

1 **Validity of Nutritional Screening Tools for Community-Dwelling Older Adults: A** 2 **Systematic Review and Meta-Analysis**

3 **Abstract**

4 *Objectives:* The aim of this systematic review was to summarize the validity of
5 nutritional screening tools to detect the risk of malnutrition in community-dwelling older
6 adults.

7 *Design:* A systematic review and meta-analysis. The protocol for this systematic review
8 was registered in the PROSPERO database (CRD42017072703).

9 *Setting and participants:* A literature search was performed in PubMed, EMBASE,
10 CINAHL and Cochrane using the combined terms “malnutrition”, “aged”, “community-
11 dwelling” and “screening”. **The timeframe of the literature interrogated was from 1**
12 **January 2001 to 18 May 2018.** Older community-dwellers were defined as: individuals
13 with a mean/median age of >65 years who were community-dwellers or attended
14 hospital outpatient clinics and day hospitals. All nutritional screening tools which were
15 validated in community-dwelling older adults against a reference standard to detect the
16 risk of malnutrition, or with malnutrition, were included.

17 *Measures:* Meta-analyses were performed on the diagnostic accuracy of identified
18 nutritional screening tools validated against the Mini Nutritional Assessment-Long Form
19 (MNA-LF). The symmetric hierarchical summary receiver operating characteristic
20 models were used to estimate test performance.

21 *Results:* Out of 7,713 articles, 35 articles were included in the systematic review, and 9
22 articles were included in the meta-analysis. Seventeen nutritional screening tools and

23 10 reference standards were identified. The meta-analyses showed an average
24 sensitivities and specificities of 0.95 (95% CI 0.75 – 0.99) and 0.95 (95% CI: 0.85 –
25 0.99) for the Mini Nutritional Assessment-Short Form ((MNA-SF), cutoff point ≤ 11), 0.85
26 (95% CI: 0.80 – 0.89) and 0.87 (95% CI: 0.86 – 0.89) for the MNA-SF-V1 (MNA-SF
27 using body mass index, cutoff point ≤ 11), 0.85 (95% CI: 0.77 – 0.89) and 0.84 (95% CI:
28 0.79 – 0.87) for the MNA-SF-V2 (MNA-SF using calf circumference instead of body
29 mass, cutoff point ≤ 11), respectively, using MNA-LF as the reference standard.

30 *Conclusions and Implications:* The MNA-SF, MNA-SF-V1 and MNA-SF-V2 showed
31 good sensitivity and specificity to detect community-dwelling older adults at risk of
32 malnutrition validated against the MNA-LF. Clinicians should consider the use of the
33 cutoff point ≤ 11 on the MNA-SF, MNA-SF-V1 and MNA-SF-V2 to identify community-
34 dwelling older adults at risk of malnutrition.

35 **Introduction**

36 The proportion of individuals over the age of 65 years worldwide is projected to rise to
37 22% by 2050.^{1, 2} Ageing may induce malnutrition due to multiple factors such as loss of
38 appetite, oral impairment,³ taste and smell, drug interactions and social isolation.⁴
39 Malnutrition is associated with a range of negative health outcomes,^{5, 6} such as low
40 quality of life, frailty,⁶ loss of autonomy, morbidity, higher frequency of hospital
41 admissions and mortality.⁷⁻¹⁰ In community-dwelling older adults, the prevalence of
42 malnutrition is reported to range between 2 to 42%.^{6, 11} The wide variation in the
43 prevalence of malnutrition may be due to the various nutritional screening tools, and the
44 many reference standards used to validate these nutritional screening tools.¹²⁻¹⁴

45 The absence of a gold standard to define the risk of malnutrition and actual malnutrition,
46 has led to different approaches in validating nutritional screening tools. A recent review
47 on the validity of nutritional screening tools used in older adults in the community,
48 residential care, rehabilitation and hospitals, identified a total of 34 nutritional screening
49 tools and 17 different reference standards.¹⁵ The most widely used and acceptable
50 reference standards were the Mini Nutritional Assessment – Long Form (MNA-LF) and
51 the clinical assessment given by a nutrition-trained professional.¹⁵ To our knowledge, no
52 meta-analysis has been performed on the diagnostic accuracy of nutritional screening
53 tools used to identify community-dwelling older adults at risk of malnutrition.

