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A systematic review and meta-analysis of the criterion validity of nutrition assessment tools for diagnosing protein-energy malnutrition in the older community setting (the MACRo Study)

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Abbreviations

CASP: Critical Appraisal Skills Programme

CKD: Chronic kidney disease

COPD: Chronic obstructive pulmonary disease

GRADE: Grading of Recommendations, Assessment, Development and Evaluation

MACRo: Malnutrition in the Aging Community Review

MNA: Mini Nutritional Assessment

SGA: Subjective Global Assessment

PEM: Protein-energy malnutrition

PG-SGA: Patient-Generated Subjective Global Assessment

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis

PROSPERO: International Prospective Register of Systematic Reviews

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Abstract

Background & aims: Malnutrition is a significant barrier to healthy and independent ageing in older adults who live in their own homes, and accurate diagnosis is a key step in managing the condition. However, there has not been sufficient systematic review or pooling of existing data regarding malnutrition diagnosis in the geriatric community setting. The current paper was conducted as part of the MACRo (Malnutrition in the Ageing Community Review) Study and seeks to determine the criterion (concurrent and predictive) validity and reliability of nutrition assessment tools in making a diagnosis of protein-energy malnutrition in the general older adult community.

Methods: A systematic literature review was undertaken using six electronic databases in September 2016. Studies in any language were included which measured malnutrition via a nutrition assessment tool in adults ≥65 years living in their own homes. Data relating to the predictive validity of tools were analysed via meta-analyses. GRADE was used to evaluate the body of evidence.

Results: There were 6,412 records identified, of which 104 potentially eligible records were screened via full text. Eight papers were included; two which evaluated the concurrent validity of the Mini Nutritional Assessment (MNA) and Subjective Global Assessment (SGA) and six which evaluated the predictive validity of the MNA. The quality of the body of evidence for the concurrent validity of both the MNA and SGA was very low. The quality of the body of evidence for the predictive validity of the MNA in detecting risk of death was moderate (RR: 1.92 [95%CI: 1.55-2.39]; *P*<0.00001; n=2,013 participants; n=4 studies; I^2: 0%). The quality of the body of evidence for the predictive validity of the MNA in detecting risk of poor physical function was very low (SMD: 1.02 [95%CI: 0.24-1.80]; *P*=0.01; n=4,046 participants; n=3 studies; I^2:89%).

Conclusions: Due to the small number of studies identified and no evaluation of the predictive validity of tools other than the MNA, there is insufficient evidence to recommend a particular nutrition assessment tool for diagnosing PEM in older adults in the community. High quality diagnostic accuracy studies are needed for all nutrition assessment tools used in older community samples, including measuring of health outcomes subsequent to nutrition assessment by the SGA and PG-SGA.

Keywords: Protein-energy malnutrition, nutritional status, nutrition assessment, community, aged, systematic review

Introduction

One of the largest challenges in helping older adults to remain independent in their own homes is protein-energy malnutrition (PEM), a predictor of hospitalisation, institutionalisation and mortality [1]. PEM is the involuntary loss of lean tissues such as muscle, viscera, and blood and immune cells, with or without loss of subcutaneous fat, as a result of inadequate energy, protein and other nutrients over time [2,3]. As a result of decreased muscle mass and other lean tissues, PEM results in decreased physical function and quality of life [4,5]. Older adults are particularly at risk of PEM due to physiological and social challenges that occur with ageing, such as social isolation, financial strain, multi-morbidities, polypharmacy, and a decreased appetite, frequently referred to as the "anorexia of ageing" [5,6]. The first step in improving the nutrition-related independence and wellbeing of older adults living at home is the accurate identification of PEM, so that appropriate intervention may follow [7].

Nutrition screening is a process whereby a quick and simple validated nutrition screening tool is implemented to identify risk of malnutrition, and should precede diagnostic assessment [8]. Nutrition assessment tools differ from malnutrition screening tools in that they are a multidimensional and global assessment tool which are applied by a qualified health professional such as a dietitian or a physician [9]. Owing to the nature of their multidimensional and detailed approach, they may be used to diagnose PEM. There are three accepted nutrition assessment tools used in practice: the Subjective Global Assessment (SGA) [10], the scored Patient-Generated Subjective Global Assessment (PG-SGA) [11] and the Mini Nutritional Assessment (MNA) [12]. Short versions of the MNA and PG-SGA (the MNA-Short Form and the PG-SGA-Short Form) are available. The intended use of these shorter forms is for screening for malnutrition, not assessment. A review of the validity of nutrition assessment tools was evaluated by Green and Watson in 2006 [13] (literature searched up until 2002) and Watterson et. al. in 2009 [14] (literature searched up until 2006). However, in addition to requiring

an update, these reviews did not pool data, used narrow search terms, and did not critically appraise studies nor the body of evidence. Therefore, further investigation of the criterion validity of nutrition assessment tools in older adults in the community-setting is warranted.

The MACRo (Malnutrition in the Ageing Community Review) Study was undertaken to systematically review, quantify, and critically appraise all existing epidemiological international literature concerning malnutrition prevalence, methods of risk detection and diagnosis, predictors of community-acquired malnutrition and long-term outcomes of the condition in older community-dwelling adults. Due to the significant amount of research undertaken on this topic, as well as diverse clinical interests in the findings, the results will be reported in a series of articles. This article reports the results of the following research question: What is the criterion (concurrent and predictive) validity and reliability of nutrition assessment tools in making a diagnosis of PEM in the general older adult community?

Materials and methods

This study protocol is reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2015 Statement [15] and flow diagram (Figure 1). This study has been registered with the International Prospective Register of Systematic Reviews (PROSPERO number: CRD42016051241).

