional Assessment; MNA-SF = MNA-short form; m-MNA = modified-MNA; MNA-SF-BMI = MNA-SF-Body Mass Index; MNA-SF-CC = MNA-SF-Calf Circumference; MST = Malnutrition Screening Tool; MRST-H = malnutrition risk screening tool-hospital; MSTC = malnutrition screening tool for hospitalized cancer patients; MUST = Malnutrition Universal Screening Tool; Mod-MUST = modified MUST; NPV = negative predictive value; NR = not reported; NRE-2017 = Nutritional Risk in Emergency-2017; NRS 2002 = Nutrition Universal Screening Tool 2002; NRSstat = NRS-2002 nutritional status only; PG-SGA = patient-generated SGA; PPV = positive predictive value; PTS = Nutritional Pre-screening; r-MNA = reduced-MNA; R-NST = Renal Nutrition Screening Tool; Ref std = reference standard; Renal iNUT = Renal Inpatient Nutrition Screening Tool; RMNST = Royal Marsden Nutrition Screening Tool; SGA = Subjective Global Assessment; SNAQ = Short Nutritional Assessment Questionnaire; TN-UMAE1 = Tamizaje Nutricional de la Unidad Médica de Alta Especialidad 1; VNC = Valoración Nutricional Completa.

[a] (E) = Excellent, (G) = Good, (F) = Fair, (I) = Insufficient, (P) = Poor.
[b] (S) = Strong, (Mod) = Moderate, (W) = Weak, (Min) = Minimal, (N) = None.
[c] Median (min–max).
[d] Median (IQR).

sensitivity of the validated tools ranged between 15% and 100%, while specificity ranged between 44% and 99%.

The MUST tool was validated against the SGA [40,56–66], SGA for patients younger or older than 65 [61], PG-SGA [97], ESPEN diagnostic tool [81,82,85], GLIM diagnostic tool [86–88], NRS-2002 [68,69,72], VNC [93], and a combined index [92]. The sensitivity of the MUST ranged from 44.4% to 98%, and the specificity ranged from 56% to 100%.

The MST tool was validated against the SGA [40,41,54–56,65,67], PG-SGA [49], PG-SGA for patients aged ≥65 years [44], ESPEN [84], GLIM [84,86], NRS-2002 [68,69,72], and VNC [93]. The sensitivity and specificity of MST varied greatly between studies, with the sensitivity ranging from 17.3% to 94% and the specificity from 58% to 97.6%. One study limited the analysis to patients aged 65 years or older.

The NRS-2002 tool was validated against the SGA [53,57,58,60,61,64,65], the SGA for patients younger or older than 65 [61], ESPEN [81,82], GLIM [87–89], MNA for patients aged ≥65 years [76], and a combined index [92]. The sensitivity ranged from 38.3% to 99.4%, and the specificity ranged from 44% to 97.9%. The NRS-2002 at cutoff point 3 was validated against the PG-SGA giving a sensitivity of 77.3% and a sensitivity of 97.7% [95].

The MNA-SF was validated against the SGA [58,61,65], ESPEN [82,83,85], GLIM [89,90], NRS-2002 [94], MNA [76,77], a combined index [92], and VNC [93]. Not all studies limited the analysis to patients aged 65 years or older. The sensitivity ranged from 42% to 100%, and specificity ranged from 34% to 100%.

The SNAQ tool was compared against the SGA [60,65], ESPEN [83] and the NRS-2002 [72]. The sensitivity ranged from 71.6% to 91.3%, and specificity from 87.4% to 90.4%.

The PG-SGA was validated against the GLIM [87] and exhibited a sensitivity of 81.1% and a specificity of 71.6%.

3.5. Synthesis of results based on the meta-analysis

The meta-analysis included 21 studies involving 7237 hospitalized patients. We conducted 34 comparisons between four common malnutrition screening tools and two reference standards. The screening tools included in the analysis were the MUST, MST, MNA, and the NRS-2002. The MUST was validated against the SGA and ESPEN; the MST was validated against the SGA; the NRS-2002 was validated against the SGA; and the MNA-SF was validated against ESPEN. The MUST was the most frequently validated screening tool across the studies, with a total of 12 studies evaluating it against the SGA.

The results of the meta-analysis (pooled sensitivity, specificity, DOR, positive likelihood ratio, and negative likelihood ratio) for the accuracy of the malnutrition screening tools against the different reference standards are shown in Table 3. The MUST as a screening tool vs SGA as a reference standard had a sensitivity (95% CI (Confidence Interval)) of 0.84 (0.73–0.91), and specificity of 0.85 (0.75–0.91). Further, pooled sensitivity and specificity of MUST as a screening tool vs ESPEN as a reference standard were 0.97 (0.53–0.99) and 0.80 (0.50–0.94), respectively. The HSROCs for the MUST, MST, MNA-SF, and the NRS-2002 compared to the reference standards are illustrated in Fig. 4.

