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Protein-energy malnutrition in the rehabilitation setting: Evidence to improve identification

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1 **Protein-energy malnutrition in the rehabilitation setting: evidence to improve**

2 **identification**

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8 **Abstract**

9 Methods of identifying malnutrition in the rehabilitation setting require further examination

10 so that patient outcomes may be improved. The purpose of this narrative review was to: 1)

11 examine the defining characteristics of malnutrition, starvation, sarcopenia and cachexia; 2)

12 review the validity of nutrition screening tools and nutrition assessment tools in the

13 rehabilitation setting; and 3) determine the prevalence of malnutrition in the rehabilitation

14 setting by geographical region and method of diagnosis. A narrative review was conducted

15 drawing upon international literature. Starvation represents one form of malnutrition.

16 Inadequate energy and protein intake are the critical factor in the aetiology of malnutrition,

17 which is distinct from sarcopenia and cachexia. Eight nutrition screening tools and two

18 nutrition assessment tools have been evaluated for criterion validity in the rehabilitation

19 setting, and consideration must be given to the resources of the facility and the patient group

20 in order to select the appropriate tool. The prevalence of malnutrition in the rehabilitation

21 setting ranges from 14-65% worldwide with the highest prevalence reported in rural,

22 European and Australian settings. Malnutrition is highly prevalent in the rehabilitation

23 setting, and consideration must be given to the patient group when determining the most

24 appropriate method of identification so that resources may be used efficaciously and the

25 chance of misdiagnosis minimised.

26 **Keywords**: Malnutrition, Subacute Care, Rehabilitation, Nutrition Assessment, Aged / Aged

27 80 and over.

28   **Abbreviations**

29   AND, Academy of Nutrition and Dietetics

30   BMI, Body Mass Index

31   Kg, kilogram

32   m, meter

33   MNA, Mini Nutritional Assessment

34   MNA-SF, Mini Nutritional Assessment – Short Form

35   MST, Malnutrition Screening Tool

36   PG-SGA, Patient-Generated Subjective Global Assessment

37   SGA, Subjective Global Assessment

38   UK, United Kingdom

39   USA, United States of America

1. Introduction

Ever since Dr Charles Edwin Butterworth Jr's seminal 1974 article "The Skeleton in the Hospital Closet", there has been a positive movement in clinical health care to address "hospital malnutrition" [1]. However, in highly developed countries, such as Australia and the UK, malnutrition remains widespread in older adults, where prevalence is the highest in rehabilitation wards (30 – 50% of inpatients) [2]. In addition, there has been confusion in the literature and in clinical practice regarding malnutrition, starvation, sarcopenia and cachexia in older adults, which are conditions characterised by involuntary loss of lean tissue [3].

Nutrition screening and nutrition assessment are essential parts of the nutrition care process, as accurate identification and diagnosis of malnutrition is required in order for patients to be adequately treated, and for nutrition resources to be used efficaciously [4]. However, it is essential that the nutrition screening tools and nutrition assessment tools used to complete these steps have undergone adequate evaluation for validity so that the most appropriate tool can be selected for the patient group [2].

The prevalence of malnutrition in rehabilitation and the nutrition screening and assessment tools appropriate for use in rehabilitation have not been reviewed since 2009 [2]. Examining the validity of nutrition screening and assessment tools in rehabilitation will help practitioners select the most appropriate tool for their facility. Additionally, understanding the limitations of a particular tool in a particular setting is required so that appropriate steps can be taken to minimise the risk of misdiagnosis. For this reason, the method of diagnosis should be considered when reviewing the prevalence of malnutrition. The prevalence of malnutrition in rehabilitation has not been evaluated with consideration given to the method of diagnosis, nor the various settings in which it was measured, such as rural versus metropolitan prevalence or by country or region. Understanding the prevalence of malnutrition in these various settings

64 will help health care workers to understand the risk of malnutrition for particular patient

65 groups and assist in the allocation of nutrition resources.

66 Therefore, the purpose of this narrative review was to: 1) examine the defining characteristics

67 of malnutrition, starvation, sarcopenia and cachexia; 2) review the validity of nutrition

68 screening tools and nutrition assessment tools in the rehabilitation setting; and 3) determine

69 the prevalence of malnutrition in the rehabilitation setting by geographical region and method

70 of diagnosis.

