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1 **Potentially Modifiable Determinants of Malnutrition in Older Adults: a**  
2 **Systematic Review**

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46

47 **Abstract**

48

49 **Background & Aims:** Malnutrition in older adults results in significant personal, social, and  
50 economic burden. To combat this complex, multifactorial issue, evidence-based knowledge is  
51 needed on the modifiable determinants of malnutrition. Systematic reviews of prospective  
52 studies are lacking in this area; therefore, the aim of this systematic review was to investigate  
53 the modifiable determinants of malnutrition in older adults.

54 **Methods:** A systematic approach was taken to conduct this review. Eight databases were  
55 searched. Prospective cohort studies with participants of a mean age of 65 or over were  
56 included. Studies were required to measure at least one determinant at baseline and  
57 malnutrition as outcome at follow-up. Study quality was assessed using a modified version of  
58 the Quality in Prognosis Studies (QUIPS) tool. Pooling of data in a meta-analysis was not  
59 possible therefore the findings of each study were synthesized narratively. A descriptive  
60 synthesis of studies was used to present results due the heterogeneity of population source  
61 and setting, definitions of determinants and outcomes. Consistency of findings was assessed  
62 using the schema: strong evidence, moderate evidence, low evidence, and conflicting  
63 evidence.

64 **Results:** Twenty-three studies were included in the final review. Thirty potentially  
65 modifiable determinants across seven domains (oral, psychosocial, medication and care,  
66 health, physical function, lifestyle, eating) were included. The majority of studies had a high  
67 risk of bias and were of a low quality. There is moderate evidence that hospitalisation, eating  
68 dependency, poor self-perceived health, poor physical function and poor appetite are  
69 determinants of malnutrition. Moderate evidence suggests that chewing difficulties, mouth  
70 pain, gum issues co-morbidity, visual and hearing impairments, smoking status, alcohol

71 consumption and physical activity levels, complaints about taste of food and specific nutrient  
72 intake are not determinants of malnutrition. There is low evidence that loss of interest in  
73 life, access to meals and wheels, and modified texture diets are determinants of malnutrition.  
74 Furthermore, there is low evidence that psychological distress, anxiety, loneliness, access to  
75 transport and wellbeing, hunger and thirst are not determinants of malnutrition. There  
76 appears to be conflicting evidence that dental status, swallowing, cognitive function,  
77 depression, residential status, medication intake and/or polypharmacy, constipation,  
78 periodontal disease are determinants of malnutrition.

79

80 **Conclusion:** There are multiple potentially modifiable determinants of malnutrition however  
81 strong robust evidence is lacking for the majority of determinants. Better prospective cohort  
82 studies are required. With an increasingly aging population, targeting modifiable factors will  
83 be crucial to the effective treatment and prevention of malnutrition.

84

85 **Keywords:** malnutrition, determinants, older adults, systematic review, prospective cohort  
86 studies

87

## 88 INTRODUCTION

89

90 Malnutrition is defined as “a state of nutrition in which a deficiency of energy, protein and  
91 other nutrients causes measurable adverse effects on tissue and body form (body shape, size  
92 and composition) and function and clinical outcome” [1]. It is common, costly and increases  
93 with age, resulting in significant personal, social and economic burden [1, 2]. Of most  
94 concern, it is an increasing health problem, mainly due to changes in worldwide population  
95 demographics. For instance, between 2010 and 2050, the global population over the age of 80  
96 has been predicted to grow from 11.5% to 21.0% worldwide and from 9.0% to 19.0% in  
97 developed countries [3]. The prevalence of malnutrition in older adults varies significantly  
98 across different population subgroups; it is higher in older persons with higher disability  
99 levels, deteriorating health and multi-morbidities, deteriorating poor physical function, and  
100 dependence in activities of daily living (ADL) [4] . Malnutrition affects less than 10% of  
101 independently living older persons in the community. **This prevalence is even lower when**  
102 **older adults are living at their home and attending senior centres [5, 6].** However, the  
103 prevalence is reported to be 50% higher in nursing home and acute care settings; estimates  
104 ranging from 30-50% [7-9], displaying the importance of examining malnutrition across  
105 multiple settings. Although malnutrition is a prognostic factor associated with morbidity,  
106 mortality, and costs of care, nutritional problems in older adults often remain undetected or  
107 unaddressed [10]. This is a serious issue, as malnutrition is strongly associated with  
108 sarcopenia and frailty, two major public health issues among older adults [2, 11].  
109 Understanding the aetiology of malnutrition, and finding effective interventions and  
110 preventive strategies is therefore of utmost importance [12-14].