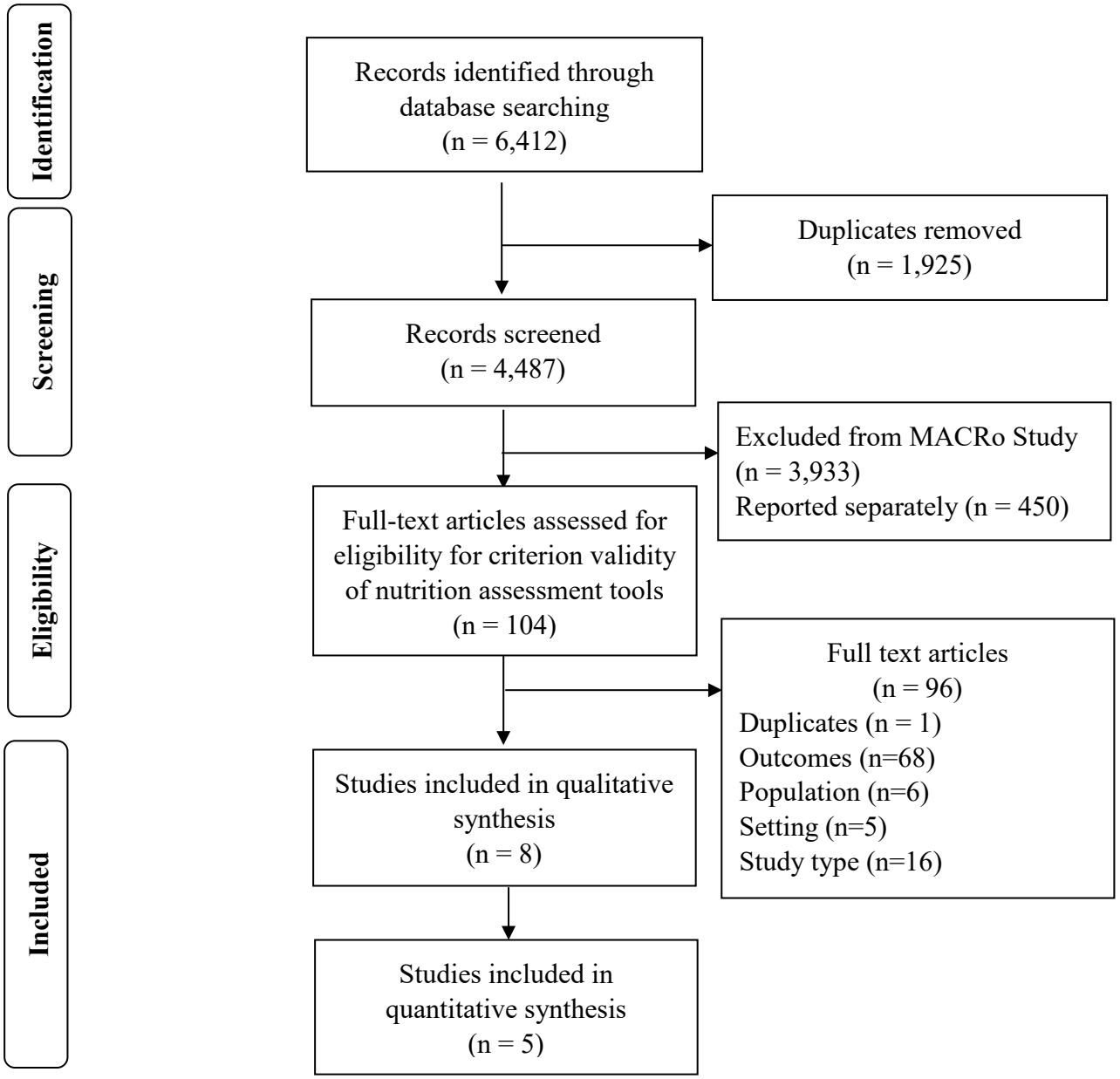

Figure 1: Flowchart of the MACRo Study search and the included studies which evaluate the criterion validity of nutrition assessment tools.

Search strategy

Peer-reviewed published studies, in any language, were searched for in the electronic databases: The Cochrane Library, CIHAHL (via Ebscohost), EMBASE, Health Source: Nursing/Academic Edition (via Ebscohost), MEDLINE (via PubMed) and Web of Science for publications from database inception to the 13 September 2016. The search strategy used a combination of keywords and each databases' controlled vocabulary (appendix). A snowball search was conducted to complement the systematic search using the reference lists of the included studies and studies included in earlier reviews.

Eligibility criteria: types of participants and setting

Inclusion criteria for types of participants were older adult samples with a mean age of ≥65 years living independently in the community (including post hospital discharge, outpatients, and medical centres), who were assessed for PEM using a nutrition assessment tool. Participants included in the current study were the general older population living in the community. Results in disease-specific samples will be reported separately. Observational, interventional (baseline or control group only), cross-sectional, retrospective and cohort studies were considered for inclusion. Exclusion criteria for participants were those assessed as inpatients of acute or sub-acute facilities (excepting observational assessment post-discharge), day hospitals, or were living in residential aged care (including nursing homes). Data where community samples were combined with patients in these settings were also excluded; however, studies which used "nationally representative data" where results were not delineated by setting were not excluded. Intervention studies were excluded for evaluation of predictive validity due to the confounding effect of intervention on prediction of outcomes. Exclusion criteria for study types were abstracts, conference papers, qualitative studies, study protocols, opinions, commentaries, news articles and reviews.

Eligibility criteria: Criterion validity of nutrition assessment tools

To answer the research question, eligible studies were required to evaluate the criterion validity or reliability of a nutrition assessment tool's ability to diagnose PEM (not risk of PEM). Reflecting this, studies in which no participants were malnourished were excluded. For the MNA, malnutrition was considered at an MNA score <17 (score 17-30 at risk/well-nourished) as per the MNA instructions [16]; for the SGA and PG-SGA, malnutrition was considered as rating B (moderately malnourished) & C (severely malnourished) as per their instructions [10,11]. Studies which evaluated the validity and reliability of modified versions of the MNA, SGA and PG-SGA were included and modifications described.

Selection of studies

Identified citations from all databases were imported into EndNote [Version X7.7, 2016, Thomson Reuters] and duplicates removed by two independent review authors (SM and DC). A two-step screening process was employed for the first phase of study selection. In step 1, two authors independently scanned the titles and abstracts of studies identified by the search for their potential eligibility. At step 2, potentially eligible articles to address each MACRo study research question were separated into participant groups by one author.

In the second phase of study selection, full-text articles were screened independently by two review authors to determine eligibility for inclusion. Disagreements regarding eligibility were discussed to reach consensus.

Data extraction and management

Criterion validity is composed of two types of validity assessment: concurrent and predictive. Concurrent validity is determined by comparing the score of a new measurement to the score of a well-established measurement, or gold standard, for the same construct. Data extracted to reflect the concurrent validity were measures of diagnostic accuracy tests, including sensitivity (malnourished correctly identified as such), specificity (well-nourished correctly identified as such), positive predictive value (correctly identified as malnourished within malnourished

sample), negative predictive value (correctly identified as well-nourished within the well-nourished sample), weighted kappa statistics (agreement of categories) and receiver operating characteristics (ROC) curve (discriminative power of a continuous score) [17]. For a nutrition assessment tool, there are no generally accepted a-priori values for sensitivity and specificity, though it would be clinically necessary to have a balance between both high sensitivity and specificity. Consideration of the reference standard used was also considered when interpreting concurrent validity, as this may vary considerably due to the absence of a gold standard for PEM diagnosis [6].

For a nutrition assessment tool, predictive validity is usually evaluated by determining a tool's ability to predict health-related outcomes known to be a consequence of PEM, such as hospitalisation and mortality [6]. Outcomes were considered only if they were measured subsequently to the implementation of the nutrition assessment tool, with a timeframe from one week to 10 years considered. For the current study, the following categorical health-related variables were considered: mortality, hospitalisation, institutionalisation, pressure ulcer/injury, and falls; and continuous variables: hospitalisation cumulative length of stay (LOS), cumulative duration of pressure ulcers, depression, physical function, and quality of life. All data was described qualitatively in tables as well as pooled where possible. Where participants were not classified dichotomously as malnourished and well-nourished, or diagnostic accuracy tests were not performed, raw data extracted from the results was used to determine diagnostic test accuracy wherever possible. For studies with missing data, the study authors were contacted. Extracted data from published papers was undertaken by one author (SM), with a random sample of 20% reviewed by a second author (DC) for accuracy.