2. Methods

72 A narrative review was conducted which drew upon international literature published up

73 until 15 August 2015. A review was conducted as part of the narrative review to identify the

74 nutrition screening and assessment tools evaluated for validity in the inpatient rehabilitation

75 facilities, as well as determine the prevalence of malnutrition. For this review, published

76 English-language literature was searched on Google Scholar from 1980 – 15 August 2015.

77 The search terms were (“MNA” OR “SGA” OR “PG-SGA” OR “ICD-10-AM” OR

78 “Malnutrition Universal Screening Tool” OR “SNAQ” OR “NRS-2002” OR “nutrition

79 screening tool”) AND “Malnutrition” AND (“Rehabilitation” OR “Subacute”). The search

80 strategy was complemented by a snowball search of literature cited by identified papers.

81 Studies were included for the prevalence study only when malnutrition was diagnosed by a

82 validated method.

3. Defining malnutrition

84 Protein-energy undernutrition, also known as protein-energy malnutrition, and frequently

85 referred to simply as *malnutrition*, occurs when food and nutrient intake is unable to meet

86 protein, energy and nutrient requirements over time leading to a disruption of homeostasis in

87 lean tissues, body weight and physical function [5, 6]. Lean tissues include fat-free,

88　metabolically active tissues such as skeletal muscle, viscera, blood cells and the immune

89　system. Lean tissues are the largest body component, comprising 35 – 50% of the total body

90　weight of a healthy adult [6]. A decrease in lean tissue is the main cause of unintentional

91　weight loss in most cases of malnutrition, although loss of fat mass may also be a

92　contributing factor, and is caused by starvation or a combination of starvation and catabolic

93　stress [6].

94　3.1 Malnutrition, starvation, sarcopenia or cachexia?

95　It has been widely recognised that muscle mass frequently decreases with age. Malnutrition,

96　starvation, sarcopenia and cachexia are all conditions characterised by loss of lean tissue and

97　typically occur in older adults, leading to confusion in the literature and in clinical practice

98　[3].

99　Starvation is the loss of both fat-mass and fat-free mass as the result of a chronic inadequate

100　intake of protein and energy [3]. Therefore, starvation may be a cause of malnutrition, as

101　reflected by the Academy of Nutrition and Dietetics (AND) standardised set of diagnostic

102　characteristics for malnutrition: a) starvation-related malnutrition, b) chronic-disease related

103　malnutrition and c) acute disease or injury-related malnutrition [7]. The AND have defined

104　starvation-related malnutrition as protein-energy malnutrition due to pure chronic starvation

105　or anorexia nervosa [7]. Overall, starvation may be an important component of malnutrition

106　in some clinical situations, but should be used with caution when discussing malnutrition in

107　general.

108　Since being coined in 1989, the definition of "sarcopenia" has continued to evolve as the

109　condition is further explored [8]. However, in 2009 and 2010 three separate groups of experts

110　met to gain consensus for the definitions of sarcopenia. As each of these consensus

111　definitions were slightly different, no definition is yet universally accepted and there still

112 remains confusion and inconsistency in the literature when describing and diagnosing this

113 "geriatric syndrome" [9]. However, all three definitions agree that sarcopenia is characterised

114 by the progressive age-related loss of lean muscle mass, muscle strength and physical

115 function, and is associated with poor health outcomes [10-12]. One important development in

116 the consensus of sarcopenia is the recognition that inadequate dietary intake and/or nutrient

117 malabsorption is a possible factor in the aetiology of the syndrome (known as nutrition-

118 related sarcopenia) by the European Working Group on Sarcopenia [10]. However, both the

119 International Working Group on Sarcopenia and the Society for Sarcopenia, Cachexia and

120 Wasting Disorders have not recognised inadequate nutrition as a potential cause in the

121 multifactorial aetiology of the syndrome; though they did recognise that it has a role in the

122 pathophysiology of sarcopenia [11, 12]. This may reflect the lack of strong research in

123 exploring the nutritional mechanisms in sarcopenia along with the fact that it may be

124 uncommon to find an older adult with sarcopenia who meets estimated energy and protein

125 requirements [8]. However, there have not been enough well designed studies to conclude

126 whether the severity or progression of sarcopenia is affected by dietary intervention. In

127 addition, it may be possible for both malnutrition and sarcopenia to present as comorbidities,

128 known as the malnutrition-sarcopenia syndrome (MSS); though it must be acknowledged a

129 method of diagnosis for MSS has not yet been evaluated for validity or reliability [13].

