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Meta-analyses

Nutrition screening tools: Does one size fit all? A systematic review of screening tools for the hospital setting☆

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SUMMARY

Background & aims: Numerous nutrition screening tools for the hospital setting have been developed. The aim of this systematic review is to study construct or criterion validity and predictive validity of nutrition screening tools for the general hospital setting.
Methods: A systematic review of English, French, German, Spanish, Portuguese and Dutch articles identified via MEDLINE, Cinahl and EMBASE (from inception to the 2nd of February 2012). Additional studies were identified by checking reference lists of identified manuscripts. Search terms included key words for malnutrition, screening or assessment instruments, and terms for hospital setting and adults. Data were extracted independently by 2 authors. Only studies expressing the (construct, criterion or predictive) validity of a tool were included.
Results: 83 studies (32 screening tools) were identified: 42 studies on construct or criterion validity versus a reference method and 51 studies on predictive validity on outcome (i.e. length of stay, mortality or complications). None of the tools performed consistently well to establish the patients' nutritional status. For the elderly, MNA performed fair to good, for the adults MUST performed fair to good. SGA, NRS-2002 and MUST performed well in predicting outcome in approximately half of the studies reviewed in adults, but not in older patients.
Conclusions: Not one single screening or assessment tool is capable of adequate nutrition screening as well as predicting poor nutrition related outcome. Development of new tools seems redundant and will most probably not lead to new insights. New studies comparing different tools within one patient population are required.

1. Introduction

Over the last decades numerous nutrition screening tools for use in the hospital setting have been developed, with the purpose to facilitate easy screening or assessment of a patient's nutritional status or to predict poor clinical outcome related to malnutrition. Some of the tools have been endorsed by international nutrition societies; e.g. the European Society for Clinical Nutrition and Metabolism advises the use of MUST,[1] NRS-2002[2] and the MNA(-SF)[3,4] for the elderly. Other tools are widely used in certain countries but less frequently applied worldwide (e.g. MST for Australia and New Zealand[5] and SNAQ for the Netherlands[6]). Some tools claim to be valid for all populations, ages and settings, whereas others have been developed for screening a specific target population. In addition, there probably are many unpublished, not validated local tools that we are unaware of.

There is no international consensus on a single 'best tool', if there is so such thing. The use of different tools in different studies hinders the comparison between studies and does not allow for the

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List of abbreviations

Screening toolsOutcome measures

LOS	length of stay
VLLOS	very long length of stay

Expression of validity

AUC	area under curve
OR	Odds Ratio
HR	Hazard Ratio
RR	relative risk
se	sensitivity
sp	specificity
k	kappa
CC	correlation coefficient
PPV	positive predictive value
NPV	negative predictive value
PLR	positive likelihood ratio
NLR	negative likelihood ratio
NS	not significant

Rating

g	good
f	fair
g/f	good/fair
p	poor
?	unable to be rated

drawing of conclusions on defining the 'best tool' for a certain patient population, age group or setting.

The purpose of this study is to systematically review the publications on screening and assessment tools and to study the validity of these tools for the general (adult and older) hospital population. This review will give an overview of the available instruments, and of the ability of tools to assess the patient's nutritional status or to predict the clinical outcome. Finally, the results of our comparisons of tools will be presented.

1.1. Background of tools

Most of the available nutrition screening tools have been developed to obtain an indication of a patient's nutritional status. Well-known examples include MST,[5] SNAQ,[6] NRI,[7] MUST,[1] SGA[8] and MNA.[3] Within this range, some of the tools are 'quick and easy'; not requiring any calculations, blood samples, anthropometric measurements, or clinical examinations (e.g. MST,[5] SNAQ[6]). A patient indicated to be at high nutritional risk by one of these tools, requires further nutritional assessment by a professional to get a more complete indication of the severity and the nature of the nutritional depletion. Such tools are typically called 'screening tools'. Other tools are more complex, requiring – for example – calculation of a BMI and/or an indication of disease severity (e.g. MUST[1]), clinical assessment (e.g. MNA[3]), or an extensive questionnaire addressing several aspects of nutritional intake (e.g. NRI[7]). These tools are more time-consuming, but on the other hand they give a better estimation of (the background of) a patient's nutritional status. Some of these tools are still regarded as screening tools (e.g. MUST,[1] NRI[7]), whereas others are qualified as assessment tools because they combine data on nutritional status with clinical observations (e.g. medical examination, evaluation of cognitive function), disease status and/or laboratory values (e.g. SGA,[8] MNA[3]).

The terms "screening" and "assessment" are often used interchangeably in both literature and practice. While in this manuscript both terms will also be used, the original purpose (screening or assessment) will be explained where appropriate.

In the absence of a gold standard for malnutrition, most of the screening and assessment tools have been developed with assessment by a professional or a full nutritional assessment as the reference method. Also, the lack of a 'gold' reference method has resulted in the use of many of the existing screening and assessment tools as the reference method, where the method considered to be the reference method is always superior to the tool to be validated. Because of the natural superiority of the reference tool this becomes confusing when, for example, in one study the NRS-2002 is validated with the SGA as a reference,[9] while in another the SGA is validated against the NRS-2002.[10]

The NRS-2002[2] is generally used as a screening tool, while, in fact, it was designed as a tool to identify patients at nutritional risk. NRS-2002 was developed differently from other tools. It was developed from a literature overview including 275 studies reporting on the effectiveness of nutritional intervention and its purpose was to identify malnourished hospitalized patients likely to benefit from nutritional support.

Few tools have been designed specifically with the purpose to predict clinical outcome (morbidity, mortality, (postoperative) complications, or length of hospital stay), for example GNRI.[11] MUST[1] and SGA[8] have been developed both to identify patients at nutritional risk and to predict outcome.

Next to the different purpose of tools, some tools were originally developed for certain subgroups of patients or for certain settings. The MNA[3] and GNRI,[11] for example, have been developed specifically for the elderly. However, in practice, studies have applied all tools for all purposes; tools designed to assess nutritional status are used to predict outcome and vice versa, and tools for the elderly are also applied to the younger hospitalized patients and the other way around. MNA,[3] developed within a group of frail and healthy elderly is most frequently used for hospitalized or nursing home patients. Thus there is a variety of studies at our disposal, applying all kinds of tools in all kinds of populations and all kinds of settings, with different results. This requires a structured approach to rate the validity of the different tools for the different purposes, which we attempt to give in this systematic review.

This systematic review will answer the following research questions:

1. How good is the performance of a tool in assessing patients' nutritional status?
2. How well can a tool predict clinical outcome?
3. Are one or more tools superior to other tools when applied in the same population?

To assess which tool is preferred, the latter research question is the most important one.

The research questions will be answered for both the adult and the elderly hospitalized population.

1.1.1. Criterion and construct validity, reference method

Studying the validity of a tool is usually done versus a gold standard. In the absence of a perfect gold standard for malnutrition, studies use different reference methods to validate their tools. Roughly the following main reference methods were identified:

- objective assessment by a professional
- nutritional assessment and anthropometry
- another screening or assessment tool
- other reference methods

For this review we decided to consider the following methods 'valid' reference methods:

- objective assessment by a professional
- nutritional assessment and anthropometry
- the assessment tools MNA[3] and SGA[8]

For these comparisons we use the term criterion validity.

The following methods were therefore considered to be less valid reference methods:

- any of the screening tools (e.g. MUST,[1] NRS-2002,[2] PG-SGA,[12] because screening tools require a further assessment by a professional), and
- laboratory values like pre-albumin and albumin (as these parameters reflect acute disease more than nutritional status)

For these comparisons we use the term construct validity. Still, many studies have used these less valid methods as a reference. Since an ideal gold standard is missing, and (research) groups may differ in their opinion on the most optimal reference method, we have chosen to include all studies, allowing the readers to decide for themselves how valid they rate a tool.

When validating a new tool versus a reference method, one should keep in mind that the new tool can never be better than the reference method. Thus, there should be convincing reasons to develop a new tool, such as: the old (reference) tool being too invasive, or too time consuming.

1.1.2. Predictive validity

The majority of studies assesses the ability of a tool to predict clinical outcome. Studies report on length of stay, mortality, or (postoperative) complications. Some studies focus on only one of these clinical outcomes, whereas others address more (or even all) outcomes, sometimes with conflicting results. It is important to note that these outcomes are influenced by more facts than nutrition alone. Therefore studies in which outcome was adjusted for other factors, such as age and disease severity, are regarded to be of higher quality than those presenting unadjusted data.

2. Methods

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement was followed as a guide for reporting.[13]

2.1. Literature review

2.1.1. Search strategy

To identify all relevant publications we performed systematic searches in the bibliographic databases PubMed, EMBASE and CINAHL (via EBSCO) from inception to February 2, 2012. Search terms included controlled terms from MeSH in PubMed, EMtree in EMBASE.com and CINAHL Headings in CINAHL as well as free text terms. Search terms expressing 'malnutrition' were used in combination with search terms comprising 'screening or assessment instruments' and terms for 'hospital setting' and 'adults'. The references of the identified articles were searched for relevant publications.

Studies were included if they had been published in the English, French, German, Spanish, Portuguese or Dutch language. The complete search strategy can be found in Appendix 1.

2.1.2. Selection process

All potentially relevant titles and abstracts were blinded for author, journal and year of publication and then screened for eligibility by 2 reviewers (PRG and MAEvB) independently. Differences in judgement were resolved through a consensus procedure.

2.1.3. Inclusion and exclusion criteria

The full text of the selected articles – no longer blinded to authors and journals – was obtained for further review by two reviewers independently (PRG and MAEvB) to judge eligibility. In case of doubt a decision was made by a third reviewer (HCWdV). Included were studies that had been performed in the general hospital population (adults and elderly, including outpatients), which (1) described the criterion or construct validity of a screening or assessment tool versus an acceptable reference method or (2) described the predictive validity of a tool on one or more outcomes (length of stay (LOS), mortality, complications).

Papers were excluded if they described:

- Tools not expressing clinimetric assessment (i.e. validity), but only defining a percentage of malnutrition (no validation study).
- Tools that were developed but never validated in another population.
- Studies including less than 25 patients.
- Modified versions of a tool, e.g. the Taiwanese modification of a tool.
- Tools that are only applicable to specific risk groups, e.g. tools specifically developed for renal/haemodialysis patients.
- Tools exclusively consisting of laboratory values (as a first step), e.g. Prognostic Nutritional Index, CONUT, INFONUT, Maastricht Index.
- Papers using the same set of questions in the tool and in the reference method (incorporation bias).
- Certain publication types: editorials, letters, legal cases, interviews etc.