Review of study strength and quality

External and internal study quality (including risk of bias) for individual studies was evaluated by two tools depending on the study type. The Critical Appraisal Skills Programme (CASP)

Diagnostic Checklist [18] was chosen to appraise the study quality of studies which evaluate the concurrent validity of nutrition assessment tools. This was chosen as diagnostic studies have unique considerations for internal and external quality. The Academy of Nutrition and Dietetics' Quality Criteria Checklist: Primary Research was chosen to evaluate studies reporting on the predictive validity of nutrition assessment tools, and designates studies as having positive (strong quality), neutral (neither strong nor weak quality) or negative (weak quality) assessment [19]. This tool was chosen to critically appraise study quality as it is applicable for all original research study designs, and evaluates the external validity in respect to nutrition-related conditions. The appraisal of study quality was conducted independently by two authors (SM and DC). Disagreements were discussed and reported.

The certainty in the body of evidence for each outcome of interest was classified using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach [20]. This approach has four levels of quality: high (very confident the true effect lies close to that estimated), moderate (moderately confident in the effect estimate), low (confidence in the effect estimate is limited) and very low (very little confidence in the effect estimate). The determination of the quality GRADE level was determined independently by two authors (SM and JK), with disagreements managed by consensus.

Meta-analysis

Pooled data was analysed using Revman [Review Manager 5, Version 5.3, 2014, Cochrane Informatics & Knowledge Management Department]. Pooled outcomes were calculated using nutrition assessment tools as a dichotomous variable of "malnourished" and "well-nourished", where well-nourished includes the "at risk of malnutrition" category for the MNA. Dichotomous outcome data was expressed as risk ratios (RR) with 95% confidence intervals, using the Mantel-Haenszel test. Effect sizes for continuous outcome data were calculated as mean differences (MD) for studies which used the same assessment tool, and standardised

mean differences (SMD) for studies which used different assessment tools for the same construct, with 95% confidence intervals, using the inverse variance test. SMD effect sizes of <0.4 were considered small, 0.4 – 0.7 moderate, and >0.7 large [21]. Where a SMD was used, this was re-expressed into the scale of one the included instruments by multiplying the SMD by the standard deviation of that tool reported in the total sample [22]. Where two or more tools had scales with opposite directions of physical function (e.g. lower score indicates worse physical function instead of better physical function), one of the directions was multiplied by -1 to ensure scales followed the same direction [23]. Acknowledging that malnutrition has significant variance in its presentation between individuals and within sample populations, a random effects model was used for both categorical and continuous variables. If the required data of included studies was not reported, or could not be calculated or obtained, the results of the study were excluded from meta-analysis and described qualitatively. Heterogeneity between studies was assessed using the I^2 statistic, and was considered substantial if I^2 was >50%. Where sensitivity analysis was required, analysis was repeated excluding studies with low study quality/high risk of bias, timeframe of the reported outcome, study design or participant characteristics. No subgroup analyses were found to be necessary to answer the research hypothesis.

Results

Search results and included studies

The search identified 6,412 records, of which 1,925 were removed as duplicates (Figure 1). The two authors agreed on a total of 104 potentially eligible records evaluating the criterion validity and/or reliability of a nutrition assessment tool in the general older adult community setting. Following full-text review, eight studies were found to be eligible (Figure 1). Studies were included from Europe (n=4 studies), Asia (n=3 studies) and South America (n=1 studies) (Table 1 and Table 2). Most study samples were recruited via home care (n=5 studies); and, two studies were conducted on the same nationally representative sample in the People's

Republic of China (Taiwan). Nutrition assessment tools were completed by nurses (n=2), trained researchers (n=2), or personal/domiciliary carers (n=1); none appear to have been completed by dietitians, although the tool was completed by "nutrition scientists" in one study (Table 2). Additionally, the two studies in the People's Republic of China (Taiwan) using the same nationally representative dataset did not complete any nutrition assessment tool with older adults, but rather constructed the MNA-T2 (MNA Taiwan-version 2) tool based on items from a larger generic health-based questionnaire [24,25]. The MNA-T2 differs from the usual MNA by using Taiwanese-specific anthropometric cut-off points. Furthermore, two items of the MNA-T2 could not be obtained by the researchers (pressure ulcers and fluid intake) so the score was proportionately adjusted where a score of 16.5 or less indicated malnutrition, 17-23.5 indicated risk of malnutrition, and 24 or more indicated normal nutrition status [24]. No studies were identified which evaluated the reliability of nutrition assessment tools in this setting. No new global and multidimensional nutrition assessment tools were identified.

Table 1: Comparison of concurrent validity of nutrition assessment tools evaluated in the community setting

Study	Nutrition assessment	Population	Sensitivity[a]	Specificity[a]	Positive Predictive Value[a]	Negative Predictive Value[a]	Kappa[b]	ROC AUC[c]	CASP[d] risk of bias
Kozakova 2012. Data pooled: No.	**Tool:** MNA[e]/ SGA[f,g] **Benchmark:** MNA/SGA	n=120, μ age 73.24 years (SD not reported). **Country:** Czech Republic & Slovakia **Setting:** Home care **Assessed by:** Research nurses.	71.7 (56.5-84.0)	86.5 (76.6-93.3)	76.7 (61.4-88.2)	83.1 (72.9-90.7)	Not reported	Not reported	High
Kozakova 2014. Data pooled: No.	**Tool:** SGA **Benchmark:** Nutrition assessment not further described[h]	n=470, μ age 77.3 years (SD not reported). **Country:** Czech Republic **Setting:** Home care **Assessed by:** 10 trained nurses.	93.3 (95%CI not reported)	70 (95%CI not reported)	62.6 (95%CI not reported)	98.4 (95%CI not reported)	Not reported	Not reported	High
Kozakova 2014. Data pooled: No.	**Tool:** SGA **Benchmark**: MNA[i]	As above.	Not reported	Not reported	Not reported	Not reported	0.442 (95%CI not reported)	Not reported	As above.

a data presented %, 95% confidence interval.

b data presented as kappa coefficient, 95% confidence interval, p-value.

c ROC AUC, Receiver Operating Characteristic Area Under the Curve. Data presented as AUC value ± standard error, 95% confidence interval, p-value.

d CASP, Critical Appraisal Skills Programme

e MNA, Mini Nutritional Assessment. MNA score of <17 indicates malnutrition.
f The comparative validity of the MNA and SGA was assessed by comparing each assessment tool against the other, where the authors considered both tools as the reference standard.
g SGA, Subjective Global Assessment. SGA ratings B and C indicate malnutrition.
h Authors report that for the reference standard, participants were grouped into two categories: good nutritional status and nutritional risk, based on their nutrition status. The nutrition risk category was created by fusing the risk of malnutrition and malnutrition categories together. However, it is unclear what was used to inform the nutritional status used to create these two categories. It cannot be the MNA, SGA or the Malnutrition Universal Screening Tool, as all these tools were compared against this standard.
i SGA (rating B & C) compared against the MNA dichotomised at <24; therefore, including both “at risk of malnutrition” and “malnourished” MNA categories for the kappa coefficient.