130 Similar to disease-related malnutrition, cachexia is a complex syndrome associated with

131 underlying illness, characterised by the loss of body weight, predominately skeletal muscle,

132 which increases the risk of misdiagnosis [14]. Conditions which predispose to cachexia also

133 increase the risk of malnutrition, including cancer, chronic infection, and chronic kidney

134 disease [14]. However, unlike malnutrition, the loss of skeletal muscle in cachexia is a result

135 of increased resting energy expenditure mediated by elevated levels of proinflammatory

136 cytokines and a prolonged acute phase protein response [15]. Therefore, cachexia is

137   purported to not respond to dietary intervention, and states of malnutrition and sarcopenia

138   have been described as a "pre-cachectic state", where nutritional intervention may have the

139   most benefit [14]. However, emerging research has shown that nutrition intervention may

140   impact upon the pathogenesis of cachexia, although nutrition intervention alone is insufficient

141   to treat the condition [14, 16, 17].

142   Therefore, inadequate energy and protein intake leading to a loss of lean-tissues in older age

143   may play a role in the pathogenesis sarcopenia and cachexia, but is a critical factor in the

144   aetiology and prognosis of all forms of malnutrition, including starvation. The diagnostic

145   criteria of malnutrition, sarcopenia and cachexia help to highlight both the unique

146   characteristics and similarities of each condition, and are compared in table 1.

147   **4. Identifying and diagnosing malnutrition**

148   Due to the variable nature of the clinical presentation of malnutrition, there is no gold

149   standard for diagnosing the condition. However, in Australian health care facilities, the

150   *International Statistical Classification of Diseases and Health Related Problems 10th*

151   *Revision Australian Modification* (sixth edition, ICD-10-AM) criteria are used to identify and

152   code for malnutrition, and are therefore used to provide case-mix funding reimbursements

153   [18]. The ICD-10-AM classification of malnutrition incorporate multiple criteria, including

154   body mass index (BMI), weight loss, dietary intake and evidence of fat and/or muscle

155   wasting [18]. However, prior to coding for malnutrition, a patient undergoes nutrition

156   screening and nutrition assessment.

157   Nutrition screening acts as the trigger to engage a patient in the nutrition care process, which

158   begins with nutrition assessment. Nutrition screening and nutrition assessment are often

159   completed through the application of a nutrition screening tool and nutrition assessment tool

160   [4]. However, the nutrition screening and assessment tools chosen should be validated for the

161 population to which they are applied. As there is no gold standard for identifying or

162 diagnosing malnutrition, the criterion validity (comprising concurrent and predictive) must be

163 established for nutrition screening and assessment tools [19]. Concurrent validity is

164 determined by comparing the results of a new tool to the results of a well-established

165 measurement for the same construct. When considering the concurrent validity of a nutrition

166 screening or assessment tool, it is important to consider the well-established measurement

167 used as a benchmark (or reference standard), and if this is a relevant benchmark for a

168 particular patient group and condition. Predictive validity is established when the score of a

169 particular measurement makes an accurate prediction about an important and related

170 outcome.

171 4.1 Malnutrition screening tools

172 Nutrition screening tools should be quick and simple to implement and able to be used by any

173 trained person or the patient themselves. Nutrition screening tools determine risk of

174 malnutrition but cannot make a diagnosis of malnutrition. In the rehabilitation setting, eight

175 nutrition screening tools have been evaluated for their criterion validity: the Mini Nutrition

176 Assessment-Short Form (MNA-SF) [20], Malnutrition Screening Tool (MST) [21, 22],

177 Malnutrition Universal Assessment Tool (MUST), Nutritional Form for the Elderly (NUFFE)

178 [23], Rapid Screen [24], Short Nutritional Assessment Questionnaire (SNAQ) [25, 26],

179 SNAQ Residential Care (SNAQ^{RC}) [25, 27] and the SNAQ for older adults (SNAQ^{65+}) [25,

180 28] . A description of their domains and criteria are described by Skipper et al. [29]. When

181 evaluating the concurrent validity of a nutrition screening tool, sensitivity (those at risk of

182 malnutrition correctly identified as such) is considered of higher importance than specificity

183 (those not at risk of malnutrition correctly identified as such) and *a-priori* values of ≥80% for

184 sensitivity and ≥60% for specificity are considered to indicate a good nutrition screening tool

185 [22]. Table 2 compares the concurrent validity of nutrition screening tools in rehabilitation.