111

112 Several different definitions and criteria have been recommended for the diagnosis of  
113 malnutrition. These include different cut-off points for weight loss, body mass index (BMI),  
114 blood parameters (e.g. albumin) and assessment tools (e.g, the full Mini Nutritional  
115 Assessment (MNA)) [15-18]. The heterogeneity across definitions and diagnostic criteria in  
116 research and clinical practice makes it very difficult to generate meaningful data or  
117 comparisons on true malnutrition prevalence, incidence and treatment response across  
118 different countries and settings. Nevertheless, focusing on which factor contribute to the  
119 development of malnutrition may aid the development of effective interventions.

120

121 Multiple factors have been correlated with malnutrition in older adults and then suspected to  
122 be determinants including reduced appetite, **female sex, social resources, poor physical**  
123 **function, poor-self related health**, sensory function, chewing and swallowing problems,  
124 physical and cognitive impairment, depression, polypharmacy, low-grade inflammation, low  
125 socioeconomic status and loneliness, lack of food choices, lack of dietary advice/education,  
126 and older age [2, 6, 15-20]. However, most of the available studies in this area are cross-  
127 sectional with limited ability to make causal inference. Less emphasis has focussed on  
128 prospective studies and on determinants that could be considered potentially modifiable.  
129 Achieving consensus on what determinants may be modifiable, and generating strategies to  
130 modify these may be useful for future prevention and treatment of malnutrition.

131

132 Several studies and narrative reviews describe determinants of malnutrition. To date, three  
133 systematic reviews [14, 21, 22] have been completed in this area. One of these systematic  
134 reviews [21] investigated the determinants of malnutrition in community adults only, and  
135 only up to January 2013. This review consisted of mainly cross-sectional studies; it excluded  
136 certain tools for measuring malnutrition, and was limited to studies conducted in Western

137 countries. The second [14] of the three reviews investigated determinants of malnutrition in  
138 nursing home patients only, from January 1990 to 2013 (16 cross-sectional studies). The third  
139 review [22] assessed determinants using prospective cohort studies which were published  
140 between January 2000 and March 2015. This review which had strict inclusion criteria based  
141 on sample size, measures of malnutrition, and methods of statistical analysis and, included six  
142 studies. No systematic review of malnutrition in older people has searched all years up to  
143 2017, included all settings, was not restricted based on definitions or outcome measures used,  
144 and was focussed on modifiable determinants, which are arguably the most important for  
145 prevention and treatment of malnutrition. It is necessary to examine all of the available  
146 evidence to achieve a better understanding of the determinants, and effectively inform the  
147 design of future studies to generate better data and outcomes. Therefore, the objective of this  
148 systematic review was to examine the potentially modifiable determinants of malnutrition in  
149 older adults, across all settings, using information from prospective studies.

150

## 151 **METHODOLOGY**

### 152 **Search Strategy**

153 This review was registered on the PROSPERO database (CRD42017070383) and has been  
154 reported in accordance with the PRISMA statement [23]. Relevant prospective cohort studies  
155 meeting the inclusion criteria were identified by a computer aided search of the MEDLINE,  
156 CINAHL, Academic Search Complete, AMED, SPORTDiscus, PsycINFO, Biomedical  
157 Reference Collection, PsycARTICLES, and Web of Science databases during February 2017  
158 from the period of inception (See **Figure 1** for search keywords). The reference lists of the  
159 included manuscripts were searched for additional papers by two independent reviewers. The  
160 search was restricted to include all studies that involved humans and were published in



161 English, French, Dutch or German only. The reference lists of the selected articles were also  
162 manually searched for any further relevant articles

163

164 Two reviewers (MOK and MK) screened the articles independently. The strategy had two  
165 components which were combined: (1) nutrition AND (2) old. The terms were searched using  
166 title and abstract. The exact search strings utilized are shown in **Figure 1**.