4. Discussion

In the current systematic review with meta-analysis, we identified 51 malnutrition screening tools compared against 9 reference standards. A total of four common malnutrition screening tools (MUST, MST, MNA-SF, NRS-2002) which were validated at least four times against the same reference standard (either SGA or ESPEN) were tested in the meta-analysis. The meta-analysis results showed

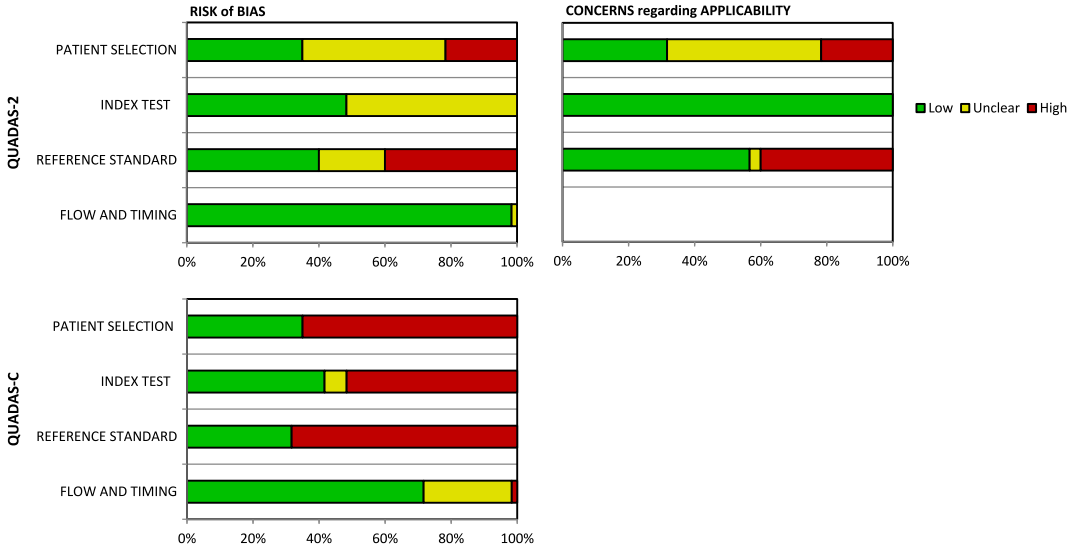


Fig. 2. Methodological quality assessment of included studies using QUADAS-2 and QUADAS-C.

that the MUST was an accurate tool in detecting malnutrition risk in hospitalized adults.

However, it is important to acknowledge that the quality of the studies included varied greatly. Differences in participant sampling methods, data collection and choice of the reference standard raise concerns regarding the reliability of tools performance. Moreover, although we limited the inclusion to studies on hospitalized patients, the differences in validity, agreement and reliability of the screening tools were very broad. While our findings do suggest that the MUST was the best performing tool, the heterogeneity in terms of quality and results across the studies highlights the need for cautious interpretation.

In this systematic review, the sensitivity and specificity of the MUST tool ranged from excellent to good, particularly in studies comparing it against ESPEN and GLIM criteria. However, its performance was notably poorer in terms of sensitivity when applied to nephrology patients and compared with the SGA [40,59]. In various systematic reviews without meta-analysis including hospitalized patients, the MUST tool showed fair-to-good performance in the general hospital population and in older adults affected by COVID-19 [20,99] or excellent performance when compared to the SGA in patients undergoing treatment for colorectal cancer [100]. In other systematic reviews including inpatients as well as outpatients, the MUST was rated as fair, exhibiting high validity and moderate agreement and reliability [101], or fair-to-good in patients with gastrointestinal cancer receiving treatment [102]. On the other hand, in a systematic review including adult patients across all care settings, the MUST showed overall low validity [103]. Nevertheless, the consensus from these reviews was that neither MUST nor any of the assessed tools had the capacity for adequate malnutrition screening in the studied populations.

The sensitivity and specificity of the MST, NRS-2002 and MNA-SF, which were the next most validated tools, were variable and inconsistent. Contrary to expectations, the MNA-SF did not seem to perform better in elderly patients as compared to any age group.

In our meta-analysis, among the four included tools (MUST, MST, MNA-SF, NRS-2002), the MUST demonstrated between good and excellent sensitivity and specificity in hospitalized adult patients from different wards when utilizing either SGA or ESPEN as reference standards. These findings are consistent with those reported in a previous meta-analysis and network meta-analysis that included adult patients scheduled for elective surgery [104]. When the MUST tool was compared against the MNA-SF, NRS-2002 and NRI, it exhibited the highest overall test accuracy with pooled mean sensitivity of 0.85 (95% CI 0.72–0.93) and specificity of 0.89 (95% CI 0.85–0.93). The variations and inconsistencies in sensitivity and specificity of many of the screening tools possibly highlight the inherent challenges in validation studies such as differences in patient populations, study methodologies, and clinical contexts. From a clinical point of view these inconsistencies perpetuate the problem around the prevalence of malnutrition in hospitals. In the cases where sensitivity values are very low most of the malnourished patients will not be detected.