237 **Table 2**: The predictive validity of the Malnutrition Screening Tool (MNA) in the community setting

Study	Population	Time-point	Malnourished with outcome[a]	Well-nourished with outcome[b]	Reported results	AND[c] study quality
Mortality						
Ferreira 2011. Data pooled: Yes.	n=1170, μ age not provided. n=675 in 60-74 year age group; n=495 in ≥75 year age group. **Country:** Brazil **Setting:** Home **Assessed by:** trained health professionals and nutrition trainees	7 years	17/30 (56.7%)	315/1140 (27.6%)	Compared with well-nourished (MNA score 24-30) adjusted odds of mortality in malnourished (MNA score <17) was: - OR: 6.05 (95%CI 5.75-6.35) for 60-74 years - OR: 2.76 (95%CI 2.51-3.04) for ≥75 years	Positive
Inoue 2007. Data pooled: Yes.	n=181, μ age 78.9±8.7 years. **Country:** Japan **Setting:** Home care **Assessed by:** trained operators	3 years	14/45 (31.1%)[d]	18/136 (13.2%)[d]	Compared with well-nourished (MNA score 24-30) via adjusted hazard ratio of mortality in malnourished (MNA score <17) was: - HR:14.05 (95%CI: 3.171-64.242)	Neutral
Kiesswetter 2014. Data pooled: Yes.	n=353[e], μ age 80.9±7.9 years. **Country:** Germany **Setting:** Home care **Assessed by:** nutrition scientists	1 year	12/42 (28.6%)	33/267 (12.4%)	Compared with well-nourished (MNA score 24-30), adjusted hazard ratio of mortality in malnourished (MNA score <17) was: - HR: 8.75 (95%CI: 2.45-31.18)	Neutral
Lee 2012 and Wang 2013[f]. Data pooled: Yes.	n=2948, μ age not provided. n=1866 in 65-74 year age group; n=1082 in ≥75 year age group. **Country:** China (Taiwan) **Setting:** Nationally representative data, not further described.	4 years	70/90 (76.9%)	591/2857 (20.7)	Compared with well-nourished (MNA score 24-30), adjusted hazard ratio of mortality in malnourished (MNA score <17) was: HR: 3.26 (95%CI: 2.31-4.6; P<0.001).	Both studies were Neutral

	Assessed by: Constructed in research setting based on individual data collected during the Taiwan Longitudinal Survey on Aging (TLSA) researchers[g].					
Saletti 2005. Data pooled: Yes.	n=353, μ age 83.0±6.8 years. **Country:** Sweden **Setting:** Home care **Assessed by:** Personal / domiciliary carers	3 years	14/29 (50%)[h]	108/324 (33.3%)[h]	Compared with well-nourished (MNA score 24-30), mortality rates in malnourished (MNA score <17) were significantly higher (*P*=0.03).	Positive
Physical function						
Kiesswetter 2014. Data pooled: Yes.	Reported above.	1 year	Not reported.	Not reported.	Barthel Index mean scores (±SD) are: Malnourished (MNA score <17): - 32.3±25.9 (n=30) At risk of malnutrition (MNA score 17 – 23.5) - 53.9±25.8 (n=148) Well-nourished (MNA score 24-30) - 76.5±25.8 (n=86). Scores differed significantly across groups (*P*<0.05)	Neutral
Lee 2012[e]. Data pooled: Yes.	Reported above.	4 years	Became or remained ADL[i]-dependent 3/21 (14.3%). Became or remained IADL[j]-dependent	Became or remained ADL-dependent 47/225 (20.9%). Became or remained IADL-dependent	ADL mean scores (±SD) are: Malnourished (MNA score <17): - 2.4±4.9 (n=21) At risk of malnutrition (MNA score 17 – 23.5) - 3.6±5.9 (n=225) Well-nourished (MNA score 24-30) - 1.2±3.8 (n=1944).	Neutral

			17/21 (81.0%).	127/225 (56.4%).	Scores differed significantly malnourished and at-risk groups (*P*<0.05) IADL mean scores (±SD) are: Malnourished (MNA score <17): - 9.4±5.3 (n=21) At risk of malnutrition (MNA score 17 – 23.5) - 7.5±6.6 (n=225) Well-nourished (MNA score 24-30) - 3.7±5.4 (n=1944). Scores differed significantly malnourished and at-risk groups (*P*<0.05)	

a For categorical/dichotomous outcomes, data reported number with the outcome at the time-point/number malnourished (MNA score <17) in sample at baseline (% with outcome within malnourished sample).

b For categorical/dichotomous outcomes, data reported number with the outcome at the time-point/number well-nourished (including at risk of malnutrition, MNA score 17-30) in sample at baseline (% with outcome within well-nourished sample).

c AND, Academy of Nutrition & Dietetics

d Data was not reported in the study publication but was provided by authors in an email dated 07/03/2017.

e n=309 (87.5%) were assessed by the MNA

f The study results on the same sample were reported across two studies, Lee 2012 and Wang 2013; Lee 2012 reported the number of deaths per category. These studies used the Taiwan Version 2 (MNA-T2) as opposed to the traditional English-language MNA. This tool adopts the Taiwanese-specific anthropometric cut-off points and replaced calf circumference with BMI.

g Data for all items in the long-form MNA (MNA), except items pressure sore/skin ulcers and fluid intake, were available in the survey database. So, the MNA was based on fifteen items with a maximum score of 28 points, rather than seventeen items for 30 points. However, the total score was proportionately adjusted on the full-score basis. A final score of 16·5 or less suggests malnourishment; 17–23·5, at risk of malnutrition; and 24 or more, normal.

h Mortality data was reported as a percentage per MNA category for 224 of the 535 who had mortality data available on public registers. However, the number of participants in the 224 subsample each MNA category was not reported. Therefore, mortality data was extrapolated to the large sample size (e.g. 50% died in malnourished group was reported as 14/29 although exact figures are not known).

i ADL, Activities of Daily Living. ADL was measured by a questionnaire adapted from the 1984 National Health Interview Survey Supplement on Aging. Becoming or remaining dependent was considered if the participant had 1 or more dependencies.

j IADL, Instrumental Activities of Daily Living. IADL was measured by a questionnaire adapted from the 1984 National Health Interview Survey Supplement on Aging. Becoming or remaining dependent was considered if the participant had 1 or more dependencies.