2.2. Summary measures

Manuscripts were assessed for the two main research questions:

- the validity of a nutrition screening tool versus a reference method (criterion and construct validity)
- the ability of a tool to predict clinical outcome (predictive validity)

Different methods were used by different studies to express the validity of the screening tools:

- Sensitivity (se) and specificity (sp) and Area Under the Curve (AUC) (criterion validity, and sometimes construct validity)
- Correlation Coefficients (CC) and kappa values (construct validity, and sometimes criterion validity)
- Odds Ratios (ORs) and Hazard Ratios (HRs) (predictive validity)
- *p*-Values (predictive validity)

For clarity reasons, we decided to rate the results of each study as good, moderate/fair or poor validity. This forced us to use cut-off points (Table 1). For correlation coefficients we used the often used cut-off points, proposed by Guilford.[14] For kappa values we used the classification system proposed by Fleiss.[15]

For sensitivity and specificity, no general cut-off points are mentioned in the literature as it highly depends on the clinical consequences. However, for the sake of transparency and clarity we

Table 1
Cut-off points applied to rate the validity of the screening tools.

	Good (g)	Good/fair (g/f)	Fair (f)	Poor (p)	Unable to rate (?)
Sensitivity/Specificity	se AND sp >80%		se OR sp <80%, but both >50%	se OR sp <50%	
AUC	>0.8		0.6–0.8	<0.6	
Correlation Coefficient[13]	>0.75		0.40–0.75	<0.40	
Kappa[14]	>0.6		0.4–0.6	<0.4	
Odds Ratio/Hazard Ratio	>3		2–3	<2	
p-value		$p < 0.05$ and $n < 200$[a]		>0.05	$p < 0.05$ and $n > 200$[b]

[a] No indication of effect size.
[b] True effect or sample size effect?

decided to also rate the values of sensitivity and specificity, and area under the curve.

The cut-off points for OR and HR were also arbitrarily chosen, based on the fact that a predictive ability with an OR/HR smaller than 2.0 will not have much practical value. An OR between 2 and 3 we rated as a moderate/fair effect and >3 as a large effect.

All proposed cut-off points are necessarily arbitrary. However, we have presented the exact values in the tables, providing readers with the opportunity to set their own cut-off points.

If studies provided sensitivity and specificity for a tool in two categories (no nutritional risk versus medium/high risk and no/medium risk vs. high risk), the mean of the reported sensitivities and specificities was used to rate the tool.

All but *p*-values of these measures give indications of the observed effect size. For example, a HR for mortality of 4 indicates a 4 times higher mortality risk. However, a *p*-value <0.05 indicates significance, but gives no indication of the effect size, because *p*-values are also influenced by the sample size. Therefore, we decided to regard a *p*-value <0.05 as a good or fair validity (no distinction possible between good and fair based on *p* value only) if the sample size was smaller than 200 patients, and not to give a judgement on validity if the sample size exceeded 200 patients (not having an indication of the magnitude of the effect). Also papers with unquantifiable conclusions like 'patients with an increased risk of malnutrition suffered significantly more complications/had longer LOS than patients not at risk of malnutrition' were uninformative about the magnitude of the effect.

3. Results

3.1. Search results

The literature search generated a total of 9049 references: 3667 in PubMed, 3606 in EMBASE.com and 1776 in Cinahl. After removing duplicates of references that were selected from more than one database, 7357 papers remained. The flow chart of the search and selection process is presented in Fig. 1.

Based on title and abstract selection, 194 publications on hospital setting were selected for full text review. After independent judgement by two authors another 126 were excluded. In all phases of the papers selections, disagreements between the 2 reviewers were resolved by consensus. Fifteen additional papers were identified by handsearching the reference lists of the included papers.

The final search yielded 83 studies, including 32 different nutrition screening tools.

3.2. Description of tools

This section describes the development studies of all 32 tools that were identified. Most, but not all tools contain questions on weight changes, appetite, underlying disease or GI symptoms. However, there is a wide variety of indicators included in the different tools. These indicators are depicted in Appendix 2.

Twenty-eight tools were originally developed with the purpose to screen or assess patients' nutritional status (part 3.2.1), and 4 tools with the purpose to predict clinical outcome (part 3.2.2). Four tools were described as designed for both purposes.

Appendices 3 and 4 show the identified tools used to express patients' nutritional status. For the development studies (printed in bold), it is described in which population the tool was developed, against which reference method, and how well the tool performed compared to the reference method (expressed by sensitivities, specificities, kappa values). The final column gives our rating of the tool. Following the development study, most tools were re-validated in the same, or in different populations or settings, applying the same, or different reference methods. These re-validation studies are listed under the original validation study (not printed in bold). As many tools have been developed specifically for the elderly hospitalized population, a distinction has been made between tools for the elderly (Appendix 3) and tools for the adult hospitalized population (Appendix 4). We were unable to identify the original development study for some tools; these are listed at the end of the table.

Appendices 5 and 6 are of the same structure and included tools that were developed, respectively applied, to express the predictive validity of screening tools for the outcome measures LOS, mortality and complications. Ratings are given for all 3 outcome measures.

The tools are presented in chronological order, with the oldest tool presented first.

3.2.1. Nutrition screening tools developed to screen or assess patients' nutritional status

3.2.1.1. Tools specifically developed for the elderly hospital population (Appendix 3).

NRI (Nutritional Risk Index)

The NRI is the oldest tool identified that met our inclusion criteria. In its development and validation studies, done among 3 groups of community dwelling elderly in 1990, the NRI was significantly correlated to BMI and different laboratory values.[7] According to present standards, the data presentation of the development study would be regarded as suboptimal, because (1) it described only significance ($p < 0.05$) which is uninformative on the strength of an association, and (2) because the reference methods applied are not considered acceptable standards according to our criteria.

MNA (Mini Nutritional Assessment)

The MNA was developed in 1994 with the purpose of identifying frail and healthy elderly at risk of malnutrition. In its development and validation study, the reference method used was assessment by a professional.[3]

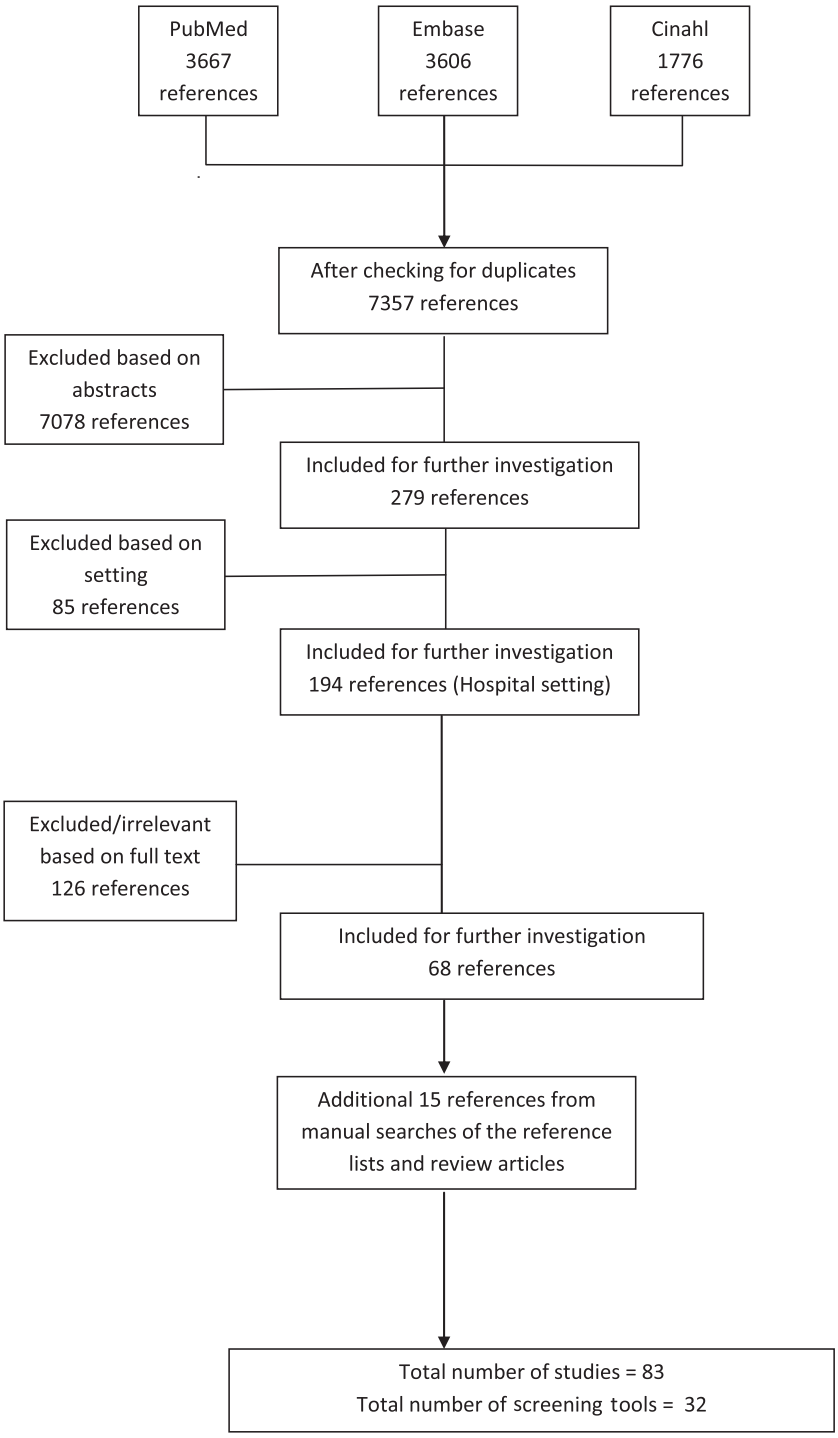

Fig. 1. Flow chart of the search and selection procedure of studies.

MNA-SF (short form) and modified MNA-SF

The short-form of the MNA[4] was developed and validated against the full MNA.[3] It showed excellent validity against the full version, which is not surprising as the first seven questions are identical (which is, in fact, a form of incorporation bias).[4] The modified version of the MNA-SF (with calf circumference substituting BMI) was also validated against the full version using the data of 27 earlier studies.[16] Again, excellent validity of the short form was asserted, which shows us that the MNA-SF (both in the original short form[4] and the modified short form[16]) can be used as a valid screening tool if full assessment with MNA[3] is not possible, for example due to time constraints.