167

168 **Figure 1: Search keywords**

Nutrition* OR nutrient* OR undernutrition OR "under nutrition" OR undernourish* OR "under nourish*" OR under-nutrition OR malnutrition OR malnourish* OR "body composition" OR body-composition OR "underweight*" OR "under weight" OR "weight loss" OR weight-loss OR underfed* OR "under fed" OR starv* OR weight* OR thinness OR sarcopeni* OR "energy intake" OR "food intake" OR anorexia* OR fasting* OR underfeeding OR hunger* OR BMI OR "body mass index" OR cachexia* OR "wasting syndrome" OR protein-energy OR protein-calorie OR "protein calorie" OR "protein energy" OR slimness OR diet* OR appetite* (Title and Abstract)
AND
old* OR elder* OR elderly OR geriatric* OR senior* OR aging* OR aged OR "old age" OR "nursing home" OR nursing-home OR "community dwell*" OR "community-dwell*" OR "home care" OR home-care OR domiciliary OR free-living OR "free living" OR "over age 65" OR "65 and over" OR "living at home" OR "home nurs*" OR "home living" OR home-living OR "home help" OR home-help OR "home health" OR home-health OR "long-term care" OR "long term care" OR "community care" OR "domestic care " OR "residential care" OR long-stay OR "long stay" (Title and Abstract)

169

170 **Inclusion/Exclusion Criteria**

171 ***Study design***

172 Only reports of completed prospective cohort studies published in peer-reviewed journals  
173 were included. Only prospective studies that looked at the impact of determinants on the  
174 evolution of malnutrition were included.

175

### 176 *Population*

177 Study participants were required to be 65 or older (if a combined population was described,  
178 the mean age had to be  $\geq 65$  years [24]. All settings (nursing home, community-dwelling,  
179 geriatric rehabilitation setting, acute care setting) were included. Studies examining specific  
180 patient groups (e.g. cancer patients) were not excluded based on the presence of these specific  
181 co-morbidities, as co-morbidity is a known determinant of malnutrition.

182

### 183 *Potential determinants*

184 Studies were required to examine one or more determinants of malnutrition. Studies  
185 examining determinants that the authors of this review deem as potentially modifiable by the  
186 older adult or by a carer-physician were included. Decisions on the potential modifiability of  
187 determinants were based on consensus within the author group. Factors considered non-  
188 modifiable, like age and genetics, were excluded. Attempts were made not to be too strict on  
189 what constituted non-modifiable, as it remains unclear whether certain factors within  
190 particular settings, are modifiable or not. Where it was unclear whether the factor was  
191 modifiable or non-modifiable (e.g. vision, cognitive state), the study was included.

192

### 193 *Clinical Outcomes*

194 Studies had to report results from an outcome measure in the domain of malnutrition.  
195 Examples include BMI, and weight loss percentage. Since there is no gold standard definition  
196 or criteria for malnutrition, no study was excluded based on the outcome measure used for

197 malnutrition. This means that studies that assessed malnutrition by screening or assessment  
198 tools (e.g. MNA and MUST) that include risk factors of malnutrition were included.  
199 Differences in definitions and criteria used for malnutrition were recorded. No restriction was  
200 placed on the time of follow-up.

201

202 A previous review [21] excluded studies that assessed malnutrition by screening or  
203 assessment tools that include determinants of malnutrition (such as the MNA and the MUST).  
204 Therefore, we also completed a descriptive synthesis without these studies to see if their  
205 removal would change the results.

206

### 207 **Study selection**

208 A standard protocol was followed for study selection and data extraction. After the removal  
209 of duplicates, two authors (MOK and MK) independently screened the titles and abstracts  
210 from the articles found, and excluded articles not meeting the eligibility criteria. If no abstract  
211 was available, or when it was not clear if the study should be included, full-text articles were  
212 retrieved in order to determine inclusion or exclusion. Both reviewers kept a record of their  
213 reasons for the inclusion or the exclusion of articles. The full-text version of an article was  
214 obtained if the title and abstract seemed to fulfil the inclusion criteria, or if the eligibility of  
215 the study was unclear. If any disagreements on study eligibility took place, the planned  
216 procedure was to hold a consensus meeting with another author (EOC). Original study  
217 authors were emailed, where required, to provide clarity on methodology.