54 This study was conducted as part of the Physical Activity and Nutrition Influences In
55 ageing (PANINI) network research¹⁴ and aimed to perform a systematic review of all
56 available nutritional screening tools validated against reference standards in

57 community-dwelling older adults. We reported on the validity of the cutoff points used on
58 the nutritional screening tools to identify those at risk of malnutrition, and with
59 malnutrition. Secondly, we performed a meta-analysis on the diagnostic accuracy of
60 identified nutritional screening tools validated against the Mini-nutritional Assessment –
61 Long Form or a health professional's rating of nutritional status.

62 **Methods**

63 The protocol for this systematic review was registered at PROSPERO International
64 prospective register of systematic reviews (Registration number: CRD42017072703).
65 The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)
66 statement was used to guide the reporting of this review.¹⁶

67 *Search Strategy*

68 A systematic search was performed by a librarian and the articles identified were
69 obtained through electronic searches of the following databases: PubMed, EMBASE,
70 CINAHL (via Ebsco) and Cochrane. The timeframe interrogated for the search was from
71 01/01/2001 to 18/05/2018. The search strategy combined the terms “malnutrition”,
72 “aged”, “community-dwelling” and “screening” and synonyms. Language was not
73 restricted in the search strategy; publications that were not in English were later
74 excluded. The reference lists of the identified articles were further searched for relevant
75 publications. The search strategy syntax can be found in *Appendix 1*.

76 *Selection Process*

77 The relevant titles and abstracts, then the full-texts were independently screened for
78 eligibility by two authors (JI and MB) using the Covidence systematic review software,
79 Veritas Health Innovation, Melbourne, Australia. When conflicts/discrepancy arose
80 between the two authors then a third author (SY) made the final judgment of the
81 articles.

82 *Inclusion criteria and exclusion criteria*

83 For the purpose of this systematic review, we included all nutritional screening tools
84 validated against a reference standard. **If a nutritional screening tool had multiple**
85 **versions, such as the Mini-Nutritional Assessment Short-Form (MNA-SF) or Seniors in**
86 **the community: risk evaluation for eating nutrition (SCREEN) then each version of the**
87 **tool was assessed independently. Our rationale for not grouping similar tools together**
88 **was because, despite their similarity, these tools differ importantly in their**
89 **measurements, questions and scoring methods. Therewith they might have different**
90 **construct validities.** As there is no gold standard for the assessment of malnutrition, the
91 MNA-LF, a detailed nutritional assessment by a dietitian or physician and Subjective
92 Global Assessment (SGA), were considered as identifiers of patients with the risk of
93 malnutrition. The European Society of Parenteral and Enteral Nutrition (ESPEN)
94 recommend the use of MNA-LF, SGA, Patient Generated Subject Global Assessment
95 (PG-SGA) to facilitate the assessment of malnutrition.¹⁸ A detailed nutritional
96 assessment should include medical, social, psychological and nutrition history, as well
97 as energy and fluid requirements.¹⁸

98 The criteria for selecting articles included: validation studies of nutritional screening
99 tools developed to identify the risk of malnutrition, or malnutrition, with description of
100 psychometric properties (sensitivity, specificity and criterion validity). Community-
101 dwelling older adults were defined as: individuals living at home with a mean/median
102 age of >65 years who attended hospital outpatient clinics, day hospitals, community
103 centres or participated in a population study.

104 The articles were excluded if the population being screened for malnutrition consisted of
105 less than 50% community-dwelling older adults. Additionally, articles were excluded if
106 the screening tool included laboratory values, such as Prognostic Nutritional Index,
107 Controlling Nutritional Status (CONUT), Maastricht Index. Conference abstracts,
108 systematic reviews and letters to editors were also excluded.

109 *Data Extraction*

110 The data was independently extracted by two authors (JI, MB) for each eligible article.
111 The extracted variables included: author, year of publication, country origin of the
112 research population, study population, number of included individuals, recruitment
113 strategy, percentage of male, age of individuals, nutritional screening tool and its
114 version, the reference standard and the prevalence of community-dwelling older adults
115 at risk of malnutrition and those with malnutrition as determined by the reference
116 standard. If the articles included a mixed population (e.g. hospitalized and community-
117 dwelling older adults) and data was available on both populations then only data
118 pertaining to the community-dwelling older adults was extracted.