The concurrent validity of nutrition assessment tools in the community

There were two studies reporting the concurrent validity of the MNA and SGA (Table 1). Two other studies were identified which reported diagnostic accuracy for the MNA; however, one study was excluded as the reference standard was the Fried Frailty Index, a construct which does not represent malnutrition and therefore does not inform on the ability of the MNA to diagnose malnutrition [26]. The second study was excluded as the authors did not report which score was used to dichotomise the MNA categories, the reference standard was not reported in the publication and this missing information could not be obtained [27]. No studies were identified which evaluated the criterion validity of the Scored PG-SGA.

In the 2012 study, the MNA (score <17 indicating malnutrition, score 17-30 indicating well-nourished) and SGA (rating B and C indicating malnutrition, rating A indicating well-nourished) were compared with each other, where neither tool was considered the "reference standard" [28]. This study provided the results in a contingency table, and therefore the diagnostic accuracy tests were performed by the current study authors (SM and checked by DC). When compared against each other, the SGA and MNA had good specificity; however, the sensitivity was lower (Table 1). Kozakova et. al. (2014) further compared the MNA and SGA against each other via a kappa coefficient in a larger sample, which revealed moderate agreement. However, the MNA included both the at risk of malnutrition and malnourished categories for this test (score <24 indicating malnutrition, score 24-30 indicating well-nourished) and therefore the two tools would be expected to have less agreement due to inconsistent categorisation [29]. In the 2014 Kozakova study, the SGA was found to have strong sensitivity but a lower specificity compared to an unknown benchmark which represents both risk of malnutrition and malnutrition. Both studies were considered to have high risk of bias (Online Supplementary Material). The quality of the evidence (GRADE) for the concurrent validity of both the MNA and SGA was "very low" (Table 3).

The predictive validity of nutrition assessment tools in the community

Studies which report the predictive validity of nutrition assessment tools were only found for the MNA (n=6 studies). Mortality was reported by five studies, and physical function (using three different measurement tools) was reported by two studies (Table 2). Although Lee and Tsai [24] and Wang and Tsai [25] were both included, their results were on the same study sample, overseen by the same senior author, and both used the MNA-T2 so were reported together (Table 2). No other outcomes were reported to evaluate the predictive validity of nutrition assessment tools in the community.

Regarding mortality, the time to follow-up ranged from 1 – 7 years, and included samples from Asia, Europe and South America. The number of deaths per MNA category were not provided in the study reported by Inoue and Kato [30]; however, the study authors provided this data by email. There was high heterogeneity in the meta-analysis of mortality when all five studies were included (RR: 2.30 [95%CI: 1.43 – 3.70]; P<0.0006; n=6,152 participants; n=5 studies; I^2: 89%). However, sensitivity analysis reduced the heterogeneity to I^2: 0% when Lee and Tsai [24], which used the MNA-T2, was deselected, as this version differs to the usual MNA in several ways. This result showed that the MNA categorisation of malnutrition (MNA score <17) was able to predict a two-fold risk of death compared to community dwelling older adults categorised as at risk of malnutrition or well-nourished (MNA score 17-30) (RR: 1.92 [95%CI: 1.55-2.39]; P<0.00001; n=2,013 participants; n=4 studies; I^2: 0%) (Figure 2). Two included studies were considered to have positive quality, two to have neutral quality (Online Supplementary Material). The quality of the evidence (GRADE) for the predictive validity of the MNA in detecting risk of death was “moderate” (Table 3).

Table 3: Quality of the body of evidence for each outcome of interest reflecting the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach

Outcome	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias[a]	Quality of evidence (GRADE)[b]
Concurrent validity of the MNA	Very serious[c]	Not applicable	Serious[d]	Not serious	Could not be assessed	⊕◯◯◯ Very Low
Concurrent validity of the SGA	Very serious[c]	Not applicable	Serious[d]	Serious (data not reported)	Could not be assessed	⊕◯◯◯ Very low
Predictive validity of the MNA (mortality)	Serious[e]	Not serious	Not serious	Not serious	Could not be assessed	⊕⊕⊕◯ Moderate
Predictive validity of the MNA (physical function)	Serious[f]	Serious[g]	Not serious	Serious[h]	Could not be assessed	⊕◯ ◯◯ Very Low

a. Could not be assessed for any outcome due to the small number of included studies.
b. Graded on a scale of high, moderate, low to very low quality of evidence. Each study was downgraded one level for having a "serious" limitation, and downgraded two levels for a "very serious" limitation to the quality of all studies informing the outcome.
c. Found to have a high risk of bias when evaluated using the CASP diagnostic checklist (Online Supplementary Material)
d. Low generalisaibility due to poor description of the persons who undertook the nutrition assessment, their level of training, how the nutrition assessment was completed, and representing only one study sample.
e. Two were found to have positive study quality and three neutral study quality by the AND tool (Online Supplementary Material).
f. Both studies were found to have neutral study quality by the AND tool (Online Supplementary Material).
g. The meta-analysis of this outcome variable showed substantial heterogeneity.
h. The meta-analysis of this outcome variable showed a substantial confidence interval.

Physical function was measured 1-year and 4-years following nutritional assessment. It was not possible to compare the malnourished participants to the combined well-nourished and at risk of malnutrition groups, so analysis was repeated comparing malnutrition to each MNA category respectively. The results by Lee and Tsai [24] were entered twice as they presented data using two measures of physical function (Table 2). There were significant results when participants in the malnourished category (MNA score <17) were compared to the well-nourished category (MNA score 24-30), revealing a large but imprecise effect size of physical dysfunction in the malnourished group (SMD: 1.02 [95%CI: 0.24-1.80]; *P*=0.01; n=4,046 participants; n=3 studies; I^2:89%) (Figure 3). When transformed back into the Barthel Index on a scale of 0 – 100, where a higher score indicates better physical function, the MNA predicted a difference of 29.4 points between the MNA malnourished and well-nourished categories. The Barthel Index was chosen to represent the difference in physical function as this was the only tool represented in the meta-analysis which has been well described and validated for use in older adults [31]. The high heterogeneity, which did not significantly improve with sensitivity analysis, is likely due to the differences in the MNA tool used between Lee and Tsai [24] and Kiesswetter [32], as well as the use of three different physical function assessment tools, which may represent different constructs of physical function. The meta-analysis found no significant result when malnutrition (MNA score <17) was compared to at risk of malnutrition (MNA score 17-23.5), and this did not improve with sensitivity analysis (SMD: 0.32 [95%CI: -0.28-0.91]; *P*=0.30; n=670 participants; n=3 studies; I^2: 82%). The two studies which reported the physical function were both rated as having neutral quality (Online Supplementary Material). The quality of the evidence (GRADE) for the predictive validity of the MNA in detecting risk of poor physical function was “very low” (Table 3).