218

### 219 **Risk of bias assessment and overall quality**

220 Two reviewers assessed the methodological quality of the studies independently and  
221 discrepancies were resolved by consensus. If necessary, a third author helped to reach

222 consensus. The methodological quality was assessed by the Quality in Prognosis Studies  
223 (QUIPS) tool, which has been recommended by the Cochrane Prognosis Methods Group  
224 [25]. The QUIPS was modified to judge bias in relation to determinants, instead of the  
225 original tool's focus on prognostic factors. The modified version has been used in a previous  
226 systematic review [26]. The following six domains were considered: 1) study participation, 2)  
227 study attrition, 3) measures of risk factors, 4) measurement of, and controlling for  
228 confounding variables, 5) outcome measures, 6) analysis and reporting. Each domain was  
229 assessed as having high, moderate or low risk of bias (ROB) The overall ROB was also  
230 assessed. We considered a study to be of high quality when the ROB was rated low on at  
231 least four of the six domains and was rated low for both study attrition and study  
232 confounding. This approach has been used for systematic reviews in other fields [26].

233

#### 234 **Data extraction and data analysis**

235 Data regarding each study were extracted by one author (MOK) and cross-checked by a  
236 second author (MK). The following data were extracted from each study:

237 - Domain of interest (eg. Oral, psychosocial, physical)

238 - Study and examined determinant (s)

239 - Setting (e.g community, nursing home, etc) and country

240 - Measure of malnutrition and length of follow-up

241 -Results (e.g odds ratio, hazard ratio, relative risk, etc)

242 -Study quality (overall rating on QUIPs)

243 -Strength of evidence (low, moderate, high)

244

245 Due to substantial heterogeneity across studies, in terms of determinants examined,  
246 measurement of determinants, definition of malnutrition, malnutrition measurement, and

247 length of follow-up, pooling of data in a meta-analysis was not possible. A descriptive  
248 synthesis [27] of studies was instead used to explore heterogeneity due to population source  
249 and setting, definitions of determinants and outcomes. Consistency of findings was assessed  
250 using the following schema.

251

252 • **Strong evidence:** consistent findings (defined as > 75% of studies showing the same  
253 direction of effect) in multiple high-quality (defined as low ROB in all domains)  
254 studies.

255 • **Moderate evidence:** consistent findings in multiple low quality (moderate to high  
256 ROB in 4 of 6 domains) studies and/or at least one low risk of bias/high-quality study.

257 • **Low evidence:** findings from one study only of moderate to high ROB (low or  
258 moderate quality).

259 • **Conflicting evidence:** inconsistent findings across studies of any risk of bias/quality.

260

## 261 **RESULTS**

### 262 **Literature search**

263 Study identification is summarised in **Figure 2**. The literature search of databases yielded  
264 **30,891** potentially relevant articles. 11,336 duplicates were removed and **19,555** titles and  
265 abstracts were scanned. Sixty five full-text studies were retrieved with 42 studies being  
266 excluded as they did not meet the eligibility criteria. Searching the reference lists of these  
267 articles did not yield any further articles. The major reasons for exclusion were cross-  
268 sectional design, mean age <65 years, and examined the association of malnutrition with  
269 mortality. Twenty three articles met the selection criteria. Two authors were emailed to  
270 obtain further information for clarification, of whom one replied.