119 As part of the systematic review, to evaluate the diagnostic accuracy of the nutritional
120 screening tools, the following data were extracted from the eligible articles: cutoff points
121 used to identify individuals at risk of malnutrition or with malnutrition, sensitivity,
122 specificity, positive predictive value (PPV), negative predictive value (NPV), area under
123 the curve (AUC), correlation coefficient and kappa. Validity of a screening tool was
124 defined as good if: sensitivity $\geq 80\%$, specificity $\geq 80\%$, AUC ≥ 0.8 , correlation
125 coefficient ≥ 0.75 and/or kappa ≥ 0.6 ; fair if: sensitivity $\geq 50\%$ but $<80\%$, specificity
126 $\geq 50\%$ but $<80\%$, AUC $0.6 - 0.8$, correlation coefficient $0.40 - 0.75$, kappa $0.40 - 0.6$;
127 poor if: sensitivity $<50\%$, specificity $<50\%$, AUC <0.6 , correlation coefficient <0.40 ,
128 kappa <0.40 .¹⁹

129 *Methodological quality of extracted papers*

130 To assess the methodological quality of the included studies, the Quality Assessment of
131 Diagnostic Accuracy Studies – version 2 (QUADAS-2) was used.²⁰ The signaling
132 questions used to assess the quality of the studies are in *Appendix 2*.

133 *Statistical analysis for the Meta-analysis*

134 Revman 5.3 was used to calculate true positives (TP), false positives (FP), true
135 negatives (TN), false negatives (FN) and PPV and NPV from the values of sensitivity,
136 specificity and prevalence reported in the articles.²¹ Symmetric hierarchical summary
137 receiver operative characteristic (HSROC) models were used to jointly estimate
138 sensitivity and specificity, positive and negative likelihood ratio, and diagnostic odd ratio
139 (DOR) using STATA statistical software, version 14.1 (StataCorp). We were unable to
140 pool estimates when the number of studies was less than 4.²² Instead, forest plots were

141 used to display sensitivity and specificity for all nutritional screening tools validated
142 against the MNA-LF, a health professional's rating of nutritional status or SGA.

143 **Results**

144 *Study Selection*

145 The search yielded 12,103 citations, including 4,394 duplicates; an additional four
146 articles were identified from checking the reference list of relevant articles and review
147 articles. After title, abstract and full text screening, 7,678 articles were excluded,
148 resulting in 35 articles which were included in this systematic review and 9 articles were
149 included in the meta-analysis. The article selection flow is shown in Figure 1.

150 *Study Characteristics*

151 The study characteristics are presented in Table 1. The median sample size was 283
152 individuals (Interquartile range (IQR) 199 to 754, range 45 – 22,007), the mean age was
153 74 years (SD \pm 3.5, range 67 – 86 years), and including a median of 39 percent males
154 (IQR 35 to 47%, range 19 – 59%). The median prevalence of malnutrition as determined
155 by the reference standard was 5% (IQR 2 to 15%), and the median prevalence of
156 individuals at risk of malnutrition was 32% (IQR 23 to 44%). Seventeen malnutrition
157 screening tools were identified: Mini-Nutritional Assessment Short-Form (MNA-SF),²³⁻²⁹
158 MNA-SF-V1 (MNA-SF using BMI)³⁰⁻³⁹ and MNA-SF-V2 (MNA-SF using calf
159 circumference instead of BMI),^{31, 32, 34, 35, 37, 39-41} Self-MNA,⁴² MNA-LF,^{12, 29, 43-46}
160 Malnutrition Risk Screening Tool (MRST),²⁷ South African Tool,⁴⁷ DETERMINE
161 Checklist,²⁴ SGA,^{12, 46} Nutritional Risk Screening Tool,⁴⁸ Seniors in the community: risk

162 evaluation for eating nutrition (SCREEN) version I⁴⁹ and II,^{50, 51} Japanese adaptation of
163 SCREEN II,⁴⁸ Malnutrition Universal Screening Tool (MUST),^{25, 34, 46, 52} Short Nutritional
164 Assessment Questionnaire (SNAQ),^{53, 54} Body Mass Index (BMI),^{25, 38} Nutritional form
165 for the elderly (NUFE)^{55, 56} and Malnutrition Screening Tool.⁵⁷

166 *Quality Assessment*

167 Figure 2 shows the methodological quality assessment of the studies. The majority of
168 the articles did not specify if the researchers interpreted the nutritional screening tools
169 without knowledge of the results of the reference standard and vice versa. Therefore,
170 the risk of bias for the interpretation of the index test and the reference standard was
171 often unclear (70% and 67%, respectively). Ten reference standards were identified.
172 The reference standard varied widely between studies: MNA-LF,^{23, 24, 26, 28, 30-37, 39, 41-44}
173 dietitian's or physician's rating,^{25, 29, 49-51} SGA,^{38, 57} Anthropometry – BMI,^{27, 45} Calf
174 Circumference and Mid Upper Arm Circumference,²⁷ self-reported unintentional weight
175 loss and BMI,⁵² MNA-SF^{42, 48, 55, 56}, MNA-SF-V1,^{34, 40} Geriatric Nutrition Risk Index
176 (GNRI)⁴⁸ and CONUT.⁵⁴ Ten out of thirty-four articles used a reference standard other
177 than the MNA-LF, a health professional's rating of nutritional status or SGA.