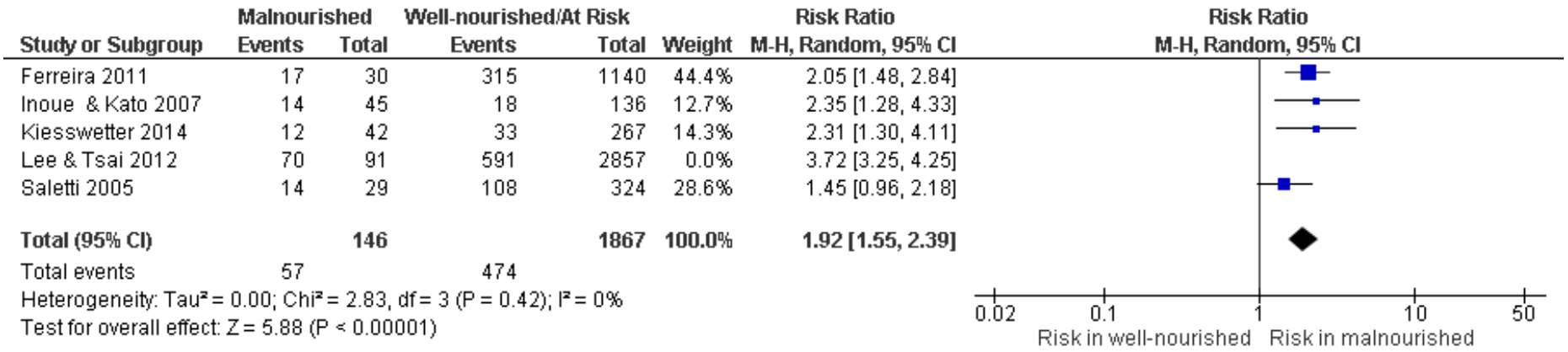

Figure 2: The relative risk of death in malnourished (MNA score <17) compared to risk of malnutrition/well-nourished (MNA score 17-30) community-dwelling older adults as determined by the Mini Nutritional Assessment (MNA).

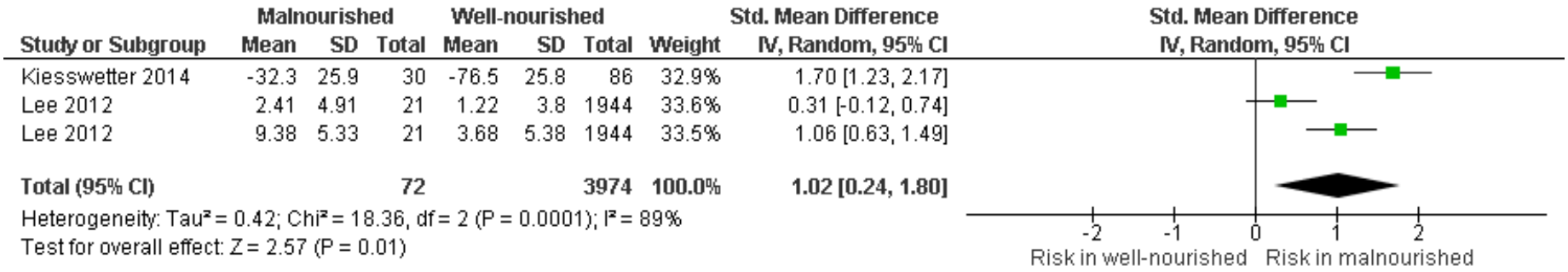

Figure 3: The standardised mean difference in physical function between malnourished (MNA score <17) compared to well-nourished (MNA score 24-30) community-dwelling older adults as determined by the Mini Nutritional Assessment (MNA).

Discussion

This is a comprehensive systematic literature review and meta-analysis of the criterion validity of nutrition assessment tools in the community for the diagnosis of PEM. Overall, few studies have evaluated the criterion validity and no studies have evaluated the reliability of nutrition assessment tools in this setting. The results presented in this study reveal that although nutrition assessment tools are frequently used by clinicians and researchers in the older community setting, the current body of evidence provides very little confidence in their diagnostic accuracy indicated by having a "very low" quality of evidence across all studies (Table 3). The 2012 study by Kozakova et. al. [33] found that when the MNA and SGA are compared against each other, there is adequate specificity (86.5%) but inadequate sensitivity for a nutrition assessment tool (71.7%). The poor sensitivity between the SGA and MNA agrees with previous research in other settings which has found that the MNA and SGA do not consider the same patients as malnourished, where the MNA has been considered to underestimate malnutrition (MNA score <17) when compared to various reference standards [6].

In the 2014 study by Kozakova et. al. [29], the SGA was reported to have excellent sensitivity (93.3%) but inadequate specificity (70%); however, it is likely that the true specificity is higher as the unknown reference standard used was reported to include both "malnourished" and "at risk of malnutrition" individuals, which would lead to a lower reported specificity. Overall, these two studies contribute little to the understanding of the concurrent validity of the MNA and SGA in the older adult community. Both were found to have a high risk of bias due to both studies being completed by non-blinded researchers who undertook all data collection, a lack of appropriate diagnostic accuracy statistics, no description of the training of the researchers who do not have backgrounds in nutrition, and reference standard used to evaluate the SGA was unknown (Online Supplementary Material). Although it must be acknowledged that the lack of a gold standard in diagnosing PEM lends to difficulties in identifying an

appropriate reference standard to evaluate the concurrent validity of nutrition assessment tools, the reference standard should be multidimensional, represent PEM, and be well described. Although the current study revealed a poor quality of evidence regarding the diagnostic accuracy of nutrition assessment tools in the community setting, the MNA, SGA and PG-SGA have undergone more rigorous evaluation in acute, subacute and disease-specific populations [6,12,34-37].

Only the MNA could be evaluated for predictive validity. This study found that the current body of evidence provides moderate confidence in the ability of the MNA category of malnutrition to predict the risk of death 1 to 7 years following the diagnosis of malnutrition. However, the body of evidence provides only very limited confidence for the ability of the MNA to predict physical dysfunction. Although the MNA has not been evaluated appropriately for concurrent validity, the finding that it has good predictive validity for risk of death is clinically relevant, as prediction of poor health outcomes may be of more clinical significance by indicating the need for intervention, than diagnostic accuracy in the community setting.

Further diagnostic accuracy, reliability and prognostic studies in the general older community will help guide which nutrition assessment tool is best suited to this setting. However, until further research is undertaken to guide tool selection, nutrition assessment should continue to be done to identify patients that may be malnourished; however, monitoring response to intervention is of high importance in the absence of evidence for accurate and reliable diagnostic tools [7]. Additionally, poor sensitivity in the nutrition assessment tools suggests that intervention may be necessary for some individuals identified as at risk of malnutrition or with borderline results, either to prevent malnutrition from developing or to provide treatment to an individual inaccurately identified as “well-nourished”. As per best practice guidelines, such treatment should be individualised [14].

Limitations

This systematic literature review is limited in that it did not include grey literature and was unable to obtain complete results for all studies. This was due to poor reporting in some original studies and because most authors were unable to be contacted or they no longer had access to the raw data to generate the results needed for this review. Although the literature search conducted for this study was comprehensive, there remains the possibility that important studies were missed due to not being included in the search or mistakenly excluded by review authors. The results of the criterion validity of nutrition assessment tools were narrowed by excluding studies undertaken with samples combining community-dwelling participants with inpatient or residential aged care participants, as this led to the exclusion of otherwise eligible studies. This study did not evaluate nutrition assessment tool translation or discriminant validity, or responsiveness. Therefore, future systematic reviews are needed to evaluate these important aspects of nutrition assessment.