271

272 **Figure 2: Flowchart**

273

Identification

278

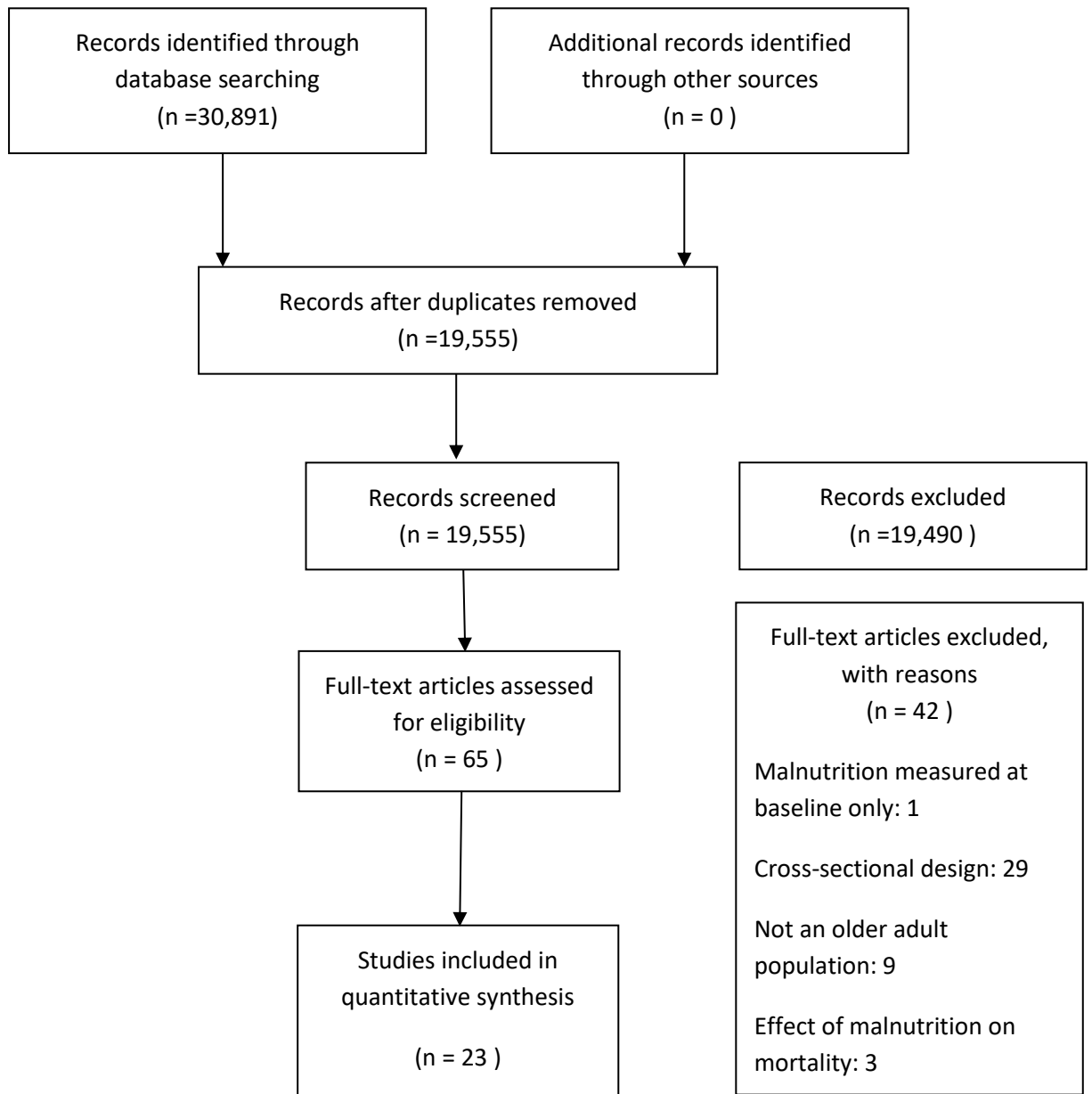
Screening

283

Eligibility

288

Included



293

294 **Quality assessment**

295 The majority of studies were rated as low quality on the QUIPS tool (n=18) [24-45]. Five  
296 studies [46-49] were rated as moderate quality on the QUIPS tool. Common methodological  
297 limitations identified across studies were attrition rates, study confounding, and statistical  
298 analysis and reporting. Common methodological strengths were description of study  
299 participants and explanation of potential determinant and outcome measurements. The quality  
300 assessment scores for all studies are shown in **Table 1**.