186   In the rehabilitation setting, only the MST, MUST, SNAQ and SNAQ[65+] met *a-priori* values

187   for sensitivity and specificity; however, of these, only the MST met *a-priori* values compared

188   to a suitable multidimensional benchmark for malnutrition. The NUFFE did not report

189   sensitivity, specificity nor a kappa statistic, and therefore no conclusions could be drawn

190   about its suitability for the rehabilitation setting.

191   The moderate agreement of the MNA-SF with the full Mini Nutritional Assessment (MNA),

192   reported by Kaiser et al. [30], is expected as the MNA-SF was designed using the six

193   questions from the full MNA which had the strongest correlations with the total MNA score.

194   However, the two subsequent studies found the MNA-SF may not be appropriate for use in

195   geriatric rehabilitation, as it was found to significantly overestimate the risk of malnutrition

196   when compared to a benchmark unrelated to the MNA [18, 21, 25]. The SNAQ[RC] was also

197   found to overestimate the risk of malnutrition. Overestimating risk of malnutrition may lead

198   to increased burden on nutrition resources, as all patients identified as at risk of malnutrition

199   will be referred to the dietitian for a nutrition assessment. Therefore, the MNA-SF may be

200   appropriate for a well-resourced rehabilitation facility focussed on prevention [32-34]. The

201   MNA-SF has displayed predictive validity for risk of institutionalisation and decreased

202   physical function and quality of life in one study [35] and length of stay and poor

203   participation in rehabilitation activities in a second study [36]. However, a two further studies

204   found it was not able to predict length of stay, complications, physical function,

205   rehospitalisation, institutionalisation, discharge location or mortality [21]. Apart from the

206   MNA-SF, only the Rapid Screen displayed predictive validity, where it was able to predict

207   discharge location [24]. The MST did not display predictive validity, whereas the MUST,

208   NUFFE, SNAQ, SNAQ[RC] and SNAQ[65+] were not evaluated for predictive validity. Overall,

209   although some nutrition screening tools are suitable for identifying risk of malnutrition, there

210   is insufficient evidence to determine if they are suitable predictors of patient outcomes in

211 rehabilitation, which highlights the importance of following nutrition screening with a full

212 nutrition assessment.

213 4.2 Nutrition assessment tools

214 The accuracy and reliability of global nutrition assessment tools in diagnosing malnutrition

215 can be attributed to incorporating multiple criteria in their assessment, such as measures of

216 anthropometry, medical status, physical function and dietary intake. The MNA and the

217 Scored Patient-Generated Subjective Global Assessment (PG-SGA) have been evaluated for

218 criterion validity in the rehabilitation setting [2]. Table 3 compares the concurrent validity of

219 these nutrition assessment tools in rehabilitation facilities.

220 The two studies which evaluated the MNA as a continuous variable reported that it has good

221 discriminatory power [37, 38]; however, when using the recommended score of <17 to

222 identify malnutrition, the lower sensitivity indicates the MNA categories carry a risk of

223 labelling a patient "at risk of malnutrition" instead of "malnourished" in rehabilitation [38].

224 The two-tiered process employed by Visvanathan et al [24], described in table 3, has

225 improved the sensitivity of the MNA. This suggests that caution should be used when

226 employing the MNA in geriatric rehabilitation, and that patients found "at risk of

227 malnutrition" may require further evaluation. However, as the number of patients classified

228 as "at risk of malnutrition" by the MNA is usually high, this may have negative impacts on

229 nutrition resources [38]. These results suggest MNA may require further study to identify a

230 more appropriate cut-off value to diagnose malnutrition in geriatric rehabilitation.

231 One study reported that the Subjective Global Assesment (SGA) ratings of nutrition status

232 were associated with anthropometric measures and grip strength, and had good

233 reproducibility when used by medical officers in rehabilitation [40]. Although the criterion

234 validity of the SGA has not been evaluated, the Scored PG-SGA ratings of nutrition status are

235   analogous to the SGA ratings, and were found to have excellent concurrent validity when

236   compared to the ICD-10-AM classification of malnutrition [38]. The Scored PG-SGA

237   primarliy differs from the SGA by including a continuous numerical score for intervention

238   triage. This score was found to be an "excellent test" [39] and also displayed strong

239   concurrent validity when using a score of 7 or higher to indicate malnutrition in this geriatric

240   population as opposed to 9 or higher currently recommended on the tool for adult populations

241   [38]. Both the MNA and Scored PG-SGA have shown strong predictive validity when

242   compared with institutionalisation, discharge location and rehospitalisation [38]. In addition,

243   the MNA and Scored PG-SGA scores have been found to be sensitive to change in nutrition

244   status during the course of rehabilitation admission [41, 42].