NUFFE (Nutritional Form For The Elderly)

The NUFFE was developed with BMI, weight and albumin as the reference for use in the elderly population, showing poor correlations to all 3.[17]

Simple screening tool I and II

The Simple screening tools number I and number II were both developed in acute care elderly with assessment by a professional as the reference method. In their development studies, the sensitivity of these tools to the reference method was less than 50% (poor validity).[18]

MEONF-II (Minimal Eating Observation and Nutrition form – version II)

MEONF-II is a recently developed tool and was specifically developed to be used in the older population. It was developed and validated with MNA[3] as the reference method, showing fair diagnostic accuracy compared to the reference method.[19]

Other

Three tools, of which the original development studies were unavailable, were used to assess the nutritional status of hospitalized elderly. These were *Rapid Screen* (for use in hospitalized elderly),[20] *Nutrition Screening* Initiative,[21] and *Chandra Nutrition Screen*,[21] the latter two originally developed to identify community dwelling at nutritional risk (see Appendix 3).

3.2.1.2. Tools developed for the general (adult) hospital population (Appendix 4).

SGA (Subjective Global Assessment)

The SGA is a tool regarded as an assessment tool and is completely based on clinical evaluations. It was developed in 1982 within a surgical population. Validity was demonstrated by correlation of the clinical classification with objective measurement of nutritional status and with three measures of hospital morbidity: incidence of infections, use of antibiotics, and length of stay.[8] The tool is mostly used to predict clinical outcome. In haemodialysis patients it is widely applied to assess patients' nutritional status; however, papers regarding haemodialysis were excluded from this review.

Nutrition Subjective Screening Tool, Nutrition Screening Equation (NSEq)

The Nutrition Subjective Screening Tool was developed in 100 consecutively admitted patients against a full nutritional assessment and then cross validated in another 151 patients showing fair validity.[22] An attempt to improve the Nutrition Subjective Screening Tool by adding pre-albumin did not improve the accuracy of the tool. In the same study populations ($n = 100$ and $n = 151$) a Nutrition Screening Equation (NSEq, based on albumin, total lymphocyte count and percentage weight loss) was developed and cross validated. In the cross validation study the NSEq showed good performance.[22] The tools were never again described in literature.

NRS (Nutrition Risk Screening)

The NRS was developed in 1995 in a population of newly admitted adult medical and surgical patients with assessment by a professional and the geriatric tool NRI[7] as the reference methods. It correlated well to the professional's clinical impression and fair to NRI. Overall, the data presentation of the development study was poor.[23]

Nutrition Risk Classification

This tool was developed in 1997, to be used by nurses, and validated against pre-albumin (which we regarded a less valid reference method, see Method section).[24] Its purpose is to identify adult hospitalized patients at a poor nutritional status.

MST (Malnutrition Screening Tool)

The MST is a 'quick and easy' screening tool, widely used in Australia and New Zealand. It was developed with the SGA[8] as the reference in adult hospitalized patients, against which it showed good validity.[5]

Screening sheet

The Screening Sheet (predominantly used in Iceland) was initially developed in newly admitted patients with nutritional assessment as the reference method. In its development study the accuracy to the reference was found to be fair.[25]

MUST (Malnutrition Universal Screening Tool)

The development paper of the MUST describes the validity of MUST against a variety of reference methods, among which: NRS,[23] SGA,[8] MNA[3] and assessment by a dietitian. Included were medical, surgical, orthopaedic and elderly patients and the validity of the MUST was expressed by kappas. Except for the correlation to the MNA[3] (for MUST score 2: kappa to MNA in medical patients 0.551 ($n = 86$) and in surgical patients 0.605 ($n = 85$)) the kappa values indicated good validity to all other reference methods used.[1]

MAG screening tool (Malnutrition Advisory Group Screening Tool)

The MAG Screening Tool, developed by the British Association of Parenteral and Enteral Nutrition (BAPEN), had already been tested for reliability, internal consistency and easiness of use, but never been validated for construct validity. This validity study describes its construct validity against SGA[8] in a group of oncology patients, in which it was found to be fairly valid.[26]

NRS-2002 (Nutrition Risk Screening Tool 2002)

The NRS-2002 was developed differently from all other tools. It was based on the analysis of 128 trials with the specific aim to identify patients that are likely to benefit from nutritional intervention. Despite its original purpose, it is usually applied to assess patients' nutritional status.[2]

British NST (Nutrition Screening Tool)

The British NST was developed in one general medical population, and cross-validated in another, with a full assessment by a dietitian as the reference method.[27]

SNAQ (Short Nutritional Assessment Questionnaire)

The SNAQ was developed as a "quick and easy" tool with the purpose to identify adult hospitalized (surgical and medical) patients at nutritional risk (reference method: nutritional assessment/anthropometry). The tool is the tool of choice in the Netherlands and has been re-evaluated in inpatient and outpatient setting.[6]

Chinese Nutrition Risk

The development and validation study describing the Chinese Nutrition Risk showed poor validity to a physician's assessment in the cross-validation sample.[28] The tool was not further applied in other studies.

Glasgow Nutrition Screening Tool

This local Scottish tool[29] had been used for a few years already before it was (cross-)validated against MUST.[1] No other manuscripts applying this tool were identified.

Of a few tools intended to screen the nutritional status of adult hospitalized patients, the original development study could not be identified (see Appendix 4): *PG-SGA (Patient Generated-SGA)*,[12] *Nutrition Screen*,[30] *INSYST I and INSYST II* (imperial nutritional screening system).[31]

3.2.2. Nutrition screening tools developed to predict clinical outcome

Only 4 tools were primarily designed to be prognostic: 1 for the geriatric hospitalized population and a group of 3 coherent tools for

the general hospital population.

GNRI (Geriatric Nutrition Risk Index)

The GNRI has been built on the longer existing Nutrition Risk Index (NRI),[7] which had not been validated for the elderly population. The GNRI consists of albumin, weight and ideal weight. It was designed and cross-validated with the aim to predict morbidity and mortality, which it did well in the design study (OR > 4).

MRCs (Screening for Malnutrition-Related Complications), ANS (Automated Nutrition Score) and ANS-B (Automated Nutrition Score-Blood Measurements)

The tool MRCs in hospitalized patients was developed to identify those requiring nutritional intervention and improve resource allocation. This study compared the MRCs with a simpler ANS (the number of abnormal results from six variables), ANS-B (the number of abnormal results from three blood measurements), and SGA[8] for prediction of complications. Out of the 4 studied tools, the MRCs showed the highest predictability of complications (largest area under curve).[32]

All tools had ORs higher than 4 for predicting complications; however neither NRCs, ANS nor ANS-B had satisfactory sensitivity and specificity to predict complications. The tools were never described again in other studies.[32]

Four tools (*SGA*,[8] *MST*,[5] *MUST*[1] and *NRS-2002*[2]) were designed to screen or assess patients' nutritional status, as well as to predict clinical outcome. These tools are incorporated in both Appendices 3 and 4, and in Appendices 5 and 6, with the corresponding diagnostic accuracies for establishing nutrition risk in Appendices 3 and 4, and predicting clinical outcome in Appendices 5 and 6 (distinguishing between the elderly (Appendices 3 and 5) and the adult (Appendices 4 and 6) populations).

3.3. Validity of the tools

After their development, most of the tools have been applied in later studies. This section of the paper describes their performance in later studies with regard to construct validity (Appendices 3 and 4) and predictive validity (Appendices 5 and 6). Irrespective of their original purpose, most tools have been used for both purposes, i.e. to assess nutritional status and to predict clinical outcome, so their validity is described in both subsections.

The description below is again subdivided into tools for the elderly population (Appendices 3 and 5), and tools for the adult hospitalized population (Appendices 4 and 6).

3.3.1. Criterion and construct validity

The primary outcome measure of this part of the review is the performance of a tool to screen or assess patients' nutritional status versus a reference method, most often expressed by sensitivities, specificities, kappas or correlation coefficients. For the outcome measures, the absolute values are provided in Appendices 3 and 4, as well as our rating according to the cut-off values as described in the Methods sections and Table 1.

3.3.1.1. Tools specifically developed for the elderly population (Appendix 3).

NRI

The NRI,[7] originally developed to assess undernutrition in community-dwelling elderly, has been applied in several studies to assess the nutritional status of patients (not only elderly but also adult) admitted to hospital. One study in newly admitted hospitalized patients showed good validity to nutritional assessment in older patients (>65 years old) and fair validity to the younger ones (<65 years old).[33] In 2 studies including hospitalized adults (not elderly), the validity was found to be poor (both newly admitted or surgical patients, reference methods SGA).[9,34] NRI[7] was furthermore applied in a study in preoperative colorectal cancer patients, and compared to two reference methods: SGA[8] and pre-albumin. It performed fair compared to both references.[35] Thus NRI[7] only performed well in a study in which it was used to assess the nutritional status of the elderly subpopulation. In adults it performed fair or poor.

MNA

The MNA[3] has originally been developed via construct validity, to assess the nutritional status of elderly. We identified 4 studies that applied the MNA[3] again to express its construct validity to assess nutritional status in elderly patients. In 2, it was validated against assessment by a professional,[20,21] in line with its original development study, showing good validity in one study[20] and poor validity (low sensitivity) in the other one.[21] In another study MNA[3] was applied with the NRS-2002[2] as the reference, showing good validity.[10] However, we would like to comment on the use of NRS-2002[2] as the reference method, since we don't consider NRS-2002 a valid 'gold standard' (see Methods section). In the last study, the validity of MNA[3] was assessed with a full nutritional assessment as the reference in a group of hospitalized elderly, in which the specificity of the tool was found to be very low, indicating that too many patients were identified as malnourished.[36]

In conclusion: the MNA[3] was originally developed to identify frail and healthy elderly at risk of malnutrition. For the hospitalized elderly population, the validity results of later studies are inconclusive.

MNA-SF and modified MNA-SF

The short version of the MNA[4] and its modified form[16] are both intended for use in the elderly population as well. Both tools are supposed to be a quick and easy substitute to the full MNA,[3] or a first step towards full nutritional assessment. In two studies re-evaluating the diagnostic accuracy of the (modified) short form versus the full version, its validity was found to be good.[16,37] In studies comparing the MNA-SF to another reference method (either assessment by a professional[38] or nutritional assessment/anthropometry),[39] it was shown that the MNA-SF showed excellent sensitivity to either reference method, but poor specificity, indicating that the tool identified too many patients at risk of malnutrition, while, in fact, they were not malnourished.