301 **Table 1: Risk of bias/quality scores**

<b>Study</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>Final quality rating</b>
<b>Agostini et al 2004 [28]</b>	Low	Low	Low	Low	Moderate	Low	Moderate
<b>Alley et al 2010 [29]</b>	Low	High	Low	High	Low	Low	Low
<b>Beck et al 2015 [30]</b>	Low	High	High	Low	High	High	Low
<b>Carrión et al 2015 [31]</b>	Low	High	Low	Low	High	High	Low
<b>Chen et al 2009 [32]</b>	Low	High	High	Low	High	High	Low
<b>Izawa et al 2014 [33]</b>	Low	High	Low	Low	Low	Low	Low
<b>Johansson et al 2009a [34]</b>	Low	High	Low	Low	High	Low	Low
<b>Johansson et al 2009b [35]</b>	Low	Moderate	Low	Low	High	High	Low
<b>Jyrkkä et al 2011 [36]</b>	Low	High	Low	Low	High	Low	Low
<b>Kagansky et al 2005 [37]</b>	Low	Moderate	Low	Low	High	High	Low
<b>Knoops et al 2005 [38]</b>	Low	Moderate	High	Low	High	Low	Low
<b>Lee et al 2004 [39]</b>	Low	Moderate	High	Low	High	High	Low
<b>Mamhidir et al 2006 [40]</b>	Low	High	High	High	High	High	Low
<b>Okabe et al 2015 [41]</b>	Low	Moderate	Low	Low	Low	Low	Moderate
<b>Ritchie et al 2000 [42]</b>	Low	Moderate	Low	Low	Low	Low	Moderate
<b>Roberts et al 2007 [43]</b>	Low	High	Low	Low	Low	Low	Low



<b>Schilp et al 2011 [44]</b>	Low	Moderate	Low	Low	Low	Low	Moderate
<b>Serra-Prat et al 2012 [45]</b>	Low	High	Low	Low	High	Low	Low
<b>Shatenstein et al 2001 [46]</b>	Low	Moderate	Low	Low	High	High	Low
<b>Söderström et al 2015 [47]</b>	Low	Moderate	Low	Low	High	High	Low
<b>St-Arnaud McKenzie et al 2010 [48]</b>	Low	Moderate	Low	Low	Low	Low	Moderate
<b>Stephen and Janssen 2010 [49]</b>	Low	High	Low	Low	High	Yes	Low
<b>Weyant et al 2004 [50]</b>	Low	Moderate	Low	Low	High	Low	Low

**High quality:** risk of bias was rated low on at least four of the six domains and was rated low for both study attrition and study confounding (shaded).

**Moderate quality:** risk of bias was rated low or moderate on at least four of the six domains and was rated moderate for both study attrition and study confounding (shaded).

**Low quality:** risk of bias was rated high on at least four of the six domains and/or was related high for study attrition and study confounding (shaded).

Studies with high risk of bias for study attrition or study confounding were rated as low quality.

1= Study Participation; 2=Study Attrition; 3=Risk Factor Measurement; 4=Outcome Measurement; 5=Study Confounding; 6=Statistical Analysis and Reporting

302

303

### 304 **Participants and follow-ups**

305 **Table 2** shows the characteristics of the 23 included studies in this review. The follow-up  
306 period of studies varied from 24 weeks to 12 years. All studies were performed in a mixed  
307 sample of males and females. Studies were conducted in the USA (n=5) [28, 29, 39, 42, 50],  
308 Canada (n=4) [43, 46, 48, 49], Sweden (n=4) [34, 35, 40, 47], the Netherlands (n=2 [38, 44]

309 ), Japan (n=2) [33, 41], Spain (n=2) [31, 45], Denmark (n=1) [30], Israel (n=1) [37], Finland  
310 (n=1) [36], and Taiwan (n=1) [32]. Studies involved participants from community dwelling  
311 setting only (n=15) [28, 29, 34, 35, 39-45, 47-50], nursing home only (n=3) [30, 33, 38],  
312 acute hospital only (n=3) [31, 32, 37], and a combination of community dwelling and nursing  
313 home settings (n=2) [36, 46]. The mean (SD) age across all studies was 74 (12) years.