245   4.3 Body Mass Index

246   The BMI was first described by Adolphe Quetelet, a Belgian astronomer, mathematician,

247   statistician and sociologist, between 1830 and 1850 [43]. The BMI, calculated by kg/m^2, has

248   been classified into widely accepted categories of adiposity, where a BMI of $\leq 18.5 kg/m^2$ is

249   considered "underweight" and has been used to diagnose chronic malnutrition for individuals

250   [18]. However, there is strong emerging evidence to suggest that the BMI of $\leq 18.5 kg/m^2$ to

251   indicate underweight is too low for older adults. In 2014, Winter et. al [44] published a meta-

252   analysis which aimed to define BMI in community-dwelling older adults (≥ 65years,

253   n=197,940 in total), and concluded that a BMI of $<23 kg/m^2$ may be considered underweight

254   in community-dwelling older adults. However, it is important to acknowledge that

255   malnutrition can occur in healthy weight or overweight/obese individuals [45]. Therefore,

256   BMI may assist in the identification of chronic malnutrition in some patients, but should not

257   be used as a sole method of screening or diagnosis.

5. Malnutrition prevalence in older adults admitted to rehabilitation

258

259 As suggested in the revision of the concurrent validity of nutrition assessment tools, the

260 reporting of malnutrition prevalence can vary depending on the method used to diagnose the

261 condition. For example, is the nutrition assessment method known to under- or overestimate

262 malnutrition? Furthermore, prevalence of malnutrition in rehabilitation is likely to differ by

263 geographical location, such as by rurality or country, reflecting the access to resources and

264 the population profile of the particular patient group. Therefore, due to the importance of the

265 diagnosis method and the participant characteristics, prevalence was only considered when

266 reported by the MNA (score of <17 to indicate malnutrition), the SGA and Scored PG-SGA

267 (ratings B or C to indicate malnutrition) or the ICD-10-AM criteria (E43, E44.0 or E44.1 to

268 indicate malnutrition); and the patient group was described.

269 Seventeen studies were identified which reported the prevalence of malnutrition in the

270 rehabilitation setting; two of which were in stroke rehabilitation [46, 47], with the remaining

271 15 in general rehabilitation facilities (table 4).

272 All malnutrition prevalence studies undertaken in the rehabilitation setting have had an older

273 adult sample, however two studies did not describe the age of participants [55, 57]. No

274 studies were identified reporting the malnutrition prevalence in rehabilitation in South

275 America or Africa, and only one study reported the prevalence in North America [48]. Only

276 two studies, both Australian, reported the prevalence of malnutrition in a rural population,

277 where the prevalence was high but varied according to type of nutrition assessment

278 (SGA=65% in one sample; ICD-10-AM criteria=46%, Scored PG-SGA=53%, MNA=28% in

279 a second sample) [38, 56]. In two studies which also measured the prevalence of malnutrition

280 in other settings, rehabilitation consistently had the highest prevalence [49, 55]. The MNA

281 was the most popular choice internationally for the assessment of nutrition status (n=11 of 17

282 studies).

283 In metropolitan settings, the prevalence of malnutrition according to the MNA is inconsistent

284 (0.06-68%), however when viewed by geographical location appears more consistent (33-

285 53% in Europe and 14-24% in Asia and approximately 30% in Australia and North America).

286 However, two studies reported outliers, 0.06% in Australia [35] and 68% in Italy [50]. It is

287 unclear if these outliers in reported prevalence of malnutrition by the MNA are due to a real

288 difference in the severity of malnutrition in each study or due to possible differences in how

289 the tool was implemented. When considering the low sensitivity of the MNA to identify

290 malnutrition in geriatric rehabilitation (table 3), the prevalence reported by the MNA may be

291 underestimated generally [38]. The metropolitan prevalence of malnutrition according to the

292 SGA was generally consistent according to studies from Australia and Sweden (32 – 49%).

6. Conclusion

294 The pathogenesis of malnutrition, including starvation-related malnutrition, is distinct from

295 sarcopenia and cachexia; however, nutrition support may have a role in preventing or treating