The importance of selecting a rapid and simple tool that accurately identifies individuals at risk of malnutrition is crucial for facilitating timely and appropriate interventions to improve patient outcomes and reduce healthcare costs [8]. Yet, in our case, the assessment of the criterion validity of the nutritional screening tools was restricted by the paucity of studies utilizing a universally accepted gold standard for diagnosing malnutrition [15]. In fact, for the meta-analysis we identified two reference standards (SGA and ESPEN), and for the systematic review, we identified 9 (SGA, NRS-2002, MNA, MUST, ESPEN, GLIM, GIM, a combined index, and VNC). The most frequently used reference standard was the SGA, which although it has its strong points, it also presents some limitations. The SGA is possibly the most established method for assessing nutritional status, proven to be valid, comprehensive, and practical, as well as a good prognostic indicator in different clinical settings. As a screening method, however, its efficacy diminishes due to its limited emphasis on tracking shifts in dietary intake and metabolic demand. This results in lower sensitivity in identifying acute nutritional alterations, especially as a consequence of recent changes in dietary intake and infection [105]. Using the ESPEN criteria as a reference standard offers the advantage of clinical relevance and reliability, as it is based on objective measures such as anthropometric data, laboratory values, and dietary intake assessments. However, nutritional criteria, including those set by ESPEN, have demonstrated to evolve over time as new evidence emerges, and validation studies should employ the most current criteria as reference standards [18].

Recent and universally accepted diagnostic criteria, established through expert consensus, are the GLIM criteria. While the GLIM criteria demonstrate high diagnostic accuracy in distinguishing patients with malnutrition, and show promise as a potential gold

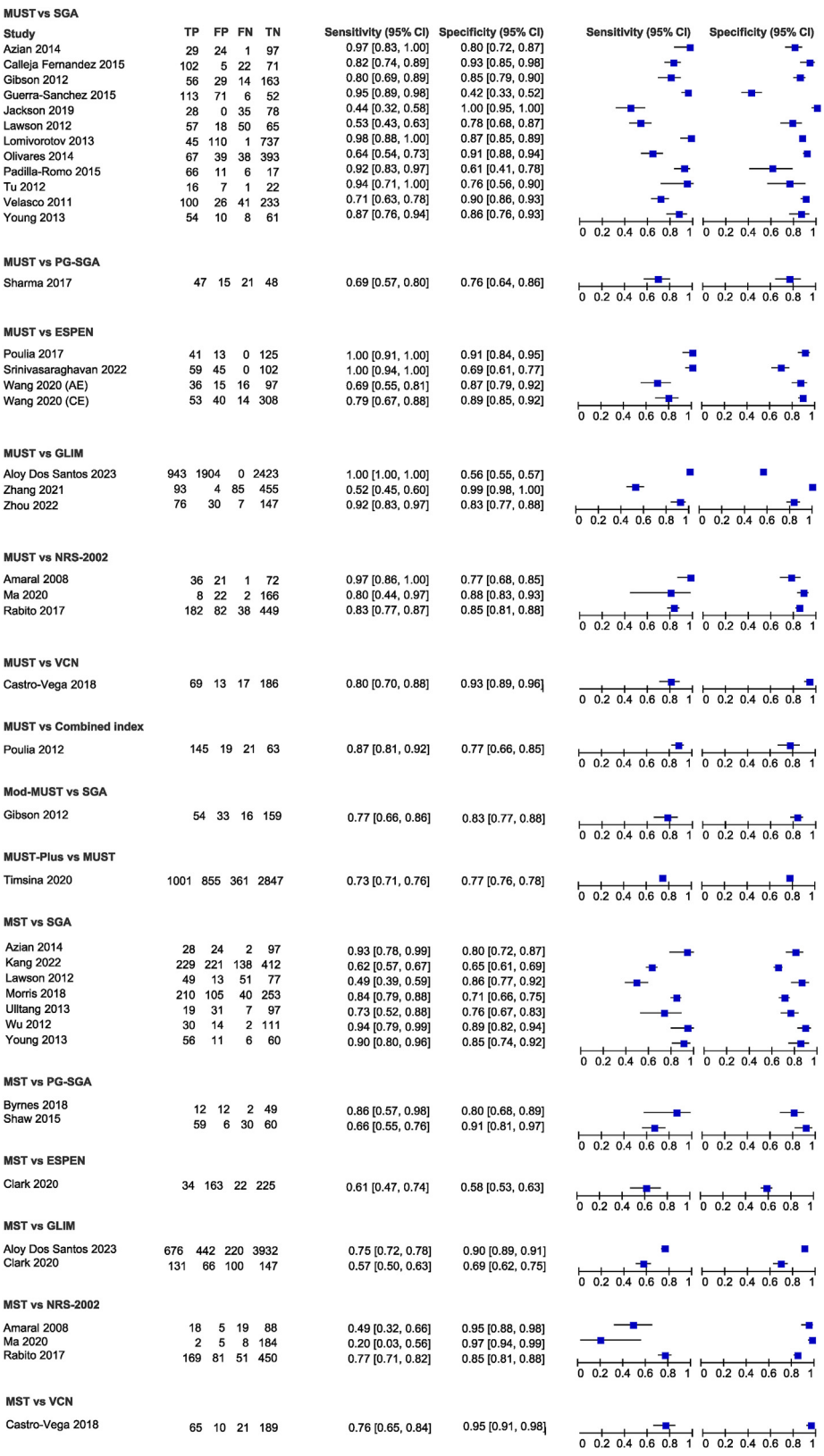
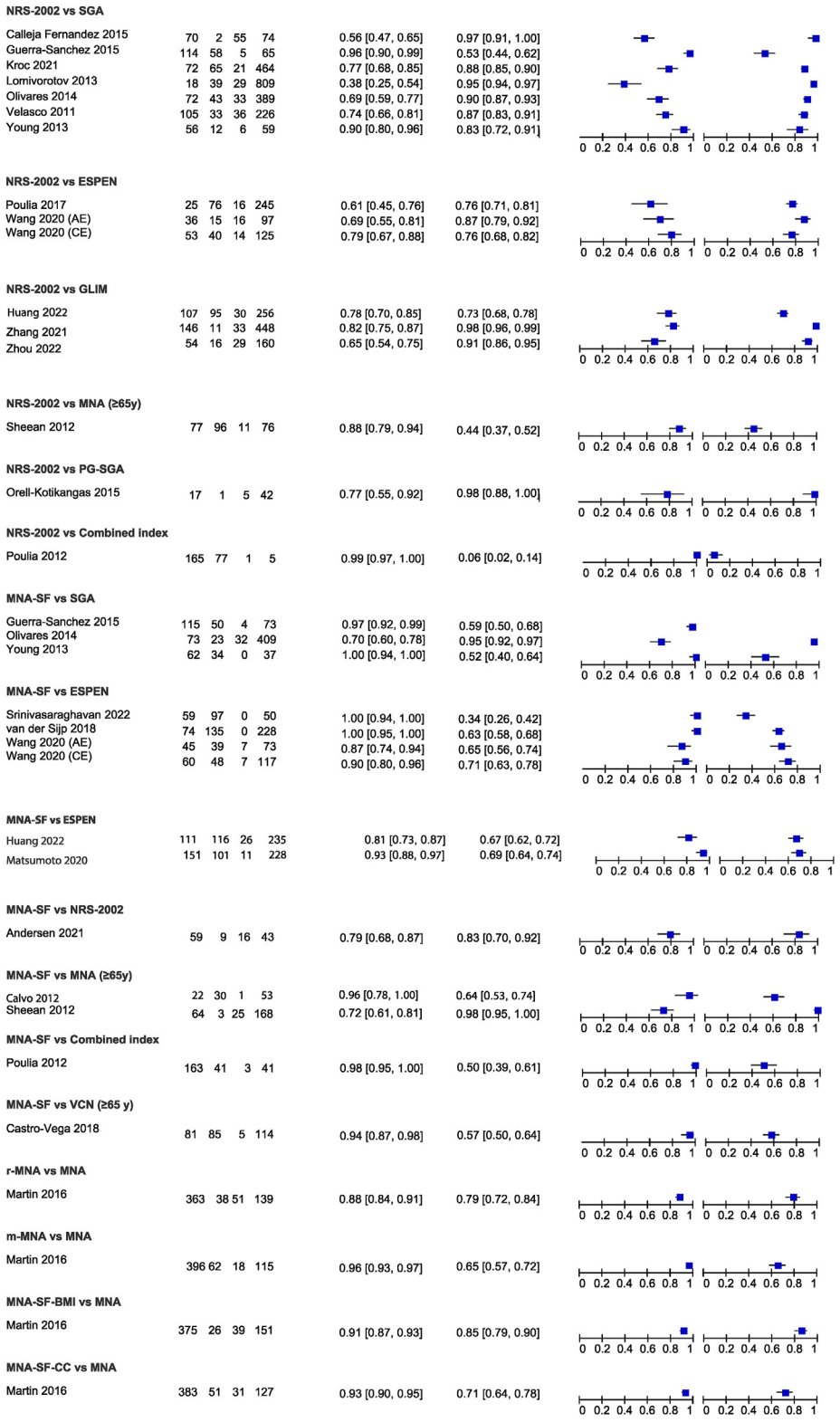