178 *Diagnostic Performance of Nutritional Screening Tools in Community-dwelling Older* 179 *Adults based on the Systematic Review*

180 Figure 3 displays the sensitivity and specificity of all nutritional screening tools validated
181 against the MNA-LF, SGA or a health professional's rating of nutritional status. The
182 most frequently tested nutritional screening tools compared to the MNA-LF or health
183 professional were the MNA-SF, MNA-SF-V1, MNA-SF-V2 and SCREEN II. On the

184 MNA-SF, MNA-SF-V1 and MNA-SF V2, the cutoff point ≤ 11 was used to identify
185 individuals at risk of malnutrition, whereas the cutoff point ≤ 7 was used to identify those
186 with malnutrition on the MNA-SF-V1 and MNA-SF-V2. On the MNA-SF, the sensitivity of
187 the cutoff point ≤ 11 ranged from 74% to 100% and the specificity ranged from 89% to
188 100%. On the MNA-SF-V1, the sensitivity of the cutoff point ≤ 11 ranged from 73% to
189 93% and specificity ranged from 85% to 93%, whereas the sensitivity of cutoff point ≤ 7
190 ranged from 76% to 100%, and specificity ranged from 94% to 87%. On the MNA-SF-
191 V2, the cutoff point ≤ 11 ranged from 73% to 90% and specificity ranged from 77% to
192 86%, whereas the cutoff point ≤ 7 ranged from 81% to 88% and specificity from 90% to
193 97%. SCREEN II was validated against a dietitian's rating of nutritional status in 2
194 articles, the cutoff points < 54 was used to identify older adults at risk of malnutrition.
195 Both of these studies showed good sensitivity (84% and 88%) and fair specificity (62%
196 and 71%). The Self MNA, MNA-CC-MAC, MNA-P, the South African tool, DETERMINE,
197 SCREEN, Abbreviated SCREEN II, MUST, BMI and MST were compared to either the
198 MNA-LF, health professionals' rating or SGA in only one study.

199 Table 2 lists the sensitivity, specificity, PPV, NPV, AUC, correlation coefficient and
200 kappa of each nutritional screenings tools and their cutoff points compared to a
201 reference standard. In community-dwelling older adults, the MUST was validated
202 against self-reported weight loss and measured BMI,⁵² MNA-LF³⁴ and a dietitian's rating
203 of nutritional risk.²⁵ The reported sensitivity of the MUST to identify individuals at risk of
204 malnutrition varied greatly between these studies (64% vs 100%); however specificity
205 was high in both studies (96% and 98%). The nutritional tool SNAQ was validated
206 against both self-reported unintentional weight loss and measured BMI,⁵² and CONUT.

207 ⁵⁴ The sensitivity and specificity of the SNAQ varied widely between these studies (31%
208 vs 92%) and (98% vs 63%), respectively. The NUFE tool was validated against another
209 nutritional screening tool, that is, MNA-SF, and the NUFE was reported to have fair
210 sensitivity, specificity and AUC compared to the MNA-SF.^{55, 56} The use of BMI and SGA
211 was used interchangeably as a nutritional screening tool^{25, 38} and a reference
212 standard.^{27, 45} Sheard *et al.*³⁸ validated BMI against SGA whereas Kozakova *et al.*⁴⁶
213 validated SGA against BMI. In community-dwelling older adults, the following nutritional
214 screening tools were validated in only one study: SCREEN,⁴⁹ self-MNA,⁴²
215 DETERMINE,²⁴ South African Tool,⁴⁷ MRST-C and MRST-H²⁷ and MST.⁵⁷

216 *Meta-analysis of the diagnostic accuracy of the MNA-SF, MNA-SF-V1 and MNA-SF-V2*
217 *to identify risk of malnutrition in community-dwelling older adults*