296 all conditions characterised by the loss of lean tissues. The MST has strong criterion validity;

297 and the MUST, SNAQ and the SNAQ[65+] may also be appropriate for use as nutrition

298 screening tools in rehabilitation. However, the MNA-SF and SNAQ[RC] may only be

299 appropriate for well-resourced settings focussed on prevention. The Rapid Screen and

300 NUFFE require further evaluation of their validity before being recommended as a screening

301 tool in the rehabilitation setting. Overall, nutrition screening tools require further

302 investigation regarding their predictive validity, reliability and accuracy when used in

303 practice. The Scored PG-SGA is appropriate for use as a nutrition assessment tool in

304 rehabilitation; however, the MNA and BMI carry a risk that a malnourished patient may not

305 be identified and may therefore not be appropriate as sole methods of diagnosis. Further

306 research examining the MNA is needed in geriatric rehabilitation, including the evaluation of

307 a new cut-off value for diagnosing malnutrition. Although the SGA can be considered

308   appropriate for use, further evidence is needed regarding its criterion validity. Malnutrition in

309   the rehabilitation setting is most prevalent in older adults, and ranges from <1 – 68%

310   worldwide and is influenced by method of diagnosis, country and rurality. The highest

311   prevalence of malnutrition has been reported in rural, European and Australian settings;

312   however, further studies investigating the prevalence of malnutrition in North and South

313   America and Africa, as well as studies reporting the prevalence in rural areas internationally,

314   is required.

315   **7. Acknowledgements**

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Table 1: The diagnostic criteria of malnutrition, sarcopenia and cachexia

Malnutrition[a]	Sarcopenia[e]	Cachexia[g]
Diagnosis based upon criterion 1 or (criterion 2 plus criterion 3 plus criterion 4)	**Diagnosis based upon criterion 1 plus (criterion 2 or criterion 3)**	**Diagnosis based upon (criterion 1 or criterion 2) and (criterion 3, criterion 4 or criterion 5)**
Criterion 1: BMI[b] <18.5 kg[c]/m[d]^2	Criterion 1: Poor physical functioning (gait speed $<1 \text{m·s}^{-1}$[f])	Criterion 1: Unintentional weight loss ($\geq 5\%$) in 12 months or less in presence of underlying illness
Criterion 2: Unintentional weight loss ($\geq 5\%$)	Criterion 2: Whole body lean mass $<20^{th}$ percentile	Criterion 2: BMI $<20 \text{kg/m}^2$
Criterion 3: Suboptimal intake	Criterion 3: Appendicular fat free mass $\leq 7.23 \text{kg/m}^2$ (men) or $\leq 5.67 \text{kg/m}^2$ (women)	Criterion 3: Fatigue
Criterion 4: Loss of fat and/or muscle		Criterion 4: Low fat-free mass (MUAMC[h] $<10^{th}$ percentile or appendicular skeletal muscle $\leq 7.25 \text{kg/m}^2$ (men) or $\leq 5.45 \text{kg/m}^2$ (women))
		Criterion 5: Abnormal biochemistry (albumin <32g[i]/L[j] (3.2 g/dL[k]), CRP[l] >5.0mg[m]/L or IL-6[n] >4.0pg[o]/ml[p], or Hb[q] <3.2g/dL)

[a] Diagnosis of malnutrition according to the *International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification* (sixth edition, ICD-10-AM) [18].

[b] BMI, body mass index

[c] kg, kilogram

[d] m, metre

[e] Diagnosis of sarcopenia according to the International Working Group on Sarcopenia [11]

[f] m·s^{-1}, meter per second

[g] Diagnosis of cachexia according to the Cachexia Consensus Working Group [14]

[h] MUAMC, mid upper arm muscle circumference

[i] g, gram

[j] L, litre
[k] dL, decilitre
[l] CRP, C-reactive protein
[m] mg, milligram
[n] IL-6, Interleukin-6
[o] pg, pictogram
[p] ml, millilitre
[q] Hb, haemoglobin

Table 2: Comparison of the concurrent validity of nutrition screening tools evaluated in the rehabilitation setting