Fig. 3. Forest plots of all malnutrition screening tools validated against different gold standards.



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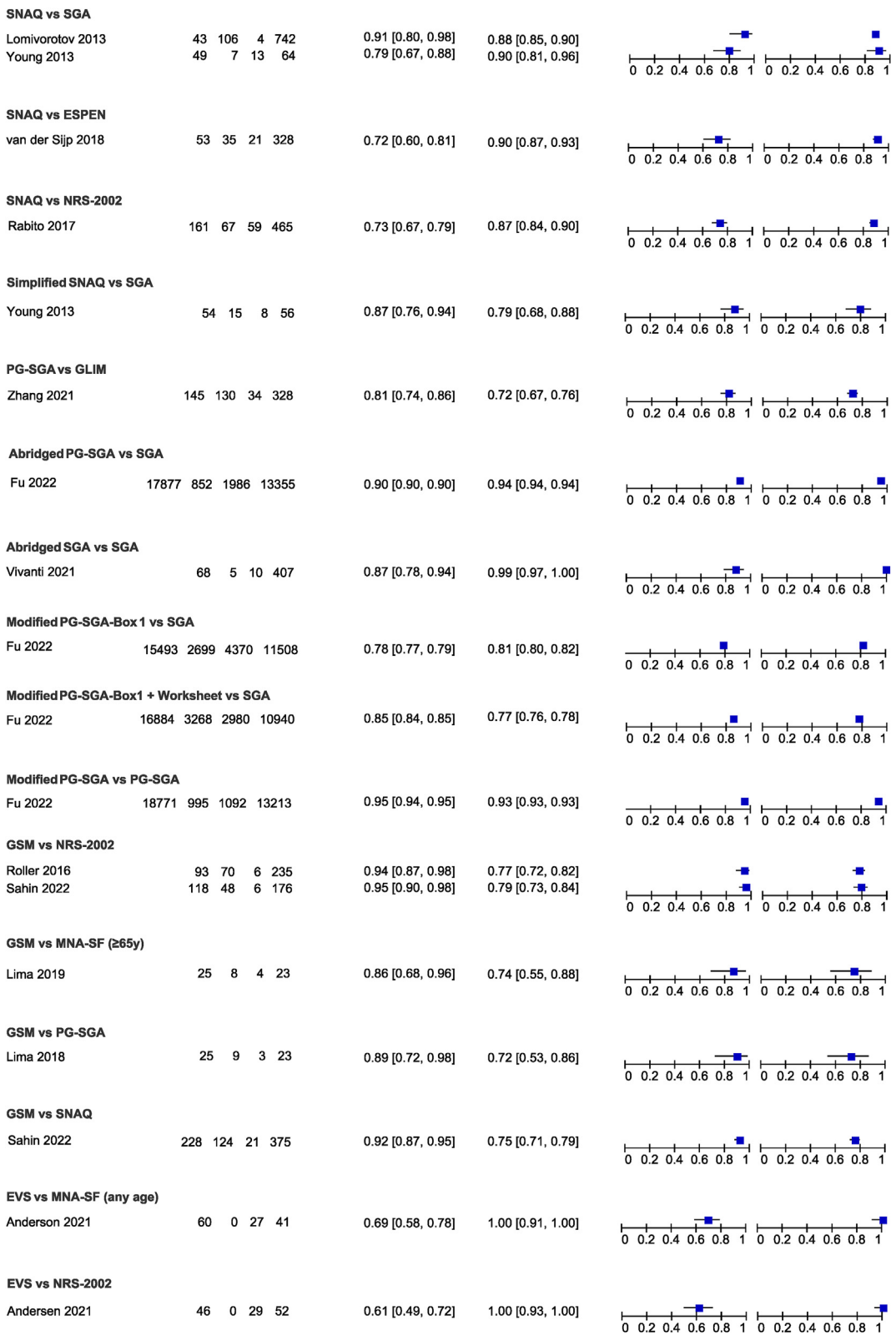

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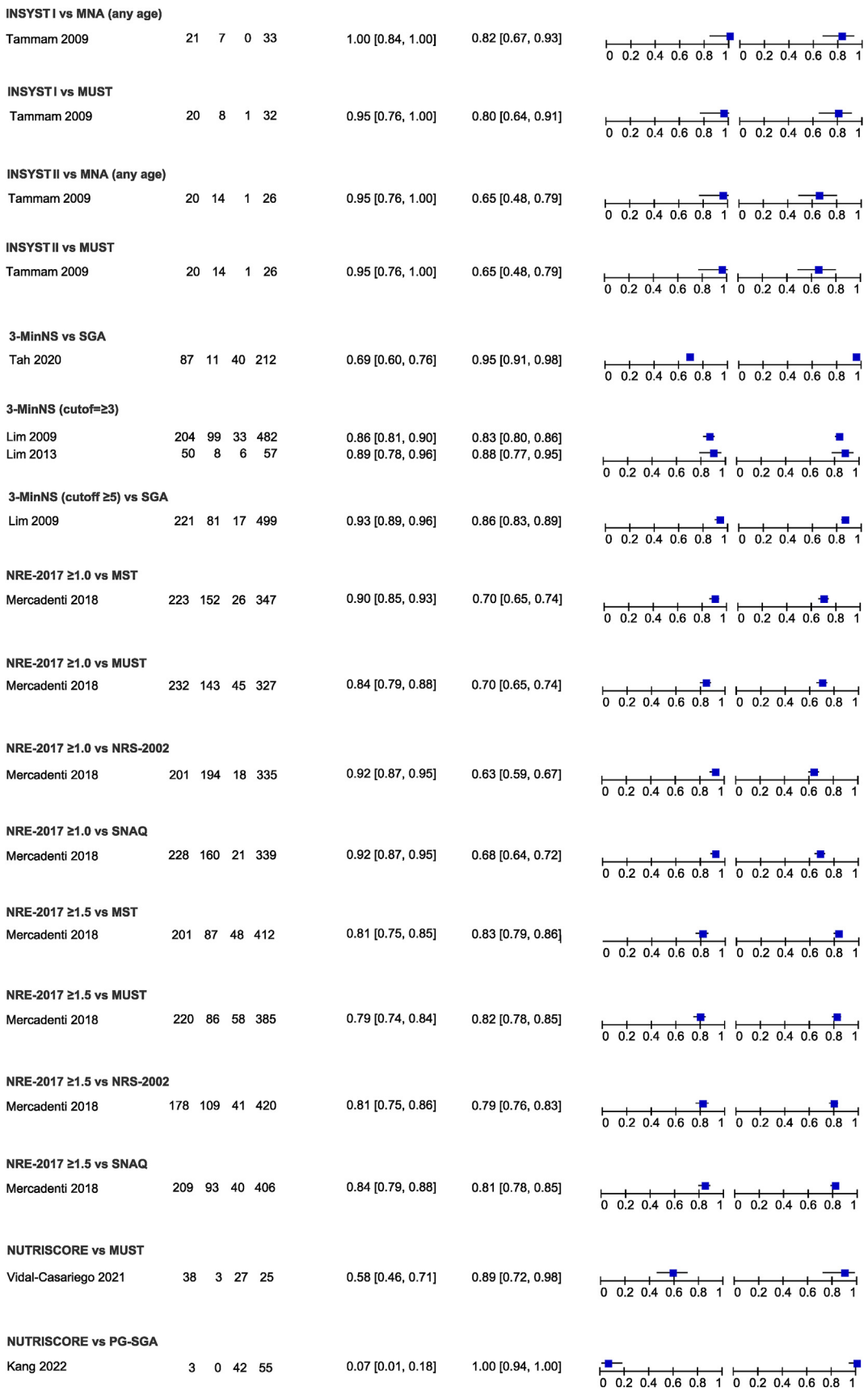

