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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

## 40 **1. Introduction**

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

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

54 The prevalence of malnutrition in rehabilitation and the nutrition screening and assessment  
55 tools appropriate for use in rehabilitation have not been reviewed since 2009 [2]. Examining  
56 the validity of nutrition screening and assessment tools in rehabilitation will help practitioners  
57 select the most appropriate tool for their facility. Additionally, understanding the limitations  
58 of a particular tool in a particular setting is required so that appropriate steps can be taken to  
59 minimise the risk of misdiagnosis. For this reason, the method of diagnosis should be  
60 considered when reviewing the prevalence of malnutrition. The prevalence of malnutrition in  
61 rehabilitation has not been evaluated with consideration given to the method of diagnosis, nor  
62 the various settings in which it was measured, such as rural versus metropolitan prevalence or  
63 **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.

## 71 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.

## 83 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 10<sup>th</sup>*  
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<sup>RC</sup>) [25, 27] and the SNAQ for older adults (SNAQ<sup>65+</sup>) [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  $\geq 80\%$  for  
184 sensitivity and  $\geq 60\%$  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<sup>65+</sup> 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<sup>RC</sup> 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<sup>RC</sup> and SNAQ<sup>65+</sup> 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 Assessment (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 primarily 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  $\text{kg/m}^2$ , has  
248 been classified into widely accepted categories of adiposity, where a BMI of  $\leq 18.5 \text{kg/m}^2$  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  $\leq 18.5 \text{kg/m}^2$  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 ( $\geq 65$  years,  
253  $n=197,940$  in total), and concluded that a BMI of  $< 23 \text{kg/m}^2$  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.

## 258 **5. Malnutrition prevalence in older adults admitted to rehabilitation**

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%).

## 293 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<sup>65+</sup> may also be appropriate for use as nutrition  
298 screening tools in rehabilitation. However, the MNA-SF and SNAQ<sup>RC</sup> 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.

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

<b>Malnutrition<sup>a</sup></b>	<b>Sarcopenia<sup>e</sup></b>	<b>Cachexia<sup>g</sup></b>
<b>Diagnosis based upon criterion 1 or (criterion 2 plus criterion 3 plus criterion 4)</b>	<b>Diagnosis based upon criterion 1 plus (criterion 2 or criterion 3)</b>	<b>Diagnosis based upon (criterion 1 or criterion 2) and (criterion 3, criterion 4 or criterion 5)</b>
Criterion 1: BMI <sup>b</sup> <18.5 kg <sup>c</sup> /m <sup>d2</sup>	Criterion 1: Poor physical functioning (gait speed <1m·s <sup>-1f</sup> )	Criterion 1: Unintentional weight loss (≥5%) in 12 months or less in presence of underlying illness
Criterion 2: Unintentional weight loss (≥5%)	Criterion 2: Whole body lean mass <20 <sup>th</sup> percentile	Criterion 2: BMI <20kg/m <sup>2</sup>
Criterion 3: Suboptimal intake	Criterion 3: Appendicular fat free mass ≤7.23kg/m <sup>2</sup> (men) or ≤5.67kg/m <sup>2</sup> (women)	Criterion 3: Fatigue
Criterion 4: Loss of fat and/or muscle		Criterion 4: Low fat-free mass (MUAMC <sup>h</sup> <10 <sup>th</sup> percentile or appendicular skeletal muscle ≤7.25kg/m <sup>2</sup> (men) or ≤5.45kg/m <sup>2</sup> (women))
		Criterion 5: Abnormal biochemistry (albumin <32g <sup>i</sup> /L <sup>j</sup> (3.2 g/dL <sup>k</sup> ), CRP <sup>l</sup> >5.0mg <sup>m</sup> /L or IL-6 <sup>n</sup> >4.0pg <sup>o</sup> /ml <sup>p</sup> , or Hb <sup>q</sup> <3.2g/dL)

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

<sup>b</sup> BMI, body mass index

<sup>c</sup> kg, kilogram

<sup>d</sup> m, metre

<sup>e</sup> Diagnosis of sarcopenia according to the International Working Group on Sarcopenia [11]

<sup>f</sup> m·s<sup>-1</sup>, meter per second

<sup>g</sup> Diagnosis of cachexia according to the Cachexia Consensus Working Group [14]