218 All articles identified used the cutoff point ≤ 11 to identify community-dwelling older
219 adults at risk of malnutrition on the MNA-SF, MNA-SF-V1 and MNA-SF-V2. These
220 nutritional screening tools were all validated against the MNA-LF and the TP, FN, TN,
221 FP, sensitivity and specificity of each study is displayed in forest plots in Figure 3. The
222 pooled sensitivity, specificity, DOR, positive likelihood ratio, negative likelihood ratio of
223 the cutoff point ≤ 11 on the MNA-SF, MNA-SF-V1 and MNA-SF-V2 are shown in
224 Supplementary Table A1. The MNA-SF had a sensitivity of 0.95 (95%CI 0.75 – 0.99)
225 and specificity was 0.95 (95% CI 0.85 – 0.99). The summary estimates for sensitivity on
226 MNA-SF-V1 was 0.85 (95%CI 0.80 – 0.89) and specificity was 0.87 (95%CI 0.85 –
227 0.89). The pooled sensitivity of the MNA-SF-V2 was 0.85 (95%CI 0.77 – 0.89) and
228 specificity was 0.84 (95%CI 0.79 – 0.87). The hierarchical summary receiver operating

229 characteristic curves for the MNA-SF, MNA-SF-V1 and MNA-SF-V2 at the cutoff point of
230 ≤ 11 is shown in Supplementary Figure A1.

231 **Discussion**

232 The nutritional screening tools which displayed good sensitivity and at least fair
233 specificity were the MNA-SF, MNA-SF-V1 and MNA-SF-V2 and **SCREEN II**. The meta-
234 analyses showed high sensitivity and specificity for MNA-SF, MNA-SF-V1 and MNA-SF-
235 V2 screening tools validated against the MNA-LF identifying community-dwelling older
236 adults at risk of malnutrition.

237 The MNA-SF was developed in 2001 and consists of six questions and a score of ≤ 11
238 points classifies individuals as at risk of malnutrition. The meta-analysis showed that the
239 MNA-SF had good sensitivity and specificity for the cutoff point of ≤ 11 ; however the
240 95% confidence interval was wide. In 2009, the MNA-SF was revised by Kaiser *et al.*⁵⁸
241 which led to a three-category system: “malnourished - ≤ 7 ”; “at risk of malnutrition 8 –
242 11”; “normal nutritional status 12 -14”. Kaiser *et al.*⁵⁸ suggested two versions of the
243 revised MNA-SF, that is, MNA-SF-V1 which includes BMI or MNA-SF-V2 in which calf-
244 circumference is used **when BMI cannot be calculated**.⁵⁸ Our meta-analysis
245 demonstrated that the cutoff point ≤ 11 on both the MNA-SF-V1 and MNA-SF-V2 had a
246 good sensitivity, specificity and a narrow 95% confidence interval. There was an
247 insufficient number of studies that reported the sensitivity and specificity of the cutoff of
248 ≤ 7 points on the MNA-SF-V1 and MNA-SF-V2 to identify malnutrition in community-
249 dwelling older adults. Overall, our findings suggest that the MNA-SF-V1 and MNA-SF-

250 V2, a simple, quick and effective screening tool, can identify community-dwelling older
251 adults at risk of malnutrition.

252 In a recent review, SCREEN II was suggested as the most appropriate tool in
253 community-dwelling older adults,¹⁵ however, it should be noted that this tool was only
254 validated in two studies including small populations.^{50, 51} The cutoff of <54 points was
255 previously recommended to detect the risk of malnutrition and our results show that this
256 cutoff point has good sensitivity but only fair specificity in community-dwelling older
257 adults. The fair specificity would suggest that this screening tool would identify many
258 false positive tests when identifying individuals at risk of malnutrition. To improve on the
259 sensitivity and specificity, lower cutoff points were suggested such as cutoff of <50
260 points⁵⁰ and cutoff of <49 points.⁵¹ Although, the cutoff of <49 points on SCREEN II
261 showed good sensitivity and specificity when identifying older adults with malnutrition,
262 this cutoff points was only validated in a small sample size (n = 45). Therefore, larger
263 studies are needed to further validate the use of this cutoff point in community-dwelling
264 older adults.