Conclusions

This review found that no nutrition assessment tool has undergone sufficient evaluation for concurrent validity in community-dwelling older adults. There is moderate confidence in the ability of the MNA to predict a two-fold risk of death and very limited confidence in its ability to predict physical dysfunction following nutrition assessment. Due to the small number of studies identified and no evaluation of the predictive validity of tools other than the MNA, there is insufficient evidence to recommend a particular nutrition assessment tool for diagnosing PEM in older adults in the community; however, nutrition assessment should continue to be undertaken to ensure malnourished patients are managed and supported. High quality diagnostic accuracy studies are needed for all nutrition assessment tools in non-disease specific older community samples; and studies are needed which measure health outcomes subsequent to nutrition assessment by the SGA and PG-SGA.

Highlights

- Quality of the evidence for the concurrent validity of the MNA and SGA was very low
- Quality of the evidence for the MNA to predict risk of death was moderate
- Quality of the evidence for the MNA to predict risk of physical dysfunction was very low
- There is insufficient evidence to recommend a particular nutrition assessment tool
- High quality diagnostic studies are needed for all nutrition assessment tools

Declarations

Competing interests

The authors declare that they have no financial, personal or potential competing interests.

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Authors' contributions

SM and DC carried out the literature search, record screening, data extraction and critical appraisal of individual studies. SM and JK completed the GRADE assessment. SM drafted and revised the manuscript and undertook the meta-analyses. JK provided advice, guidance in the planning of the meta-analysis, and assisted in interpretation of pooled results. DC, JK and EI provided guidance and revision of the manuscript.

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Appendix: Search strategy implemented across six electronic databases and results of total records retrieved

Set	Search Terms
MEDLINE (via PubMed) - searched 13 September 2016 using keywords (text word) and MeSH Terms. Result = 1,766 records	
#1	PGSGA [Text Word] OR SGA[Text Word] OR MNA[Text Word] OR "Patient generated subjective global assessment"[Text Word] OR "subjective global assessment"[Text Word] OR "mini nutritional assessment"[Text Word]
#2	Nutrition* [Text Word] OR malnutrition [Text Word] OR "nutrition* status" [Text Word] OR undernutrition [Text Word] OR emaciation [Text Word] OR undernourish* [Text Word] OR protein energy malnutrition [MeSH term] OR malnutrition [MeSH term] OR nutritional status [MeSH term] OR undernutrition [MeSH term] OR nutritional deficiency [MeSH term] OR protein calorie malnutrition [MeSH term] OR emaciation [MeSH term] OR nutrition status [MeSH term] OR protein deficiency [MeSH term]
#3	Screen* [Text Word] OR mass screening [MeSH Terms]
#4	2 AND 3
#5	Diagnos* [Text Word] OR evaluat* [Text Word] OR valid* [Text Word] OR compar* [Text Word] OR "outcome assessment" [Text Word] OR "outcome measure*" [Text Word] OR agreement [Text Word] OR precision [Text Word] OR kappa* [Text Word] OR specificit* [Text Word] OR sensitiv* [keyword] OR accura* [Text Word] OR outcome assessment health care [MeSH term] OR diagnostic related groups [MeSH term] OR diagnosis [MeSH term] OR diagnoses and examinations [MeSH term] OR examinations and diagnoses [MeSH term] OR validity of results [MeSH term]
#6	4 AND 5
#7	Community [Text Word] "community dwelling" [Text Word] OR "community living" [Text Word] OR "community based" [Text Word] OR "community setting" [Text Word] OR "free living" [Text Word] OR "independent living" [Text Word] OR "home" [Text Word] OR "general practice" [Text Word] OR "primary health care" [Text Word] OR "primary care" [Text Word] OR "primary healthcare" [Text Word] OR "primary nursing" [Text Word] OR [Text Word] OR "primary nursing care" [Text Word] OR general practice [MeSH term] OR primary health care [MeSH term] OR primary care nursing [MeSH term] OR primary healthcare [MeSH term] OR primary nursing [MeSH term] OR care, primary nursing [MeSH term] OR primary nursing care [MeSH term] OR agencies, home care [MeSH term] OR home care services [MeSH term] OR home nursing [MeSH term] OR independent living [MeSH term]
#8	(1 OR 6) AND 7

CINAHL (via Ebscohost) was searched on 13 September 2016 using keywords and CINAHL Headings. Results = 1,068 records	
#1	“PGSGA” [keyword] OR “SGA” [keyword] OR “MNA” [keyword] OR "Patient generated subjective global assessment"[keyword] OR "subjective global assessment"[keyword] OR "mini nutritional assessment"[keyword]
#2	(MH "Geriatric Nutrition") OR (MH "Malnutrition") OR "malnutrition" OR (MH "Protein-Energy Malnutrition+") OR (MH "Nutritional Status") OR "nutrition status" OR "undernutrition" OR "nutritional deficiency" OR (MH "Nutrition") OR "Nutrition" OR (MH "Nutritional Assessment") OR "nutritional assessment"
#3	(MH "Health Screening+") OR (MH "Rescreening")
#4	2 AND 3
#5	"(MH "Diagnosis+") OR "DIAGNOSIS" OR (MH "Diagnosis, Differential") OR (MH "Predictive Validity") OR (MH "Criterion-Related Validity+") OR (MH "Concurrent Validity") OR (MH "Validity+") OR "VALIDITY" OR (MH "Reliability and Validity+") OR (MH "External Validity") OR (MH "Internal Validity") OR (MH "Sensitivity and Specificity") OR (MH "Outcome Assessment") OR "OUTCOME MEASURE" OR (MH "Kappa Statistic") OR "KAPPA" OR (MH "Intrarater Reliability") OR (MH "Interrater Reliability") OR (MH "Consensus")
#6	4 AND 5
#7	"(MH "Community Living+") OR (MH "Communities+") OR "community" OR "community dwelling" OR (MH "Community Health Nursing+") OR "community health nursing" OR (MH "Community Health Services+") OR (MH "Home Nursing, Professional") OR (MH "Home Nutritional Support") OR (MH "Primary Nursing") OR "primary nursing" OR "free living" OR "independent living" OR (MH "Family Practice") OR "general practice" OR (MH "Home Health Care+") OR "meals on wheels" OR "community dietitian" OR "community dietician" OR (MH "Rehabilitation, Community-Based")
#8	(1 OR 6) AND 7
The Cochrane Library was searched on 13 September 2013 using keywords and MeSH Headings. Results = 885 records	
#1	“PGSGA” [keyword] OR “SGA” [keyword] OR “MNA” [keyword] OR "Patient generated subjective global assessment"[keyword] OR "subjective global assessment"[keyword] OR "mini nutritional assessment"[keyword]
#2	Nutrition* [Text Word] OR malnutrition [Text Word] OR “nutrition* status” [Text Word] OR “nutrition risk” [Text Word] OR undernutrition [Text Word] OR “nutrition* defici*” [Text Word] OR emaciation [Text Word] OR undernourish* [Text Word] OR protein-energy malnutrition [exp] [MeSH term] OR malnutrition [exp] [MeSH term] OR nutritional status [exp] [MeSH term] OR emaciation [exp] [MeSH term] OR nutrition status [MeSH term] OR protein deficiency [MeSH term]