<sup>h</sup> MUAMC, mid upper arm muscle circumference

<sup>i</sup> g, gram



<sup>j</sup> L, litre

<sup>k</sup> dL, decilitre

<sup>l</sup> CRP, C-reactive protein

<sup>m</sup> mg, milligram

<sup>n</sup> IL-6, Interleukin-6

<sup>o</sup> pg, pictogram

<sup>p</sup> ml, millilitre

<sup>q</sup> Hb, haemoglobin

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

<b>Nutrition screening tool</b>	<b>Benchmark used</b>	<b>Population</b>	<b>Sensitivity</b>	<b>Specificity</b>	<b>Kappa statistic</b>	<b>Kappa statistic classification<sup>a</sup></b>
MNA-SF <sup>b</sup> - Kaiser et al. 2011 [30]	Full MNA <sup>c</sup>	n=99, $\mu$ 74.9 $\pm$ 6.2 years Rome, Italy	Not reported	Not reported	0.626	Substantial agreement
MNA-SF - Marshall et al. 2015 [21]	ICD-10-AM <sup>d</sup> classification	n=57, $\mu$ 79.1 $\pm$ 7.3 years NSW <sup>e</sup> , Australia	100%	22.6%	0.210	Fair agreement
MNA-SF - Hertroijs et al. 2012 [25]	Low BMI <sup>f</sup> or weight-loss	n=366, $\mu$ 55 years Netherlands	92%	37%	Not reported	Not reported
MST <sup>g</sup> - Marshall et al. 2015 [21]	ICD-10-AM	n=57, $\mu$ 79.1 $\pm$ 7.3 years NSW, Australia	80.8%	67.7%	0.478	Moderate agreement
MUST <sup>h</sup> - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, $\mu$ 55 years Netherlands	100%	97%	Not reported	Not reported
NUFFE <sup>i</sup> - Söderhamn & Söderhamn, 2002 [23]	BMI, MAC <sup>j</sup> , CC <sup>k</sup> and MNA	n=114, $\mu$ 78.0 $\pm$ 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, $\mu$ 76.5-79.8 years SA <sup>l</sup> , Australia	78.6%	97.3%	Not reported	Not reported
SNAQ <sup>m</sup>						

- Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, $\mu$ 55 years Netherlands	96%	71%	Not reported	Not reported
SNAQ <sup>RC,n</sup> - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, $\mu$ 55 years Netherlands	99%	48%	Not reported	Not reported
SNAQ <sup>65+,o</sup> - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, $\mu$ 55 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 10<sup>th</sup> 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<sup>RC</sup>, Short Nutritional Assessment Questionnaire Residential Care

o SNAQ<sup>65+</sup>, Short Nutritional Assessment Questionnaire for older adults