The conclusion is that the MNA-SF[4] is a good substitute for the full MNA[3] in the older hospitalized population, but that it classifies too many patients at risk of malnutrition compared to other reference methods.

NUFFE

After its original development study, NUFFE[17] was applied in one later study with MNA[3] as the reference standard, as well as BMI, and two anthropometric measures (arm circumference and calf circumference).[40] Newly admitted elderly were included. The correlation to MNA[3] was good, but the correlation to the individual anthropometric measures was poor. This study raises the suggestion that NUFFE[17] performs well when compared to a valid reference method in the elderly population.

Simple Screening Tool I and II

In contrast to the poor results in the validation study, the simple screening tools I and II[18] showed fair validity to assessment by a professional in elderly in acute care and in long term care.[41]

MEONF-II

After its validation study, in which MEONF-II was found to be fairly valid compared to MNA[3] as a reference,[19] MEONF-II again showed fair validity to assess patients' nutritional status, in both adults and older people.[42]

Rapid screen

We were unable to identify the paper describing the development of the Rapid Screen, but in the re-validation study reviewed in this systematic review it showed poor validity (especially: low specificity) to assessment by a professional in a group of elderly in day treatment.[20]

Nutrition Screening Initiative and Chandra Nutrition Screen

These two tools, originally developed for nutrition screening in community-dwelling elderly, showed fair and poor validity (respectively) in a group of medical and surgical hospitalized elderly.[21]

General conclusion for construct validity of tools for the elderly population: out of 10 tools specifically designed to screen elderly at nutritional risk, none performed consistently well in later studies; for that reason we cannot advise a preferred tool for undernutrition screening in the elderly hospitalized population.

3.3.1.2. Tools developed for the general hospital population (Appendix 4).

SGA

In its development study, in surgical adult patients, the goal of the SGA was two-fold: to assess patients at high nutritional risk and to predict postoperative outcome.[8]

Two later studies applied the SGA[8] to assess patients' nutritional status. In one study, SGA[8] was compared to pre-albumin in a comparable population (pre-operative surgical patients), showing fair validity.[35] In the other study, it was compared to NRS-2002[2] in a completely different population (elderly), again showing fair validity.[10] Due to the poorly chosen reference methods (pre-albumin and NRS-2002[2]), it is difficult to say whether SGA[8] is a tool with good construct validity.

NRS

One study was identified describing the validity of NRS[23] versus nutritional assessment. In this study it was applied in both adults and elderly, although the tool was not specifically developed for use in the elderly. It showed good validity in the elderly (>65 years old), whereas in patients under 65 years it performed fair.[33]

Implementation is hindered by the different performance among different age groups.

MST

MST, a quick and easy screening tool for the adult population,[5] was applied to screen for nutritional status in different populations in 4 studies.

When compared to nutritional assessment/anthropometry, it performed fair in both adult and older patients.[39] When compared with 2 reference methods (3 studies) not considered acceptable reference methods in this review (PG-SGA[12] and NRS-2002[2]), the MST performed good in oncology outpatients,[43] poor in oncology inpatients[44] and fair in orthopaedic elderly.[10] Based on these studies, we conclude that the MST[5] possibly has fair validity in determining malnutrition in hospitalized patients (both adults and elderly), although more studies with acceptable reference methods are necessary.

Screening Sheet

The (Icelandic) Screening Sheet[25] was originally developed in a group of newly admitted hospitalized patients. In later studies its use was described in two completely different study populations: in a study with COPD patients it showed fair validity to nutritional assessment,[45] and in hospitalized elderly it performed well.[36] Based on the heterogeneity in study populations, we do not have enough scientific evidence to recommend implementation of this tool on a wide basis.

MUST

The MUST[1] has originally been developed for all health care settings and for all patient groups. Its validity to screen for malnutrition was described in 6 later studies, all 6 included adult hospitalized patients, either medical, surgical or both; in 2 studies elderly patients were also included. It was applied twice in surgical patients, once with SGA[8] as the reference method, showing good validity,[34] and once with both pre-albumin and SGA[8] as reference methods, showing fair validity to both constructs.[35]

In a large mixed population of newly admitted patients its validity compared to SGA[8] was found to be fair,[9] and in another mixed population (both adult and older patients) it showed good validity with nutritional assessment as the reference.[39]

When compared to NRS-2002[2] (a less valid reference method) in a group of oncology patients, it also showed fair validity.[44]

In the last study MUST[1] was compared to five other tools and agreement between tools was described.[46] Construct validity was expressed against 2 of the other tools (MNA[3] and MST[5]). Both in hospitalized elderly and in surgical patients, the validity was found to be fair with MNA[3] as the reference. In medical inpatients, sensitivity and specificity to MST[5] were good.

In conclusion: MUST[1] may have fair validity when it comes to screening nutritional status of different subgroups of adult hospitalized patients. The fair results in the older hospital population confirm the fair performance in the development study, in which the correlation between MUST[1] and MNA[3] was only moderate.

MAG Screening Tool

The study reviewed describes the validation of this tool, which was tested for reliability but never for validity. The tool was compared to SGA[8] and it was found to be fairly valid in oncology patients.[26] No later studies applying this tool were identified.

NRS-2002

The NRS-2002[2] was designed to identify patients at increased nutritional risk expected to benefit from nutritional support.

Four studies were identified in which the NRS-2002[2] was used to screen patients' nutritional status by validating the tool against another reference method. The patients included were either newly admitted adult patients, elderly patients, or surgical patients. In none of these studies, the original purpose of the NRS-2002[2] was further elaborated: did the patients at risk benefit from a nutritional intervention? Two studies applied SGA[8] as the reference method, one showing good validity in adult surgical patients[34] and one showing fair validity in a large group of newly admitted patients of heterogeneous specialities.[9] One study compared NRS-2002[2] to MNA[3] in adult and elderly patients, showing poor validity in both age groups.[19] The last study was performed in both adult and older hospitalized patients, with body composition/nutritional assessment as a reference, showing good validity for both age groups.[47]

It can be concluded that the NRS-2002[2] shows inconsistent validity to screen for malnutrition among different hospitalized populations and age groups. Its original purpose, i.e. its value to identify patients who will benefit from nutritional support has not been described in the studies reviewed.

British NST

One study was identified in which the NST British Nutrition Screening Tool[27] was re-evaluated for validity, showing good sensitivity and fair specificity to assessment by a professional in a patient group quite similar to the patient group in the development study.[48]

SNAQ

Following its original development and validation study, the SNAQ[6] was applied again in a comparable group of inpatients, showing fair validity against nutritional assessment,[39] and in a group of both general and preoperative outpatients, again showing fair validity.[47]

Nutrition screen, PG-SGA, INSYST I and INSYST II

Only single studies were identified applying different screening tools to different hospitalized populations. The interpretation of these studies is limited, as we do not know how, and in which populations, these tools were developed. Results of the 4 studies are described in Appendix 4.[12,30,31]

3.3.1.3. In conclusion

Forty-three studies describing 28 tools were identified which were judged for construct validity against a reference method. In the absence of a generally recognized gold standard for malnutrition, assessment by a professional, assessment of anthropometric measures/body composition, and the assessment tools MNA[3] and SGA[8] were considered 'valid' reference methods by our research group. Screening tools and laboratory values were thus considered less valid comparisons. The heterogeneity in populations, age groups, tools and reference methods was large. Therefore, pooling of results was impossible. Also, most tools were applied in only one or a few studies, thus making the drawing of 'general' conclusions difficult.

Some tools have been developed to identify malnutrition in the elderly subpopulation.

The MNA,[3] the tool most frequently recommended for nutritional assessment in the older population, did not show consistently good results in the later validations studies. Its short form was found to correspond well to the full MNA.[3] However, the MNA-SF[4] overestimates the number of malnourished patients. The less well-known tool NUFFE[17] showed good validity to MNA,[3] whereas MEONF-II,[19] and the 2 Simple Screening Tools[18] (all developed for the elderly population as well) did fair. The latter 3 tools have been described only infrequently, which hinders their use for wide implementation.

For the general hospitalized population, all tools showed inconsistent results with regard to their construct validity. Even when the tools were applied in patient and age groups that were comparable to the ones in the development studies, results were equivocal.

MUST,[1] one of the tools that has been studied most, did not show poor results on construct validity. Half of the studies showed fair, and the other half good validity. Its performance to screen for undernutrition in the older subpopulation of patients remains behind.

NRS-2002[2] showed inconsistent results; its validity ranged from poor to good in different patient groups, but consistency within the groups (e.g. surgical patients, or medical patients) was not found.

The assessment tool SGA[8] performed poorly in the 2 studies in which it was used to assess nutritional status, however, one should be critical on drawing conclusions from these studies, since the reference methods applied were regarded less valid reference methods.

The quick and easy screening tools MST[5] and SNAQ[6] performed fair (sensitivities <80%) in the majority of studies in which they were used. A note must be added on the acceptability of the reference methods in the studies describing the validity of the MST.[5] Only one study used a – in our opinion – valid reference method. The simple pre-screen tool INSYST I[31] showed good performance (in only 1 study). Keeping in mind that quick and easy tools always need follow-up in the form of detailed nutritional assessment and taking into account that these tools 'miss' at least twenty percent of the undernourished patients at first screening one might consider implementing these tools as a first step in identifying patients at increased risk.

Some of the less well-known tools showed fair or good validity against a construct in 1 or 2 studies. However, they have probably fallen into oblivion during the years. For example, a fair amount of tools developed by the British Association of Parenteral and Enteral Nutrition (BAPEN) was found which must have been overtaken after the introduction of MUST,[1] since these tools have not appeared in later literature.

A final remark concerns the use of tools in outpatients. Length of hospital stay is diminishing worldwide, and outpatient screening is widely advocated to enable timely nutritional treatment. Remarkably, and in contrast to those developments, only 2 studies described the validity of tools in the outpatient setting. Further studies investigating the validity of screening tools in different outpatient populations are warranted.