#3	Screen* [keyword] OR Mass Screening [exp] [Mesh term]
#4	2 AND 3
#5	Diagnos* [Text Word] OR evaluat* [Text Word] OR valid* [Text Word] OR compar* [Text Word] OR "outcome assessment" [Text Word] OR "outcome measure*" [Text Word] OR agreement [Text Word] OR precision [Text Word] OR kappa [Text Word] OR specificit* [Text Word] OR sensitiv* [keyword] OR accura* [Text Word] OR Outcome Assessment (Health Care) [exp] [MeSH term] OR "Diagnosis-Related Groups" [exp] [MeSH term] OR Diagnosis [exp] [MeSH term] OR Reproducibility of Results [exp] [MeSH term]
#6	4 AND 5
#7	Community [Text Word] OR "free living" [Text Word] OR "independent living" [Text Word] OR "home" [Text Word] OR "general practice" [Text Word] OR "primary health care" [Text Word] OR "primary healthcare" [Text Word] OR "primary nursing" [Text Word] OR "home nursing" [Text Word] OR General Practice [exp] [MeSH term] OR Primary Health Care [exp] [MeSH term] "Primary Nursing" [exp] [MeSH term] OR "Home Care Services [exp] [MeSH term] OR Home Care Agencies [exp] [MeSH term] OR Independent Living [exp] [MeSH term]
#8	(1 OR 6) AND 7
Health Source: Nursing/Academic Edition (via Ebscohost) was searched 2 September 2016 using keywords (all text for #1 keywords, title only for other keywords) and Health Source Subject Terms. Results = 128 records	
#1	PGSGA [keyword] OR SGA [keyword] OR MNA [keyword] OR "patient generated subjective global assessment" [keyword] OR "subjective global assessment" [keyword] OR "mini nutritional assessment" [keyword]
#2	Nutrition* [keyword] OR malnutrition [keyword] OR "nutrition* status" [keyword] OR undernutrition [keyword] OR undernourish* [keyword] OR malnutrition [exp] [subject term] OR nutritional status [exp] [subject term] OR nutrition evaluation [exp] [subject term] OR deficiency diseases [exp] [subject term] OR protein-energy malnutrition [exp] [subject term] OR malnutrition diagnosis [exp] [subject term]
#3	Screen* [keyword] OR medical screening [exp] [subject term]
#4	2 AND 3
#5	Community [keyword] OR "free living" [keyword] OR "independent living" [keyword] OR "home" [keyword] OR general practice [keyword] OR "primary care" [keyword] OR home care services [exp] [subject term] OR Home Nursing [exp] [subject term] OR Independent Living [exp] [subject term] OR family medicine [exp] [subject term] OR primary health care [exp] [subject term]

#6	(1 OR 4) AND 5
EMBASE was searched 2 September 2016 for citations from both Embase and MEDLINE using keywords (abstract and title) and Emtree terms (limits: human studies, adults, middle aged, aged, very elderly). Results = 1,187 records	
#1	PGSGA [keyword] OR SGA [keyword] OR MNA [keyword] OR "patient generated subjective global assessment" [keyword] OR "subjective global assessment" [keyword] OR "mini nutritional assessment" [keyword]
#2	Nutrition* [keyword] OR malnutrition [keyword] OR "nutrition* status" [keyword] OR undernutrition [keyword] OR "nutrition* deficien*" [keyword] OR emaciation [keyword] OR undernourish* [keyword] OR malnutrition [exp] [Emtree term] OR protein deficiency [exp] [Emtree term] OR protein calorie malnutrition [exp] [Emtree term] OR nutritional status [exp] [Emtree term] OR nutritional assessment [exp] [Emtree term]
#3	Screen* [keyword] OR screening [exp] [Emtree term] OR screening test [exp] [Emtree term] OR mass screening [exp] [Emtree term]
#4	2 AND 3
#5	Diagnos* [keyword] OR evaluat* [keyword] OR valid* [keyword] OR compar* [keyword] OR "outcome assessment" [keyword] OR "outcome measure*" [keyword] OR agreement [keyword] OR precision [keyword] OR kappa* [keyword] OR specificit* [keyword] OR sensitiv* [keyword] OR accura* [keyword] OR diagnostic accuracy [exp] [Emtree term] OR diagnostic test [exp] [Emtree term] OR diagnostic test accuracy study [exp] [Emtree term] OR diagnostic value [exp] [Emtree term] OR diagnosis [exp] [Emtree term] OR differential diagnosis [exp] [Emtree term] OR quantitative diagnosis [exp] [Emtree term] OR qualitative diagnosis [exp] [Emtree term] OR validity [exp] [Emtree term] OR concurrent validity [exp] [Emtree term] OR criterion related validity [exp] [Emtree term] OR discriminant validity [exp] [Emtree term] OR external validity [exp] [Emtree term] OR predictive validity [exp] [Emtree term]
#6	4 AND 5
#7	Community [keyword] OR "free living" [keyword] OR "independent living" [keyword] OR "home" [keyword] OR general practice [keyword] OR "primary health care" [keyword] OR "primary care" [keyword] OR 'independent living' [exp] [Emtree term] OR 'community care' [exp] [Emtree term] OR 'community living' [exp] [Emtree term] OR 'home care' [exp] [Emtree term] OR 'home health agency' [exp] [Emtree term] OR general practice [exp] [Emtree term] OR primary medical care [exp] [Emtree term] OR primary health care [exp] [Emtree term] OR general practitioner [exp] [Emtree term]
#8	(1 OR 6) AND 7
Web of Science was searched 2 September 2016 for the following keywords in topic or title (limits: article, editorial material). Results = 1,377 records	

#1	PGSGA OR SGA OR MNA OR “patient generated subjective global assessment” OR “subjective global assessment” OR “mini nutritional assessment”
#2	Nutrition* OR malnutrition OR “nutrition* status” OR undernutrition OR “nutrition* deficien*” OR emaciation OR undernourish* OR protein deficien*
#3	Screen*
#4	2 AND 3
#5	Diagnos* OR evaluat* OR valid* OR compar* OR “outcome assessment” OR “outcome measure*” OR agreement OR precision OR kappa* OR specificit* OR sensitiv* OR accura*
#6	4 AND 5
#7	Community OR “free living” OR “independent living” OR “home” OR general practice OR “primary care”
#8	(1 OR 6) AND 7
Total	***6,412 records***