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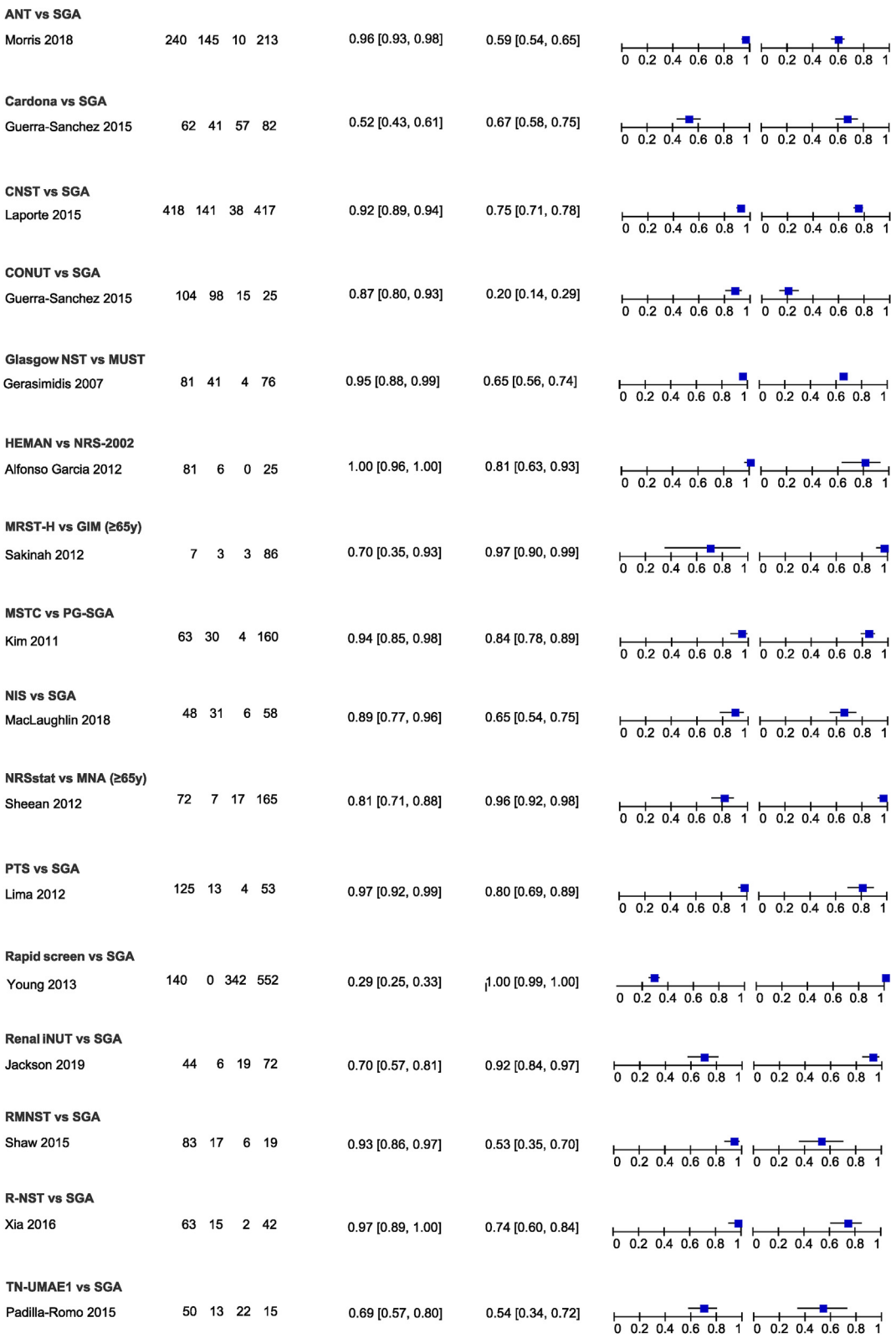

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standard for diagnosing malnutrition in clinical practice, the evidence validating nutritional screening tools against these criteria in hospitalized patients remains insufficient [106]. Possible reasons for this insufficiency include the poor quality of validation studies [107], the ambiguity surrounding the combination of phenotypic and etiological criteria in most studies [108], and the heterogeneous application of the criteria [109]. These challenges highlight the need for methodologically sound validation studies across various pathologies using all GLIM criteria, where the recommendations of the GLIM criteria validation guide are being met.