3.3.2. Predictive validity

The primary outcome measure of this part of the review is the performance of a tool to predict LOS, mortality or complications, most often expressed by ORs, HRs, RRs or AUCs, or *p*-values. For these outcome measures the absolute values are provided in Appendices 5 (elderly) and 6 (adults), as well as our rating according to the cut-off values (as described in the Methods sections and Table 1).

Risk of bias: clinical outcome is known to be influenced by many other factors than nutritional status alone, i.e. age, disease severity or diagnosis. Studies may have been biased if they did not adjust for these variables. In addition, nutritional intervention of malnourished patients is likely to improve clinical outcome. Only few studies described that they actually provided nutritional support.

3.3.2.1. Tools specifically developed for the elderly population (Appendix 5)

MNA

Although MNA[3] was designed as a tool with the primary goal to assess nutritional status of older persons, 11 studies used the tool to predict clinical outcome. All but one[49] of these studies were performed in older patients.

Five studies reported on the endpoint length of stay (LOS). However, only one of these studies reported ORs for LOS, and in this study MNA scores had low predictive value for LOS (OR 1.42).[10] In the other studies Bauer et al. reported a significant association ($p < 0.05$) in a relatively small patient group ($n = 121$), suggesting a good or fair predictive validity of MNA on LOS.[50] The significant associations described in the studies by Cansado and Van Nes are less plausible, as the sample size of both studies exceeded 200 patients.[51,52] Finally, the study by Sanchez-Munoz was negative on the predictive value of MNA for LOS.[53]

Also 5 studies reported on the endpoint mortality. In one, MNA had good predictive validity for long term mortality (OR/HR > 3).[54] Another one applied the typically geriatric tool MNA to predict outcome of adult patients with heart failure.[49] Patients underwent a nutritional assessment with MNA at discharge from hospital and the association with long-term mortality was studied. In the Cox

multivariate analysis, the malnutrition state remained an independent predictor of mortality. The mean age of the patients was 73 years old, which is close to the target group for which MNA was originally designed.

In contrast to these 2 studies, a third study showed poor predictive validity for either 1-year or 4-year mortality.[55] In another study MNA scores were reported to be related to mortality, however data were presented as *p*-values and the sample size exceeded 200 patients, thus not giving information on the magnitude of the effect.[52] The last study described that MNA was not related to mortality, without presenting further data.[53]

Three studies were identified with respect to the third endpoint, complications/adverse clinical events, all showing that MNA was not predictive for poor outcomes.[56–58] Finally, one study reported that patients with lower MNA scores were more often discharged to other institutions.[20]

In conclusion: there is no evidence that MNA,[3] originally designed to assess a patient's nutritional status, has good predictive validity for all clinical outcomes in elderly patients. It might have predictive value for both mortality and LOS, however, the quality of the studies does not allow us to draw firm conclusions. We found no evidence that MNA scores may predict complications.

MNA-SF

The short form of the MNA[4] was described to be related to a longer length of stay in one study, however data were reported as *p*-values only without information about the magnitude of the effect.[59] It showed no association with long term mortality in another study.[55] Thus, we cannot conclude that MNA-SF is a valid instrument to predict clinical outcome in the geriatric population.

Although the tool is typically designed for the elderly, MNA-SF[4] was also applied in a 'younger' (mean age 56 years old) study population, concurrently with NRS-2002 and MUST.[60] Tool performance in predicting complications, very long length of hospital stay (LOS), and death was analysed using receiver operating characteristic curves. For all 3 tools, AUCs for the 3 outcome measures were between 0.6 and 0.8 indicating fair predictive validity, with only small differences between the 3.

Similarly, MNA-SF, together with NRS, Nutrition Risk Classification and MST, was applied in one study to predict postoperative wound and infectious complications in a group of patients undergoing abdominal surgery (mean age 56 years old). Results were adjusted for the effects of other risk factors for postoperative infections. MNA-SF had no independent predictive validity for postoperative complications.[56]

Based on these 2 studies in adults, we would not advise to use the MNA-SF[4] as a tool to predict outcome in adult hospitalized patients.

NRI

The NRI,[7] originally designed to assess the nutritional status of community-dwelling elderly, was used in 8 studies to predict outcome. Only 2 studies applied the tool to predict outcome in the elderly population; in one, there was no correlation between NRI and LOS or complications.[57] After stratifying for surgical and non-surgical patients, NRI was correlated to complications in surgical patients ($p < 0.05$) but not in non-surgical patients ($n = 113$). The other study only described a significant difference between NRI and NRS with regard to clinical outcome.[33] This information is insufficient to advise the use of NRI as a screening tool to predict outcome in the elderly subpopulation.

The performance of the NRI to predict LOS of adult (not elderly) hospitalized patients was described in 6 studies. In a large two-center study by Kyle, moderate and severe, but not mild, nutritional risk by NRI was significantly associated with longer LOS.[61] Subanalysis of medical, but not surgical, patients showed significant ORs, adjusted for age and hospital centre. Another study showed NRI to have poor validity to predict length of stay in decompensated heart failure patients.[62] In a more recent study by Kyle, a high risk (but not medium risk) score on the NRI was associated with longer length of stay (adjusted for age), however, the sample size ($n = 995$) did not allow us to quality rate the performance of this tool.[9] We were also unable to rate the study by Filipovic because the sample size exceeded 200 patients and results were given in *p*-values only.[63] In this study, malnourished patients, according to NRI, were reported to have an increased length of hospital stay.

Two studies reported on more than one endpoint. In a study by Schiesser,[64] both NRI and NRS were applied to predict postoperative complications in GI surgery patients. Using multiple regression analysis, only NRS and malignancy remained prognostic factors for the development of complications. NRI was not predictive for postoperative complications (AUC 0.34). This study indicates superiority of NRS over NRI to predict postoperative complications in GI cancer patients. In this same study, moderate and severe malnutrition according to NRI scores were reported to be related to longer LOS.

In another study a low score on NRI was significantly related ($p < 0.05$) to length of stay and mortality, but not to complication rate.[65] Included were 39 patients, making the significance of the association likely, but preventing us from rating the strength of the association.

In conclusion: there is weak evidence to advise NRI[7] as a screening tool to predict clinical outcome, either in the elderly or in the adult population. In addition, studies contradict each other in subgroups in which NRI may be a valid tool.

GNRI

GNRI is a recently developed tool with the specific aim to predict outcome of elderly patients.[11] Its predictive validity was described in one retrospective study that included elderly receiving nutritional support, in which no correlation with length of stay, length of nutrition or complications was observed.[57] A risk of bias may have occurred due to the nutritional intervention that was given to the patients simultaneously.

This single study does not confirm the predictive validity of GNRI.

We have to conclude that none of the tools specifically designed for the geriatric population was found to perform good in predicting outcome in the elderly subpopulation of patients. NRI[7] has also been described in 6 papers including adults (not elderly), but also in this population fair or good predictive validity for the outcome LOS was only shown in the minority of studies.

3.3.2.2. Tools specifically developed for the general hospital population (Appendix 6)

In the different studies reviewed we faced a heterogeneity in background of disease and timing of screening within the group of 'general hospital patients'. The descriptions ranged from a mixture of general internal medicine and/or surgery patients, newly admitted patients, to gastrointestinal/colorectal/heart failure patients etc. Some of the tools for the adult population were also applied to elderly. Sometimes patients' nutritional status was screened on admission, sometimes this was not mentioned. This should be kept in mind when reading the manuscripts and drawing conclusions.

SGA

SGA[8] is the oldest assessment tool and also the tool most frequently described when it comes to predicting clinical outcome.

Indeed, in its development study predictive validity of the tool was also described, with longer LOS for more malnourished patients.[8]

Nine studies were identified regarding the endpoint LOS; in 3 of these data were presented as ORs/RRs. In 2, SGA scores were not predictive for LOS; one of these studies was performed in an elderly population,[10] the other one in clinical and surgical patients on admission.[66] In the study by Goiburu in trauma patients SGA scores were moderately predictive for length of stay (OR 2.3).[67]

Six studies reported on the association between SGA scores and LOS by presenting their results in *p*-values only. A study by Wakahara et al. indicated the highest predictive validity for SGA on hospital stay, followed by disease category and malignancy in the multivariate model.[68] Another 3 studies reported significant associations between the SGA scores and LOS,[63,69,70] one reported a significant association for subgroups only,[71] and one showed no association in the elderly.[50] The interpretation of these *p*-values is presented in Appendix 4 (with significant *p*-values being rated as good or fair (g/f) if the sample size was <200 patients, and being unable to be rated (in the table presented with "?") if the sample size was >200 patients).

Eleven studies reported on the association between SGA scores and mortality. In 5 of them, patients with SGA scores reflecting undernutrition expressed HRs for mortality higher than 3, which we regard as a large effect.[54,67,70,72,73] The study by Lim et al. controlled for diagnosis, age, gender and race and showed an independent predictive effect of a poor SGA score on mortality and readmissions.[70] In the study by Rodriquez-Pecci adjustments were made for comorbidities, age and gender as well.[72] Patients who were identified as malnourished had a significantly higher OR (OR 6.1) for mortality than those identified as not at risk. Goiburu and co-workers found fair to good predictive validity of SGA on the outcome measures mortality (HR 4.4) as well as LOS, and complications, after adjustment for other possible risk factors.[67] In Gupta's study, SGA score was predictive for mortality in both univariate and multivariate analyses, with significantly different survival probabilities for patients with SGA A versus SGA B/C (after partitioning for stronger prognostic factors).[73] The study by Persson showed fair predictive validity of SGA on mortality in a group of elderly.[54] In contrast, 6 studies showed no predictive effect of SGA on mortality, either presented by HRs (<2) or by non-significant *p*-values.[50,66,69,71,74,75]

Four studies described the association between SGA scores and complications. Smith's study used the SGA, as well as 3 other tools (MRCs, ANS, and ANS).[32] Morbidity was prospectively recorded. Receiver operating characteristic analysis indicated that the predictability of complications was lowest with the SGA. Still, SGA had a good OR for predicting complications (OR 3.11). Goiburu indicated fair predictive validity of SGA for complications (RR 2.0),[67] whereas this was poor in the study by Beghetto, after adjusting for other variables.[66] The study by Pham[76] only indicated that patients with a SGA C score had significantly more infectious complications than patients with SGA A/B.