314

### 315 **Definitions and measurement of malnutrition**

316 Table 2 shows the outcome measures used for malnutrition in the 23 included studies in this  
317 review. Type and cut-off for measures of malnutrition significantly varied across studies.  
318 Four studies [30, 38, 40, 44] used low BMI as a measure of malnutrition. However, the BMI  
319 cut off for being defined as malnourished varies across the four studies: One study [38] had  
320 no cut off; one study [30] defined <18.5 as malnourished; one study [40] defined <22 as  
321 malnourished, and one study [44] defined <20 as malnourished. Eight studies defined  
322 malnutrition by weight loss. Four studies [39, 46, 48, 50] used >5% loss of body weight as a  
323 measure of malnutrition, but the time period of weight loss varied from one to two years  
324 across studies. Two studies [42, 49] used >10% loss of body weight as a measure of  
325 malnutrition. One study [28] used >10 pounds loss of body weight over a one-year period.  
326 One study [29] used weight loss measured by DEXA as a measure of malnutrition. Two  
327 studies [40, 44] used combinations of low BMI and weight loss to measure malnutrition.  
328 Seven studies [31, 32, 34, 35, 37, 45, 47] used the long form MNA (MNA-LF). One of these  
329 [45] defined <23.5 as malnourished, another [47] defined <17 as malnourished. Three studies  
330 [33, 36, 41] used the short form MNA (MNA-SF). Two of these studies [33, 41] defined <7  
331 as malnourished, while one study [36] defined <11 as malnourished. One study [43] used the  
332 Elderly Nutrition Screening Tool.

333 Table 2. Description of studies

Domain	Study and determinant examined	Setting and country	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
Oral	Dental status					Conflicting
	Knoops et al 2005 [38]	Nursing home. Netherlands  N=108  83% female  Mean-age: 82.1(7.6)	BMI   Follow-up: 24 weeks	NS	Low	
	Lee et al 2004 [39]	Community dwelling. USA  N=3075  52% female  Mean age: unclear, ranged from 70-79	Weight loss $\geq 5\%$ of body weight in 1 year   Follow-up: 1 year	NS	Low	
	Mamhidir et al 2006 [40]	Community dwelling. Sweden  N=503  72% female  Mean age: 86.2(5.5)	BMI < 22 and weight of 5% or 10% of total body weight   Follow-up: 1 year	NS	Low	

	Okabe et al 2016 [41]	Community dwelling. Japan N=197 Mean age: unclear	MNA- Short Form <7  Follow-up: 1 year	NS	Moderate	
	Ritchie et al 2000 [42]	Community dwelling. USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	OR = 1.63 for 4% weight loss  OR = 2.03 for 10% weight loss	Moderate	
	Roberts et al 2007 [43]	Community dwelling. Canada N=839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6-13)  Follow-up: 1 year	NS	Low	
	<b>Chewing</b>					Moderate
	Beck et al 2015 [30]	Community-dwelling. Denmark N=441 80% female Mean age: 85.2(7.5)	BMI<18.5  Follow-up: 6 months and 1 year	OR= 2.16	Low	
	Izawa et al 2014 [33]	Nursing home. Japan	MNA-Short Form <7	NS	Low	

		N=392 77.7% female Mean age: 84.3(7.2)	Follow-up: 2 years			
	Knoops et al 2005 [38]	Nursing home. Netherlands  N=108 83% female Mean-age: 82.1(7.6)	BMI  Follow-up: 24 weeks	NS	Low	
	Lee et al 2004 [39]	Community dwelling. USA  N=3075 52% female Mean age: unclear, ranged from 70-79	Weight loss $\geq 5\%$ of body weight in 1 year  Follow-up: 1 year	NS	Low	
	Mamhidir et al 2006 [40]	Community dwelling. Sweden  N=503 72% female Mean age: 86.2(5.5)	BMI < 22 and weight of 5% or 10% of total body weight  Follow-up: 1 year	NS	Low	

	Ritchie et al 2000 [42]	Community dwelling. USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	NS	Moderate	
	Schilp et al 2011 [44]	Community dwelling. Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq 5\%$ of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Mouth Pain</b>					Moderate
	Lee et al 2004 [39]	Community dwelling. USA N=3075 52% female Mean age: unclear, ranged from 70-79	Weight loss $\geq 5\%$ of body weight in 1 year  Follow-up: 1 year	NS	Low	
	Mamhidir et al 2006 [40]	Community dwelling.	BMI < 22 and weight of 5% or 10% of total body weight	NS	Low	