Table 3
Summary of diagnostic accuracy of nutritional screening tools for identifying malnutrition in hospitalized patients.

Screening tool	Reference standard	Summary estimate (95% CI)
MUST	SGA	Sensitivity: 0.84 (0.73–0.91) Specificity: 0.85 (0.75–0.91) DOR: 29.22 (16.27–52.48) LR+: 5.57 (3.49–8.89) LR−: 0.19 (0.11–0.32)
MST	SGA	Sensitivity: 0.81 (0.67–0.90) Specificity: 0.79 (0.72–0.74) DOR: 16.28 (6.16–42.99) LR+: 3.85 (2.66–5.59) LR−: 0.24 (0.12–0.46)
NRS 2002	SGA	Sensitivity: 0.76 (0.58–0.87) Specificity: 0.86 (0.76–0.93) DOR: 19.58 (14.29–26.82) LR+: 5.54 (3.64–8.41) LR−: 0.28 (0.17–0.47)
MUST	ESPEN	Sensitivity: 0.97 (0.53–0.99) Specificity: 0.80 (0.50–0.94) DOR: 150.55 (4.21–4690.88) LR+: 4.84 (1.64–14.29) LR−: 0.03 (0.00–0.96)
MNA-SF	ESPEN	Sensitivity: 0.99 (0.41–0.99) Specificity: 0.60 (0.45–0.73) DOR: 271.66 (1.53–48212.16) LR+: 2.46 (1.77–3.43) LR−: 0.01 (0–1.97)

Validating a nutritional screening tool across diverse patient groups with varying ages and medical conditions can be challenging as the tool's effectiveness is influenced by the population's characteristics, possibly impacting its performance [20]. Some authors suggest that screening tools should be validated within a representative sample that reflects the intended use of the tool, and thus limiting the validation to specific age groups and/or medical condition relevant to the targeted population [110]. Conversely, some others argue that utilizing different tools according to specific contexts is highly impractical, and that a single tool should be used regardless of age, medical history, and setting [101]. Importantly, despite the efforts employed to create new tools or validating existing ones, malnutrition remains under-detected and under-treated, emphasizing the ongoing need for effective screening strategies.

The MUST screening tool, along with the NRS-2002 and the MNA-SF incorporate BMI as one of the parameters to determine the risk of malnutrition [81]. In contrast, the MST, which in the present meta-analysis presented a good sensitivity and a fair specificity, simply inquiries about weight loss and the extent of the loss, and, in case this information is not available, its score can still be calculated [25]. In practical terms, the applicability of tools that require information about body weight, whether it is measured or self-reported, can face limitations. Patients might not always be aware of their usual or actual body weight, or the weight cannot be measured. Moreover, the presence of edema or ascites can influence the BMI, and, in case of obesity or sarcopenia, a low muscle mass can go undetected, with patients being incorrectly classified as well-nourished [17,111]. Further work is needed to refine the applicability and reliability of these tools, especially in cases where body weight data (reported or measured) may be challenging to obtain or may not accurately reflect the patient's nutritional status.