Nutrition screening tool	Benchmark used	Population	Sensitivity	Specificity	Kappa statistic	Kappa statistic classification[a]
MNA-SF[b] - Kaiser et al. 2011 [30]	Full MNA[c]	n=99, μ74.9±6.2 years Rome, Italy	Not reported	Not reported	0.626	Substantial agreement
MNA-SF - Marshall et al. 2015 [21]	ICD-10-AM[d] classification	n=57, μ79.1±7.3 years NSW[e], Australia	100%	22.6%	0.210	Fair agreement
MNA-SF - Hertroijs et al. 2012 [25]	Low BMI[f] or weight-loss	n=366, μ55 years Netherlands	92%	37%	Not reported	Not reported
MST[g] - Marshall et al. 2015 [21]	ICD-10-AM	n=57, μ79.1±7.3 years NSW, Australia	80.8%	67.7%	0.478	Moderate agreement
MUST[h] - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, μ55 years Netherlands	100%	97%	Not reported	Not reported
NUFFE[i] - Söderhamn & Söderhamn, 2002 [23]	BMI, MAC[j], CC[k] and MNA	n=114, μ78.0±6.3 years Western Sweden	Not reported	Not reported	Not reported	Not reported
Rapid Screen - Visvanathan et al. 2004 [24]	Standardised nutrition assessment	n=65, μ76.5-79.8 years SA[l], Australia	78.6%	97.3%	Not reported	Not reported
SNAQ[m]						

- Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, μ55 years Netherlands	96%	71%	Not reported	Not reported
SNAQ[RC,n]						
- Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, μ55 years Netherlands	99%	48%	Not reported	Not reported
SNAQ[65+,o]						
- Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, μ55 years Netherlands	96%	77%	Not reported	Not reported

a Landis and Koch kappa statistic classification [31]

b MNA-SF, Mini Nutritional Assessment – Short Form

c MNA, Mini Nutritional Assessment

d ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification (sixth edition) classifications for protein-energy malnutrition in adults

e NSW, New South Wales

f BMI, body mass index

g MST, Malnutrition Screening Tool

h MUST, Malnutrition Universal Assessment Tool

i NUFFE, Nutritional Form for the Elderly; Spearman rank correlations used to determine concurrent validity with the BMI at admission (r_s -0.25, P=0.008), BMI at discharge (r_s -0.23, P=0.014), MAC (r_s -0.23, P=0.014), CC (r_s -0.25, P=0.008) and the MNA (r_s -0.74, P=0.000)

j MAC, mid arm circumference

k CC, calf circumference

l SA, South Australia

m SNAQ, Short Nutritional Assessment Questionnaire

n SNAQ[RC], Short Nutritional Assessment Questionnaire Residential Care

o SNAQ[65+], Short Nutritional Assessment Questionnaire for older adults

Table 3: Comparison of concurrent validity of nutrition assessment tools evaluated in the rehabilitation setting

Nutrition screening tool	Benchmark used	Population	ROC AUC[a]	ROC AUC classification[b]	Sensitivity	Specificity	Kappa statistic	Kappa statistic classification[c]
MNA[d] - Neumann et al. 2007 [37]	Body fat	n=34, median 84 (IQR[e], 78-88) years SA[f], Australia	0.74	Good test	Not reported	Not reported	Not reported	Not reported
MNA - Marshall et al. 2015 [38]	ICD-10-AM[g]	n=57, μ79.1±7.3 years NSW[h], Australia	0.85	Very good test	57.7%	96.8%	0.562	Moderate agreement
MNA[i] - Visvanathan et al. 2004 [24]	Standardised nutrition assessment	n=65, μ76.5-79.8 years SA, Australia	N/A[j,k]	N/A	89.5%	87.5%	Not reported	Not reported
Scored PG-SGA[l] ratings - Marshall, et al. 2015 [38]	ICD-10-AM	n=57, μ79.1±7.3 years NSW, Australia	N/A[k]	N/A	100%	87.1%	0.860	Almost perfect agreement
Scored PG-SGA score[m] - Marshall, et al. 2015 [38]	ICD-10-AM	n=57, μ79.1±7.3 years NSW, Australia	0.910	Excellent test	92.3%	83.9%	0.7555	Substantial agreement

a ROC AUC, Receiver Operating Characteristic Area Under the Curve

b ROC AUC classification for the discriminative power of a test [39]

c Landis and Koch kappa statistic classification [31]

d MNA, Mini Nutritional Assessment

e IQR, Interquartile range

f SA, South Australia

g ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification (sixth edition) classifications for protein-energy malnutrition in adults

h NSW, New South Wales

i Non-standard calculation of the MNA. A two-step process was used, where participants which were identified as "at risk of malnutrition" (score 17 – 23.5) underwent further nutritional assessment to re-classify as "malnourished" or "well-nourished". Traditional scoring of the MNA considers a participant "malnourished" if they scored <17, and "well-nourished" if they scored 17 - 30, which includes participants "at risk of malnutrition".

j N/A, Not applicable

k ROC AUC applies to continuous variables only

l PG-SGA, Patient-Generated Subjective Global Assessment

m A score of 7 or more used to indicate "malnutrition" in geriatric rehabilitation [38]

Table 4: International prevalence of malnutrition in the rehabilitation setting according nutrition assessment tools validated for the rehabilitation setting.