Two studies were different in design. They compared the predictive probability of more than one tool on more than one outcome in a single patient population. This has the advantage that tools can be compared to each other without bias due to a different study population or a different timing. In the study by Raslan and co-workers, SGA was executed concurrently with NRS-2002.[77] Included were 705 newly admitted patients and the tools were rated for their ability to predict: death, very long length of hospital stay (VLLOS), complications, and combinations of these outcomes. Compared to those patients not at nutritional risk, patients scoring malnourished on the NRS-2002 (NRS-positive patients), but not SGA B or SGA C patients had an increased risk of death (OR 3.9). SGA B and C patients (but not NRS-positive patients) had an increased likelihood of VLLOS (OR 1.9 and 3.8, respectively). Both NRS-positive patients, SGA B and SGA C patients were at increased risk for moderate or severe complications (ORs for complications between 1 and 3 for all). Severe complications could only be predicted by a positive score on the NRS-2002 (OR 2.6), but not by a SGA B or C score.

This study nicely illustrates the difficulty of applying tools to predict different outcomes. Preferably, one would like to be able to predict complications, increased risk of death, or VLLOS with one tool. This study illustrates that neither tool was capable of doing all. For clinical practice, it would be unadvisable to use one tool to predict complications, and the other for predicting death. Note should be given to the fact that it remains unknown, in this study as well as in many other studies, whether patients who had a poor screening/assessment score were given nutritional support. Nor were outcomes adjusted for other factors affecting outcome, such as disease severity, and age.

The study by Ozkalkanli also compared 2 tools concurrently, SGA and NRS-2002 in a group of orthopaedic patients.[78] Both showed good predictive validity for occurrence of postoperative complications. Results were not adjusted for possible confounders in this study either.

We conclude that SGA[8] showed fair or good predictive validity in approximately half of the identified studies, on some, but not all outcomes. In the better quality studies, the studies in which adjustments were made for possible other risk factors affecting outcome, SGA performed mostly well with regard to (independent) predictive validity on LOS, mortality and complications. Therefore, we dare to recommend SGA as a tool predictive for clinical outcome.

NRS

NRS[23] is typically applied to predict postoperative complications. In the study by Schiesser,[64] it showed high predictive validity (OR for postoperative complications 4.2). In contrast, in Putwatana's study, it performed poorly: NRS was not independently predictive for surgical outcome, and inferior to Nutrition Risk Classification[24] after adjusting for possible confounders for postoperative complications.[56] In the elderly hospitalized population, NRS had poor predictive validity for mortality.[79]

MST

MST[5] proved to be not predictive for length of stay in an oncological population,[44] nor in an elderly population.[10]

In a study by Putwatana MST proved to be not predictive for postoperative complications. Moreover, it had the worst predictive validity, compared to MNA-SF, NRS and Nutrition Risk Classification.[56] Overall, MST – designed as a 'quick and easy' screening tool, performed poorly in predicting clinical outcome.

MUST

MUST[1] was originally designed to not only establish nutritional status, but also to predict outcome in adult, as well as in elderly hospitalized patients.

In 2 studies, patients identified at high risk of undernutrition by MUST were found to have increased LOSs.[9,44] In Kyle's study, 'high risk' MUST patients showed longer lengths of stay (OR 3.1), whereas 'medium risk' did not.[9] In the study by Amaral, patients with a higher MUST score stayed longer in hospital than those with a low score, adjusted for sex and age (OR 3.24).[44] A similar result was described in the study by Clugston, in which MUST high risk patients were described to have longer LOS than low risk patients, described by *p*-values.[65] The study sample was 39 patients; MUST thus probably had fair or good validity. All malnourished patients were given nutritional intervention.

Two studies reported on the validity of MUST to predict LOS in the geriatric population. These studies reported in *p*-values only, both of them showing longer lengths of stay for patients classified as malnourished. As we decided that we would rate studies good or fair only if the study population did not exceed 200 patients, both studies were rated good/fair.[51,80]

For the outcome measure mortality, MUST was shown to be capable of predicting in-hospital mortality in a recent study by Koifman.[81] Included were 1000 patients who were newly admitted to the internal medicine departments, and the results were adjusted for other risk factors. A MUST score of 2 or more (high risk) remained independently predictive for in-hospital mortality (OR 5.9). In another study MUST was found to have fair predictive validity for both death, LOS and complications, with areas under the curve for all outcome measures around 0.6.[60] In this study, its performance was compared to NRS-2002 and MNA-SF, and MUST was found to have a slightly poorer performance than the other two.

Two studies were specifically performed in the elderly. In one, high risk patients had a higher mortality (in-hospital and at six months) ($p = 0.03$), probably indicating fair or good predictive ability of MUST.[80] In another study in the elderly, MUST and NRS were used in parallel to predict mortality in older hospitalized patients.[79] For both tools, hazard ratios for increased risk of mortality were less than 2, indicating poor predictive validity.

The conclusion is that a MUST score of 2 or higher is likely to have fair predictive validity for both LOS and mortality in adult hospitalized patients, as has been proven in more than 1 study. More studies are needed to confirm the predictive validity of MUST in the elderly subpopulation.

NRS-2002

Seven studies applied the NRS-2002[2] as a tool to predict length of stay. One study including geriatric patients was negative.[50] Six studies reported that patients identified at high nutrition risk by NRS-2002 had a longer length of stay. The strength of this association could only be derived from 3 studies (reporting ORs or AUCs) in which NRS-2002 was found to have fair predictive validity.[10,44,60] For the other studies no verdict could be given on the ability of NRS-2002 to predict LOS, due to large sample sizes.[9,82,83]

For the endpoint mortality 2 studies were found. One reported a fairly predictive value of NRS-2002, with an AUC of 0.79,[60] the other showed different results between patients admitted to ICU and to internal medicine wards. Moreover, this study presented results in *p*-value only, which does not allow us to rate the strength of the association in the ICU subgroup.[84]

With regard to complications, higher NRS-2002 scores were found to be fairly predictive for complications after adjusting for other risk factors in two studies.[82,83]

Several studies applied different tools concurrently. The earlier section addressing SGA also addressed the performance of NRS-2002 in one of two studies by Raslan,[77] showing good predictive validity of NRS-2002 on the outcome measures mortality and complications, but not on very long LOS.

Another study by Raslan's group compared NRS-2002 to MUST and MNA-SF in a sample of 705 patients.[60] NRS-2002 had fair areas under the curve for the outcome measures death, very long length of stay, and complications. The areas under the curve for NRS-2002 were slightly better than those for MNA-SF and MUST, which made the authors conclude that NRS-2002 performed better than the other tools. Based on the data provided, we do not support this conclusion as differences were very small.

A study by Ozkalkanli also compared two tools concurrently, SGA and NRS-2002, in a group of orthopaedic patients.[78] Both showed good predictive validity for occurrence of postoperative complications. In this study too, authors prefer NRS-2002 over SGA, which, again, we do not confirm based on the data. Results were not adjusted for possible confounders.

Our conclusion is that NRS-2002[2] may have fair to good predictive validity for mortality, length of stay and complications in adults. For the elderly population, only 2 studies were identified, describing the association between NRS-2002 results and LOS and these studies were not convincing.

Rapid Screen

The study on Rapid Screen in the elderly is likely to have good/fair predictive validity with a *p*-value for poor discharge outcomes of 0.004 and a sample size of 65 patients.[20]

Nutrition Risk Classification

This tool[24] was described in a study applying multiple tools (other tools: MNA-SF, NRS, MST) to predict surgical outcome.[56] The MNA-SF, NRS, and Nutrition Risk Classification had the larger receiver operating characteristic areas. Only the Nutrition Risk Classification was significantly related to the occurrence of postoperative complications after adjusting for other risk factors of postoperative infections (OR 2.92). The other remaining risk factors were serum albumin level and operative time.

PG-SGA

In one study PG-SGA[12] scores were associated to length of stay in newly admitted patients. Although a weak association between PG-SGA score and LOS was described, the number of days admitted to hospital did not differ significantly between well-nourished and malnourished patients.[85] In a relatively small study involving acute stroke patients, PG-SGA was significantly associated to length of stay and complications, but not to infections and mortality.[86]

3.3.2.3. *In conclusion*

For the adult hospital population, SGA,[8] MUST[1] and NRS-2002[2] turned out to have fair to good predictive validity in approximately half of the studies. Not a single nutrition screening or assessment tool was found to hold good enough predictive validity to advise its use for the elderly hospital population.

3.4. *Comparison between tools*

In order to assess which instrument performs best, studies comparing several tools in the same population are the most valuable. Seventeen of these studies, comparing tools to predict outcome, were identified (Table 2). These studies are very informative, since they are not biased by differences between populations, setting, or age. Ultimately, this kind of studies will help us decide whether it is possible to recommend a single best tool (for a certain patient population or age group).

The studies are presented in Table 2. First of all, this table shows that not all tools were executed for all outcomes. Some studies only reported on the validity of a tool to predict LOS, others focused on predicting mortality or complications. Only 3 studies[60,65,77] reported on all 3 outcome measures. Secondly, different studies compared different tools, thus complicating making comparisons between studies. Thirdly, the studies are not consistent in their results. For example, the study by Bauer compared MNA, NRS-2002 and SGA in a group of elderly and found MNA to be superior to NRS-2002 and SGA in predicting LOS.[50] In contrast, when Martins used MNA, NRS-2002, SGA and MST to evaluate the predictive validity for LOS in elderly,[10] NRS-2002 was superior to the other three by being the only tool predictive for LOS.

Table 2
Comparison of predictive validity of different tools within 1 patient population.