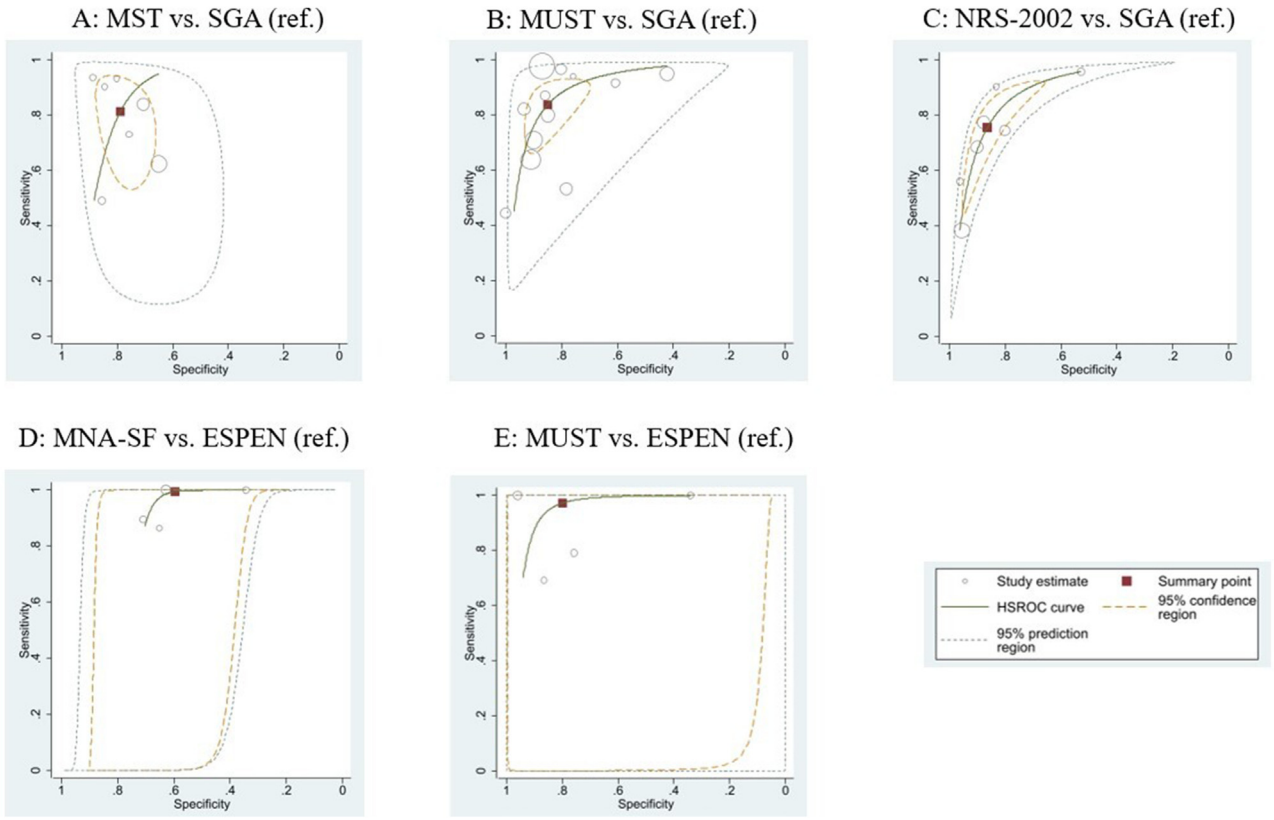

Fig. 4. Pooled sensitivity, specificity and HSROC curve for screening for the risk of malnutrition in hospitalized patients. A: MST vs SGA (ref.): number of studies = 7, number participants = 2392; B: MUST vs SGA (ref.): number of studies = 12, number participants = 3833; C: NRS-2002 vs SGA (ref.): number of studies = 7, number participants = 3026; D: MNA-SF vs ESPEN (ref.): number of studies = 4, number participants = 1039; E: MUST vs ESPEN (ref.): number of studies = 4, number participants = 964. ref. = reference standard.

4.1. Limitations

The main limitation of this systematic review and meta-analysis is that the included studies employed a wide array of nutritional assessment tools as reference standards. Moreover, they exhibited a significant degree of heterogeneity in terms of population characteristics, medical conditions, age and wards in which studies were conducted. These disparities presented significant challenges in directly comparing the study results. Additionally, the quality of the studies varied, with a notable proportion failing to specify patient sampling methods and relying on convenience sampling. This practice could introduce bias, potentially compromising the validity of the studies [112]. Moreover, there was often ambiguity regarding the blinding procedures during the conduct and interpretation of both the index test and reference standard. This lack of clarity may introduce bias, potentially overestimating the diagnostic accuracy of the index test. Finally, almost half of the studies used nutrition screening tools as reference standards, impacting the reliability of sensitivity and specificity measurements for the index tests. Overall, these biases may lead to overestimation or underestimation of the diagnostic accuracy of the index tests, highlighting the need for cautious interpretation.

Finally, although we cannot disregard possible publication bias, it is not clear whether this phenomenon occurs among diagnostic accuracy studies [113]; moreover, tests usually used to evaluate publication bias should not be used in this case [114]. Nevertheless, by running the search in different databases, which are appropriate to the review question, and by manually identifying potentially eligible studies, we have contributed to limiting potential selective publication bias [113].

5. Conclusions

The MUST emerges as a potentially accurate tool for malnutrition screening in adult hospitalized patients, however, its practical applicability is limited by the requirement of the BMI measurement. The MST tool, while possibly less accurate than the MUST, offers the advantage of a rapid assessment, thus facilitating its use in routine clinical practice.

The present study also emphasizes the importance of establishing a universally accepted gold standard for diagnosing malnutrition, ensuring the reliable assessment of the criterion validity of nutritional screening tools. The validation process of the GLIM criteria is a significant step toward achieving this goal.

Looking ahead, new studies should validate the most used screening tools within a single patient population, using GLIM criteria as a valid gold standard; possibly specifying which combination of the GLIM phenotypic and etiological criteria led to the diagnosis of malnutrition. Using the most appropriate screening tool is crucial for the early detection of malnutrition, as it serves as the first step of the GLIM criteria. Relying on screening tools that poorly agree with the GLIM criteria may lead to either overdiagnosis or misdiagnosis of malnutrition. Solving such criticalities can lead to meaningful advances in malnutrition screening and ultimately improve patient care and outcomes as well as reduce healthcare costs.

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Author contributions

Regina Cortés-Aguilar: Conceptualization, Methodology, Investigation, Data Curation, Writing – Original Draft, Supervision. **Narges Malih:** Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Visualization. **Manuela Abbate:** Methodology, Investigation, Data Curation, Writing – Original Draft, Visualization. **Sergio Fresneda:** Methodology, Data Curation, Writing – Review & Editing. **Aina Yañez:** Conceptualization, Methodology, Writing – Review & Editing, Supervision. **Miquel Bennasar-Veny:** Conceptualization, Methodology, Writing – Review & Editing, Supervision.

Conflict of interest

All authors declare that they have no conflicts of interest.

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