Study	Setting	Diagnosis method	Prevalence
MNA in North America			
Thomas et al. 2002 [48]	• St Louis, USA • n=104, μ75.8 years	MNA	29%
MNA in Europe			
Compan et al. 2000 [49]	• Nîmes, France • n=196, μ83.4±6.8 years	MNA	33%[a]
Donini et al. 2002 [50]	• Rome, Italy • n=167, μ79 – 83 years	MNA	68%
Kaiser et al. 2011 [30]	• Rome, Italy • n=99, μ74.9±6.2 years	MNA	41%
MNA in Asia			
Shum et al. 2005 [51]	• Regional Hong Kong • n=120, μ80.3±7.4 years	Chinese MNA[b]	17%
Tsai et al. 2009 [46]	• Wen-Hua District, Taiwan[c] • n=74, 82% were ≥60 years	MNA, MNA-TI (population specific)[d]	24% (MNA), 14% (MNA-TI)
MNA in Australia			
Visvanathan et al. 2004 [24]	• Adelaide, SA • n=65, μ76.5 – 79.8 years	MNA	29%
Neumann et al. 2005 [35]	• 3 Hospitals across SA • n=167, μ81±6 years	MNA	0.06%
Charlton et al. 2010 [52]	• Sydney, NSW • n=2076, μ80.6±27.7 years	MNA	33%
McDougall et al. 2015 [42]	• Melbourne, Victoria • n=114, 83±7 years	MNA	32%

Marshall et al. 2015 [38]	• Rural NSW • n=57, μ79.1±7.3 years	MNA	28%
SGA in Europe			
Westergren et al. 2001 [47]	• Metropolitan Sweden[e] • n=162, μ78.62 years	SGA[f]	32%
Westergren et al. 2002 [53]	• Metropolitan Sweden • n=520, μ81.0 years	SGA[f]	46%
Andersson et al. 2002 [54]	• South Sweden • n=237, μ78.5 – 78.6 years	SGA[f]	34%
SGA in Australia			
Beck et al. 2001 [55]	• Wollongong, NSW • n=344, age not described	SGA	49%[g]
Thomas, et al. 2014 [56]	• Ballarat, Victoria • n=20, "geriatric", age not described	SGA	65%
Breik, et al. 2015 [57]	• Metropolitan Victoria • n=69, age not described	SGA	49%
Scored PG-SGA in Australia			
Marshall et al. 2015 [38]	• Rural NSW • n=57, μ79.1±7.3 years	Scored PG-SGA	53%
ICD-10-AM classification of protein-energy malnutrition in Australia			
Marshall et al. 2015 [38]	• Rural NSW • n=57, μ79.1±7.3 years	ICD-10-AM	46%

CI, Confidence interval; ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems, 10th Revision, Australian Modification*;* MNA, Mini Nutritional Assessment; SA, South Australia; PG-SGA, Patient-Generated Subjective Global Assessment; SGA, Subjective Global Assessment.

a Compan et al. [49] found that rehabilitation had a higher prevalence than acute care than those in acute care (24.5%) or long-term residential care (24.7%).

b Malnutrition is considered at an MNA score of <18.5 as opposed to the usual <17 in the modified Chinese MNA.

c Result reported from a combined community and inpatient stroke rehabilitation study sample as opposed to a general rehabilitation inpatient sample

d Cut-points for the modified MNA-TI not described by the authors.

e Results reported from a stroke rehabilitation study sample as opposed to a general rehabilitation inpatient sample

f The SGA used in Sweden has four ratings of nutrition status, A, B, C and D instead of the usual A, B or C. The authors report malnutrition prevalence comprising ratings B, C and D.

g Beck et al. [55] found that rehabilitation had the highest prevalence of malnutrition compared to other inpatient medical wards