Author/ year	Population	Sample size	Tool	LOS[a]	Rating[b]	Mortality	Rating[b]	Complications	Rating[b]
Bauer, JM (2005)[50]	Geriatric (mean age 80.2 ± 7.7)	121	MNA	MNA 'at risk' and 'malnourished': significant longer LOS than MNA 'well-nourished' ($p = 0.044$)	g/f				
			NRS-2002	LOS: $p = 0.377$ significant difference between NRS, MNA, SGA ($p < 0.001$)	p				
			SGA	No significant association with LOS $p = 0.130$, significant differences between NRS, MNA, SGA $p < 0.001$	p				
Kyle, UG (2006)[9]	All newly admitted adults	995	NRI	"High risk" longer LOS ($p = 0.032$), "medium risk" no longer LOS	?				
			MUST	"High risk": longer LOS OR = 3.1 (95% CI 2.1−4.7) medium risk: not predictive for LOS	g				
			NRS-2002	"Medium" and "high risk": longer LOS ($p < 0.001$)	?				
Martins, CPAL (2005)[10]	Elderly (≥65 y)	207	NRS-2002	Longer LOS: OR 2.25 (95% CI 1.03−4.88)	f				
			MST	LOS not significantly prolonged: OR = 1.17 (95% CI 0.62−2.23)	p				
			MNA	Moderately and severely undernourished combined: LOS not significantly prolonged: OR 1.42 (95% CI 0.69−2.92)	p				
			SGA	LOS not significantly prolonged: OR 1.66 (95% CI 0.73−3.74)	p				
Amaral, TF (2008)[44]	Oncology	130	MUST	MUST score ≥1: OR for longer LOS, adjusted for other variables = 3.24 (95% CI 1.5−7)	g				
			MST	No significant OR for longer LOS, adjusted for other variables (OR = 2.31 (95% CI 0.84−6.36))	p				
			NRS-2002	Longer LOS, adjusted for other variables: OR = 2.47 (95% CI 1.05−8)	f				
Cansado, P (2009)[51]	Elderly on admission (≥65 y)	531	MUST	MUST "moderate/high risk" longer LOS ($p = 0.002$)	?				
			MNA	MNA "at risk/undernutrition" longer LOS ($p = 0.003$)	?				
Filipovic, BF (2010)[63]	Gastroenterology	299	SGA	Malnourished longer LOS (chi^2, $p < 0.001$)	?				
			NRI	Malnourished longer LOS (chi^2, $p < 0.001$)	?				
Henderson, S (2008)[79]	Newly admitted elderly (≥65 y)	115	MUST			HR MUST score 1: 1.91 (95% CI 0.95−3.83)	p		
						HR MUST score ≥2: 1.98 (95% CI 1.15−3.42)	p		
			NRS				p		

(*continued on next page*)

Table 2 (*continued*)

Author/ year	Population	Sample size	Tool	LOS[a]	Rating[b]	Mortality	Rating[b]	Complications	Rating[b]
						HR medium risk: 1.74 (95% CI 1.01–3.01) HR high risk: 1.17 (95% CI 0.68–2.05)	p		
Vischer, UM (2012)[55]	Elderly (≥75 y)	444	MNA			MNA scores not significantly related to 4 y mortality HR. At risk HR 0.80 (95% CI 0.57–1.12) and 'malnourished' HR 0.88 (95% CI 0.58–1.33).	p		
						MNA scores not correlated to 1 y mortality	p		
			MNA-SF			MNA-sf scores not significantly related to 4 y mortality HR. At risk HR 0.79 (no 95% CI given) and 'malnourished' HR 0.89 (no 95% CI given).	p		
						MNA scores not correlated to 1 y mortality	p		
Visvanathan, R (2004)[20]	Geriatric (≥65 y)	65	MNA					Predicting poor discharge outcomes ($p = 0.017$)	g/f
			Rapid Screen					Predicting poor discharge outcomes, $p = 0.004$	g/f
Putwatana, P (2005)[56]	Abdominal surgery	430	Nutrition Risk Classification					OR for postoperative complications = 2.92 (95% CI 1.62–5.26)	f
			MNA-SF					No significant OR for postoperative complications	p
			MST					No significant OR for postoperative complications	p
			NRS					No significant OR for postoperative complications	p
Smith RC, 2009[32]	Surgical on admission	148	MRCS					ROC curves: SGA had the highest AUC for complications, compared to MRCS or ANS	–
			SGA					OR = 3.11, SGA (A vs B/C): se 41, sp 82, PLR 2.25, NLR 0.72, PPV 29, NPV 11	g
			ANS-B					OR = 5.26, ANS values ≥2: se 45, sp 86, PLR 3.43, NLR 0.62, PPV 38, NPV 10	g
			ANS					OR = 5.46, ANS values ≥2: se 95, sp 48, PLR 1.86, NLR 0.09, PPV 25, NPV 100. ANS values ≥3: se 68, sp 71, PLR2.35, NLR 0.44, PPV 0.30, NPV 0.07	g

Ozkalkanli, MY (2009)[78]	Orthopaedic surgery	256	NRS-2002					OR for complications = 4.1 (95% CI 2.0–8.5), se 69, sp 80, in predicting postoperative complications	g
			SGA					OR for complications = 3.5 (95% CI 1.7–7.1), se 50, sp 77, in predicting postoperative complications	g
Schiesser, M (2009)[64]	GI surgery	200	NRS					Correlation with postoperative complications ($p = 0.004$), multivariate regression OR for complications = 4.2 (95% CI 1.2–14.8)	g
			NRI					Correlation with postoperative complications ($p < 0.001$), multivariate regression OR for complications = 1.7 (95% CI 0.4–8.1)	p
Clugston, A (2006)[65]	Obstructive jaundice, malnourished patients received nutritional support	39	NRI	NRI <83.5 longer LOS ($p = 0.001$)	g/f	NRI <83.5, higher mortality ($p = 0.044$)	g/f	No association with complication rate	p
			MUST	MUST high risk: longer LOS ($p = 0.008$)	g/f	MUST high risk: no higher mortality ($p = 0.575$)	p	No association with complication rate	p
Lopez-Gomez, JJ (2011)[57]	Elderly medical receiving nutritional support (≥75 y)	113	GNRI	No correlation with LOS	p			No correlation with complications	p
			NRI	No correlation with LOS	p			No correlation with complications	p
			MNA	No data	-			No relation with complications	p
	Elderly surgical receiving nutritional support (≥75 y)	113	GNRI	No correlation with LOS	p			No correlation with complications	p
			NRI	No correlation with LOS	p			Correlation with complications in surgical patients ($p < 0.05$)	g/f
Raslan M, 2010[60]	Internal medicine and surgery	705	NRS-2002	AUC for VLLOS: 0.65	f	AUC for mortality: 0.79	f	AUC for complications: 0.65	f
			MNA-SF	AUC for VLLOS: 0.62	f	AUC for mortality: 0.75	f	AUC for complications: 0.65	f
			MUST	AUC for VLLOS: 0.61	f	AUC for mortality: 0.64	f	AUC for complications: 0.60	f
Raslan M, 2011[77]	Internal medicine and surgery	705	SGA	SGA B: VLLOS: OR 1.9 (95% CI 1.2–3.2)	p	SGA B: Death: OR NS 3.5 (95% CI 0.9–13.3)	p	SGA B: moderate or severe complications: OR 2.0 (95% CI 1.1–3.4)	f
				SGA C: VLLOS: OR 3.8 (95% CI 2.0–7.2)	g	SGA C: Death: OR NS 3.9 (95% CI 0.9–17.0)	p	SGA B: severe complications: OR NS 1.6 (95% CI 0.7–4.0)	p
								SGA C: moderate or severe complications: OR 2.9 (95% CI 1.4–5.8)	f
								SGA C: severe complications: OR NS 2.5 (95% CI 0.9–7.0)	p
			NRS-2002	NRS-2002: VLLOS: OR NS (95% CI 1.5, 0.8–2.5)	p	NRS-2002: Death: OR 3.9 (95% CI 1.2–13.1)	g	NRS-2002: moderate or severe complications: OR 1.9 (95% CI 1.1–3.5)	p
								Severe complications: OR 2.6 (95% CI 1.1–6.4)	f
				SGA B: severe complications or VLLOS or death: OR 2.0 (1.3–3.3)					f

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Table 2 (*continued*)

Author/ year	Population	Sample size	Tool	LOS[a]	Rating[b]	Mortality	Rating[b]	Complications	Rating[b]
Raslan M, 2011[77]	Internal medicine and surgery	705		SGA B: severe complications and VLLOS and death: OR NS 0.7 (0.1–5.2)					p
				SGA C: Severe complications or VLLOS or death: OR 3.7 (2.0–6.9)					g
				SGA C: Severe complications and VLLOS and death: OR NS 1.3 (0.2–7.4)					p
				NRS-2002: Severe complications or VLLOS or death: OR 1.7 (1.0–2.8)					p
				NRS-2002: Severe complications and VLLOS and death: OR 10.8 (1.5–75.7)					g

[a] LOS = length of stay, VLLOS = very long length of stay OR = Odds Ratio, HR = Hazard Ratio, AUC = area under curve, se = sensitivity, sp = specificity, PPV = positive predictive value, NPV = negative predictive value, PLR = positive likelihood ration, NLR = negative likelihood ratio, NS = not significant.
[b] Rating: g = good, f = fair, g/f = good/fair, p = poor, ? = unable to be rated.

As most of the studies have been discussed in part 3.2 and 3.3 of this manuscript, this will not be repeated here. The comparison between performance of the tools is presented in Table 2. Overall, it is striking to see that most of the tools showed the same tendency when applied in the same population, leading to the conclusion that the general condition of the patient might be more predictive for the outcome than the tool applied. In addition, in the 3 studies investigating both LOS, mortality and complications, none of the tools showed a good predictive validity on all three.

4. Discussion

This review summarises the criterion and construct validity (how well can a tool screen or assess patients' nutritional status?) and the predictive validity (how well can a tool predict LOS, mortality or complications?) of nutrition screening and assessment tools for adult and elderly hospitalized patients.

In total, 83 studies, describing 32 tools were identified.

4.1. Criterion and construct validity

Forty-three studies described the performance of tools to compare patients' nutritional status to a reference method. As described in the Methods section, we considered the assessment tools MNA[3] and SGA,[8] a full nutritional assessment, and an assessment by a professional to be 'valid' reference methods (criterion validity).

Remarkably, as a tool that was specifically designed for the elderly population and is widely used as an assessment tool for the elderly, the MNA[3] has seldom been re-validated. In those scarce studies, its performance varied from fair to good. The short form of the MNA[4] was found to show good agreement to the full MNA,[3] but to have low specificity when compared to other reference methods. Thus, it seems to overestimate the number of undernourished patients.

MUST[1] showed fair to good criterion or construct validity in several studies when applied to adult hospital patients. The performance of MUST[1] for older patients remains to be confirmed. The performance of NRS-2002[2] was inconsistent.

The 'quick and easy' tools, requiring only a few minutes to fill out and not requiring any calculations, usually showed a fair performance to obtain an estimation of a patient's nutritional status. However, taking into account that identified or imminent malnutrition always needs a further assessment, we do not want to condemn these tools outright. They may be useful for screening large groups of patients, in case time is a major constraint.

4.2. Predictive validity

The majority of identified studies used screening/assessment tools to predict clinical outcome. For the elderly subpopulation, none of the tools was found to have good enough predictive validity to advise the implementation of any tool.