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

<b>Nutrition screening tool</b>	<b>Benchmark used</b>	<b>Population</b>	<b>ROC AUC<sup>a</sup></b>	<b>ROC AUC classification<sup>b</sup></b>	<b>Sensitivity</b>	<b>Specificity</b>	<b>Kappa statistic</b>	<b>Kappa statistic classification<sup>c</sup></b>
MNA <sup>d</sup> - Neumann et al. 2007 [37]	Body fat	n=34, median 84 (IQR <sup>e</sup> , 78-88) years SA <sup>f</sup> , Australia	0.74	Good test	Not reported	Not reported	Not reported	Not reported
MNA - Marshall et al. 2015 [38]	ICD-10-AM <sup>g</sup>	n=57, $\mu$ 79.1 $\pm$ 7.3 years NSW <sup>h</sup> , Australia	0.85	Very good test	57.7%	96.8%	0.562	Moderate agreement
MNA <sup>i</sup> - Visvanathan et al. 2004 [24]	Standardised nutrition assessment	n=65, $\mu$ 76.5-79.8 years SA, Australia	N/A <sup>j,k</sup>	N/A	89.5%	87.5%	Not reported	Not reported
Scored PG-SGA <sup>l</sup> ratings - Marshall, et al. 2015 [38]	ICD-10-AM	n=57, $\mu$ 79.1 $\pm$ 7.3 years NSW, Australia	N/A <sup>k</sup>	N/A	100%	87.1%	0.860	Almost perfect agreement
Scored PG-SGA score <sup>m</sup> - Marshall, et al. 2015 [38]	ICD-10-AM	n=57, $\mu$ 79.1 $\pm$ 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 10<sup>th</sup> 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
<b>MNA in North America</b>			
Thomas et al. 2002 [48]	<ul style="list-style-type: none"> <li>• St Louis, USA</li> <li>• n=104, <math>\mu</math>75.8 years</li> </ul>	MNA	29%
<b>MNA in Europe</b>			
Compan et al. 2000 [49]	<ul style="list-style-type: none"> <li>• Nîmes, France</li> <li>• n=196, <math>\mu</math>83.4<math>\pm</math>6.8 years</li> </ul>	MNA	33% <sup>a</sup>
Donini et al. 2002 [50]	<ul style="list-style-type: none"> <li>• Rome, Italy</li> <li>• n=167, <math>\mu</math>79 – 83 years</li> </ul>	MNA	68%
Kaiser et al. 2011 [30]	<ul style="list-style-type: none"> <li>• Rome, Italy</li> <li>• n=99, <math>\mu</math>74.9<math>\pm</math>6.2 years</li> </ul>	MNA	41%
<b>MNA in Asia</b>			
Shum et al. 2005 [51]	<ul style="list-style-type: none"> <li>• Regional Hong Kong</li> <li>• n=120, <math>\mu</math>80.3<math>\pm</math>7.4 years</li> </ul>	Chinese MNA <sup>b</sup>	17%
Tsai et al. 2009 [46]	<ul style="list-style-type: none"> <li>• Wen-Hua District, Taiwan<sup>c</sup></li> <li>• n=74, 82% were <math>\geq</math>60 years</li> </ul>	MNA, MNA-TI (population specific) <sup>d</sup>	24% (MNA), 14% (MNA-TI)
<b>MNA in Australia</b>			
Visvanathan et al. 2004 [24]	<ul style="list-style-type: none"> <li>• Adelaide, SA</li> <li>• n=65, <math>\mu</math>76.5 – 79.8 years</li> </ul>	MNA	29%
Neumann et al. 2005 [35]	<ul style="list-style-type: none"> <li>• 3 Hospitals across SA</li> <li>• n=167, <math>\mu</math>81<math>\pm</math>6 years</li> </ul>	MNA	0.06%
Charlton et al. 2010 [52]	<ul style="list-style-type: none"> <li>• Sydney, NSW</li> <li>• n=2076, <math>\mu</math>80.6<math>\pm</math>27.7 years</li> </ul>	MNA	33%
McDougall et al. 2015 [42]	<ul style="list-style-type: none"> <li>• Melbourne, Victoria</li> <li>• n=114, 83<math>\pm</math>7 years</li> </ul>	MNA	32%

Marshall et al. 2015 [38]	<ul style="list-style-type: none"> <li>• Rural NSW</li> <li>• n=57, <math>\mu</math>79.1<math>\pm</math>7.3 years</li> </ul>	MNA	28%
<b>SGA in Europe</b>			
Westergren et al. 2001 [47]	<ul style="list-style-type: none"> <li>• Metropolitan Sweden<sup>e</sup></li> <li>• n=162, <math>\mu</math>78.62 years</li> </ul>	SGA <sup>f</sup>	32%
Westergren et al. 2002 [53]	<ul style="list-style-type: none"> <li>• Metropolitan Sweden</li> <li>• n=520, <math>\mu</math>81.0 years</li> </ul>	SGA <sup>f</sup>	46%
Andersson et al. 2002 [54]	<ul style="list-style-type: none"> <li>• South Sweden</li> <li>• n=237, <math>\mu</math>78.5 – 78.6 years</li> </ul>	SGA <sup>f</sup>	34%
<b>SGA in Australia</b>			
Beck et al. 2001 [55]	<ul style="list-style-type: none"> <li>• Wollongong, NSW</li> <li>• n=344, age not described</li> </ul>	SGA	49% <sup>g</sup>
Thomas, et al. 2014 [56]	<ul style="list-style-type: none"> <li>• Ballarat, Victoria</li> <li>• n=20, “geriatric”, age not described</li> </ul>	SGA	65%
Breik, et al. 2015 [57]	<ul style="list-style-type: none"> <li>• Metropolitan Victoria</li> <li>• n=69, age not described</li> </ul>	SGA	49%
<b>Scored PG-SGA in Australia</b>			
Marshall et al. 2015 [38]	<ul style="list-style-type: none"> <li>• Rural NSW</li> <li>• n=57, <math>\mu</math>79.1<math>\pm</math>7.3 years</li> </ul>	Scored PG-SGA	53%
<b>ICD-10-AM classification of protein-energy malnutrition in Australia</b>			
Marshall et al. 2015 [38]	<ul style="list-style-type: none"> <li>• Rural NSW</li> <li>• n=57, <math>\mu</math>79.1<math>\pm</math>7.3 years</li> </ul>	ICD-10-AM	46%

CI, Confidence interval; ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems, 10<sup>th</sup> 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