265 When choosing a nutritional screening tool to identify individuals at risk of malnutrition, it
266 is important to ensure that the nutritional screening tool accurately identifies individuals
267 at risk of, or with, malnutrition. However, one of the major limitations is that there is no
268 “gold standard” for the diagnostic criteria for malnutrition. Indeed, we identified ten
269 different reference standards in this review alone. When assessing the quality of the
270 studies, we reasoned that the MNA-LF, dietitian/physician’s rating of nutritional status or
271 SGA would be most likely to correctly identify patients at risk of malnutrition, or with
272 malnutrition. However, it should be noted that in recent years societies such as The

273 European Society of Clinical Nutrition and Metabolism (ESPEN)⁵⁹ and more recently the
274 Global Leadership Initiative on Malnutrition (GLIM) proposed consensus schemes for
275 diagnosing malnutrition.^{59, 60} To our knowledge there are a growing number of studies
276 evaluating the ESPEN definition of malnutrition^{5, 13} and no studies that have validated
277 any nutritional screening tools against the GLIM definition of malnutrition in community-
278 dwelling older adults.

279 *Risk of Bias*

280 It was often unclear whether the nutritional screening tools were interpreted without
281 knowledge of the results of the reference standard and vice versa. The lack of blinding
282 may have inflated the diagnostic accuracy of the nutritional screening tool. It is
283 recommended for future studies to be more transparent in their methodology and
284 provide details on whether assessors were blinded to the index test results and vice
285 versa. To reduce the risk of bias, investigators should follow the guidelines described by
286 the Standards for Reporting of Diagnostic Accuracy Studies.⁶¹ Additionally, a high risk of
287 bias was considered if a single measurement such as BMI was the reference standard
288 and if a nutritional screening tool was considered as the reference standard (e.g. MNA-
289 SF). Interestingly, the MNA-SF, MNA-LF and SGA were interchangeably used as either
290 the index test (screening tool) or the reference standard (assessment tool).

291 *Strengths and Limitations*

292 The strengths of this systematic review is that we identified: i) all nutritional screening
293 tools validated against a reference standard, ii) the cutoff points that were validated to
294 identify community-dwelling older adults at risk of malnutrition, or with, malnutrition, and

295 iii) summarized the results in a meta-analysis. To our knowledge, this is the first meta-
296 analysis on the diagnostic accuracy of nutritional screening tools used to identify
297 community-dwelling older adults at risk of malnutrition, and those with malnutrition.
298 However, a limitation of our study is that our search strategy started after 2001;
299 therefore any validity studies prior to that time were excluded. Furthermore, it was out of
300 the scope of this review to describe reliability, repeatability and predictive validity of the
301 nutritional screening tools.

302 *Conclusions and Implications*

303 This systematic review further highlights that there is a need for a universal gold
304 standard for the diagnostic criteria of malnutrition. The results from this meta-analysis
305 show **evidence for the use of** the cutoff of ≤ 11 points on the MNA-SF or MNA-SF-V1 or
306 MNA-SF-V2 to detect community-dwelling older adults at risk of malnutrition. **Although,**
307 **it should be noted, that we were unable to analyze the other cutoff points on these**
308 **nutritional screening tools. Overall, our results suggest that, in** the community setting if
309 scales and stadiometers are available, and thus BMI can be calculated, then the MNA-
310 SF-V1 should be used. Otherwise, if a scale is not available then calf circumference
311 should be obtained, and the MNA-SF-V2 should be used to identify community-dwelling
312 older adults at risk of malnutrition, or with malnutrition. Further research is needed in
313 community-dwelling older adults on the validity of the other available nutritional
314 screening tools such as SCREEN II and NUFE.

Conflict of Interest: No conflicts to declare.

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Figure Captions:

Figure 1. PRISMA flowchart of the article selection procedure for the systematic review

Figure 2. Methodological quality assessment of included studies using QUADAS-2

Figure 3. Forest plots of all nutritional screening tools validated against the MNA-LF, a health professional's rating of nutritional status and the SGA. Abbreviations: MNA-LF: Mini nutritional Assessment - Long form, SGA: Subjective global assessment.

Supplementary Figure A1. Pooled sensitivity, specificity and HSROC curve for screening for the risk of malnutrition using the cutoff point ≤ 11 on the MNA-SF (A), MNA-SF-V1 (B) and MNA-SF-V2 (C) compared to the MNA-LF. Abbreviations: HSROC: Hierarchical Summary Receiver-Operating Characteristic, MNA-SF: Mini nutritional assessment - Short form (left panel, number of articles = 4, number of participants = 23,331), MNA-SF-V1: Mini nutritional assessment - Short form Version 1 using body mass index (middle panel, number of articles = 6, number of participants = 4,037), MNA-SF-V2: Mini nutritional assessment - Short form Version 2 using calf-circumference instead of body mass index (right panel, number of articles = 4, number of participants).