SGA is the tool that has been most extensively described for the adult (but not elderly) population.[8] Although the results of the studies were sometimes equivocal, the higher quality studies, which incorporated adjustments for possible confounding factors, indicate fair to good predictive validity of SGA for both LOS, mortality and complications. In about half of the studies, fair to good predictive validity was described for the performance of MUST[1] (for the outcome measures LOS and mortality, but not complications) and NRS-2002[2] (for LOS, mortality and complications).

Some less well-known tools showed good criterion validity or good predictive validity in one or two studies. However, they are rarely used and most of these tools are relatively old. Their

predictive value needs to be reconfirmed in new studies. However, whether they perform better than the more well-known tools should be examined in studies in which their predictive value is compared with other tools.

4.3. Earlier reviews

Although earlier reviews of screening tools were identified, in none of them the subject has been so systematically approached as in this review.

The review by Green and Watson was published in 2005, and does not include many of the newer tools.[87] It focussed on tools to be used by nurses. The authors summarise the range of published screening and assessment tools, and explain their limitations. They do not qualify the tools and advise that tools be chosen dependent on use and patient group.

The review by Van Venrooij was performed systematically, but was limited to 'quick and easy tools' only, thus excluding many of the tools included in the present review.[88] The authors advise to use either MST[5] or SNAQ[6] to screen the general hospital population for malnutrition.

The ASPEN 2011 clinical guidelines on nutrition screening, assessment, and intervention in adults address instruments commonly cited in literature, but is not exhaustive.[89] This manuscript provides a set of guideline recommendations for adult nutrition screening and assessment; screening for nutrition is suggested for hospitalized patients, nutrition assessment is suggested for all patients identified to be at nutrition risk by nutrition screening, and nutrition support intervention is recommended for patients identified as at risk for malnutrition. The review lacks recommendations for the use of individual tools for different patients groups.

The recent review by Skipper is an analysis of the validity and reliability of 11 nutrition screening tools for the hospital setting.[90] The review is limited to a selection of screening and simple assessment tools, it excludes the more complicated tools. Eleven tools were graded based on the quality of the supporting evidence, including reliability and validity. Grade I was assigned to NRS-2002,[2] grade II to MNA-SF,[4] MST,[5] and MUST,[1] and grade III or lower to the other tools studied. MST[5] was the only tool shown to be both valid and reliable for acute care and hospital-based ambulatory care. In contrast to Venrooij's review, SNAQ[6] was not evaluated against a reference standard considered acceptable by the authors, and was thus given a grade V.

Finally, a narrative review published in 2011[91] elaborates on careful decision making in the selection of screening tools, dependent on specific characteristics, e.g. concurrent validity, predictive validity, target population, or intended user (e.g. doctor, nurse, dietitian). This review proposes tool selection based on aim (what is the purpose of screening?), application (care setting, age group, disease background) and process (user implementation, care plan). The data presented in the present review may be helpful for such decision making.

4.4. Elderly

Many of the studies included in this review focussed on validity of tools designed for the elderly. In their recent review Elia and Stratton, highlighted that age per se can often predict mortality and length of hospital stay more effectively than screening tools. Moreover, age is a non-modifiable risk factor. If the primary point of interest would be the prediction of outcome by nutritional intervention, they are weary on relying on age too heavily.[92]

The conclusions drawn in this review are in line with the findings by Elia and Stratton. None of the tools studied was found good enough to be advised as a predictive screening tool in the elderly subpopulation.

4.5. Outpatients

The prevalence of undernutrition among hospital outpatients is relatively low. However, due to the large number of outpatients treated, it still adds up to thousands of undernourished patients per year. Surprisingly, none of the commonly used screening tools for undernutrition has been validated for the outpatient setting. In this review, we identified 2 studies in which outpatients were included. In one, both MUST[1] and SNAQ[6] showed fair validity to screen for undernutrition.[47] In the other, the validity of MST[5] was found to be good compared to the PG-SGA.[43] More studies focussing on the construct and predictive validity of tools for outpatient screening are warranted, especially since care is increasingly shifting to the outpatient setting.

4.6. Nutritional intervention

Screening for undernutrition is useless if this is not accompanied by a nutrition intervention care plan. It is expected that adequate nutritional intervention prevents a further decline of the nutritional status and may have a positive influence on disease outcomes (compared to no treatment). In fact, the NRS-2002 was even designed to select patients who are expected to benefit from nutritional intervention. Contrary to expectations, the majority of studies reviewed did not report on any nutritional intervention, while we think that most of the patients identified as malnourished should have received nutritional support, even if solely for ethical reasons.

Future studies should describe whether or not nutrition intervention has been given. Randomised controlled trials, providing no versus adequate nutritional intervention, can answer the question of the effectiveness of nutritional intervention. However, we fear that these kinds of study protocols will no longer receive ethical approval.

4.7. Studies applying more than 1 tool in the same study population

The most worthwhile studies are those applying different tools in the same population, because these studies avoid bias due to different patient populations, disease backgrounds, or age groups. In the studies describing construct validity, this kind of studies was only scarcely available, whereby the construct validity was expressed versus difference reference methods. For predictive validity, a considerable amount of studies applied more than one tool; however they were carried out in different patient populations and among different age groups. We observed little differences between tools within studies in these comparative studies. None of the tools was predictive for all outcome measures (length of stay, mortality, and complications). If a tool would predict length of stay accurately, it would probably predict mortality only poor or fairly, or the other way around. Moreover, results between studies were inconsistent.

We recommend more of these studies enabling pooling and meta-analyses in the near future.

4.8. Risk of bias

The absence of a gold standard for undernutrition is a hurdle in every study on this topic. By expert opinion, we considered assessment by a professional, a full nutritional assessment, and the assessment tools SGA[8] and MNA[3] as 'valid' reference methods to assess the construct validity of other tools. Of course, opinions may

differ on whether these reference methods are the only, or the best. We therefore chose to also present studies that were compared to – in our opinion – less valid reference methods, thus allowing the reader to draw his own conclusion.

Also, full nutrition assessments were different between studies, ranging from measuring BMI or weight loss to extensive evaluation of laboratory parameters or medical diagnosis. In addition, the use of BMI as a 'gold' reference may be disputed. Even overweight or obese subjects can be at nutritional risk.

Finally, in this review we depended on the information presented in the original paper. This concerns, for example, the definition of the elderly, or the distinction between nutritional assessment, nutritional screening or nutritional risk. Where possible, we tried to elucidate these lacks of clarity, but this was not always possible.

In the Western society, disease is the primary cause of undernutrition. Next to age, disease severity, inflammatory activity, tumour stage and effectiveness of treatment are factors known to carry prognostic value for outcome. Therefore, studies investigating the predictive validity of a nutrition screening tool on prognosis, without adjusting for the other prognostic factors, are considered to be less valuable. In this review, at least half of the studies describing the predictive validity of tools did not adjust for these risk factors. Therefore, we relied most on studies adjusting for covariates.

4.9. Strengths and limitations

One of the strengths of this review is that it provides a complete overview of criterion, validity, construct validity and predictive validity of nutrition screening and assessment tools. The tools have been rated systematically according to a pre-defined list of cut-off points.

We did not describe reliability, repeatability and other clinimetric outcome measures in this review.

This review was limited to tools for the general (adult and elderly) hospitalized population. Disease specific tools, for example those designed for the haemodialysis (renal) population, were not included in this review, neither were tools specific to the nursing home population or for the community. However, reviews addressing these settings are planned for the near future.

4.10. New tools

New tools are still being developed. We strongly advise not to do so. None of the 32 available tools studied proved to be ideal, therefore a new (future) tool is unlikely to become the ideal tool either. Although all of the items that are indicative of nutritional status have been incorporated in earlier tools, either in extensive (assessment) tools or in short (screening) tools, this never resulted in one superior tool. It is unlikely that a new tool, probably differing only slightly from existing tools, will become better than those in existence.

5. Conclusion

This systematic review shows that none of the 32 screening and assessment tools performed consistently well on either screening/assessing patients' nutritional status or predicting (poor) nutrition related outcomes.

For the adult hospital population only MUST[1] showed fair to good criterion or construct validity to different reference methods. All other tools showed worse results. The so-called 'quick and easy' tools lacked sensitivity, and only should be applied with this shortcoming in mind. The well-known SGA[8] did not score well on construct validity. For the older population MNA[3] is widely used, but only few validity studies are available and here the tool did not perform consistently well. Its short form (MNA-SF[4]) overestimates the number of malnourished patients. NUFFE[17] seems to be a valid tool for the elderly, but more validation studies are needed.

None of the studied tools proved to be predictive for all outcome measures (LOS, mortality, complications) in all patient groups, all settings, and across all ages. In fact, for the older population, none of the tools scored well. Age per se is probably a better predictive factor than any of the tools.

For the adult hospital population the well-known SGA,[8] NRS-2002[2] and MUST[1] all showed fair to good predictive validity to predict LOS, mortality or complications. In studies comparing the tools within one patient population, remarkably little differences were found between these tools (and the other tools included in these studies). The less well-known Nutrition Risk Classification[24] showed promising results, but more validation studies are needed.

Therefore, our recommendation would be to never fully rely on one single tool to screen or assess patients' nutritional status. All tools also showed low diagnostic accuracies when compared to the reference methods in different studies and none of the tools showed good predictive validity for all outcome measures. Hence clinical judgement should always remain to play a major role. Screening and assessment tools can always be applied as a first step in nutritional screening, however, the users should be aware of which limitations the tools hold. Patients identified at nutritional risk, always need a further assessment by a professional. In addition, we recommend to use different tools for the adult hospitalized population and for the elderly.

Next steps for future research would be to apply different tools in the same patient population, allowing for comparisons between tools and pooling of results. Studies investigating the predictive validity of tools should focus on the independent predictive value of tools (adjusted for possible confounders). The development of new tools seems redundant and will most probably not lead to new insights.

Statement of authorship

MAEvB and HCWdV designed the study. EPJ performed the systematic literature search. PRG and MAEvB judged eligibility of papers and performed data extraction. MAEvB and PRG drafted the manuscript. All authors contributed to the writing of the manuscript. All authors approved the final version of the manuscript.

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Conflict of Interest

None declared.

Appendix A. Supplementary material

Supplementary material associated with this article can be found in online at http://dx.doi.org/10.1016/j.clnu.2013.04.008.

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