		Sweden N=503 72% female Mean age: 86.2(5.5)	Follow-up: 1 year			
	Ritchie et al 2000 [42]	Community dwelling USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	NS	Moderate	
	<b>Gum issues</b>					Conflicting
	Beck et al 2015 [30]	Community- dwelling. Denmark N=441 80% female Mean age: 85.2(7.5)	BMI < 18.5  Follow-up: 6 months and 1 year	NS	Low	
	Ritchie et al 2000 [42]	Community- dwelling USA N=563	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	NS	Moderate	

		57.9% female Mean age: unclear, range 70 and over				
	Weyant et al 2004 [39]	Community dwelling USA N=1053 50.3% female Mean age: 72.7(2.8)	Weight loss $\geq 5\%$ of body weight over 2 years  Follow-up: 2 years	OR = 1.66	Low	
	<b>Swallowing</b>					Conflicting
	Beck et al 2015 [30]	Community- dwelling. Denmark N=441 80% female Mean age: 85.2(7.5)	BMI < 18.5  Follow-up: 6 months and 1 year	OR = 2.3 with BMI < 18.5  OR = 2.18 with weight loss at 6 months	Low	
	Carrión et al 2015 [31]	Acute hospital Spain N=1662 61.7% Female Mean age: 85.1(6.23)	MNA < 17  Follow-up: 6 months and 1 year	OR: 2.31	Low	



	Knoops et al 2005 [38]	Nursing home Netherlands N=108 83% female Mean-age: 82.1(7.6)	BMI  Follow-up: 24 weeks	NS	Low	
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or10% of total body weight  Follow-up: 1 year	NS	Low	
	Okabe et al 2016 [41]	Community dwelling Japan N=197 Mean age: %female unclear	MNA- Short Form <7  Follow-up: 1 year	RR: 5.21	Moderate	
	Serra-Prat et al 2012 [45]	Community dwelling Spain N=254 46.5% female Mean age: 78	MNA<23.5  Follow-up: 1 year	NS	Low	

Psychosocial	Cognitive function					Conflicting
	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17  Follow-up: 6 months	beta = 0.09	Low	
	Johansson et al 2009a [34]	Community dwelling Sweden N=579 % female Mean age: unclear	MNA<17  Follow-up: 6 years	NS	Low	
	Johansson et al 2009b [35]	Community dwelling Sweden N=258 % female: unclear Mean age: 74.2(2.55)	MNA<17	OR = 12.6 for men	Low	
	Kagansky et al 2005 [37]	Acute hospital Israel N=414 65.7% female	MNA<17  Follow-up: 2 years	dementia: OR = 3.85	Low	

		Mean age: 84.8(6.1)				
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight  Follow-up: 1 year	OR = 1.84	Low	
	Okabe et al 2016 [41]	Community dwelling Japan N=197 %female unclear Mean age: unclear	MNA- Short Form <7  Follow-up: 1 year	NS	Moderate	
	Ritchie et al 2000 [42]	Community dwelling USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq$ 10% of body weight in 1 year  Follow-up: 1 year	NS	Moderate	
	Roberts et al 2007 [43]	Community dwelling Canada N=839	Elderly Nutrition Screening (6-13)	NS	Low	

		68.7% female Mean age: 79.6	Follow-up: 1 year			
	Shatenstein et al 2001 [46]	Community dwelling and nursing home Canada N=584 59.6% female Mean age: unclear, ranged from 70-90	Weight loss $\geq 5\%$ of body weight  Follow-up: 5 years	-0.63 in logistic regression	Low	
	<b>Depression and depressive symptomology</b>					<b>Conflicting*</b>
	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17  Follow-up: 6 months	beta=-0.35	Low	
	Johansson et al 2009a [34]	Community dwelling Sweden N=579 % female: unclear	MNA<17  Follow-up: 6 years	OR = 1.52	Low	

		Mean age: unclear				
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight  Follow-up: 1 year	NS	Low	
	Ritchie et al 2000 [42]	Community dwelling USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	NS	Moderate	
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq 5\%$ of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	Shatenstein et al 2001 [46]	Community dwelling and institutionalised Canada	Weight loss $\geq 5\%$ of body weight	NS for depression.  For loss of interest in life beta = -0.63 in institution	Low	

		N=584 59.6% female Mean age: unclear, ranged from 70-90	Follow-up: 5 years	individuals; beta = - 0.58 for community individuals		
	<b>Psychological distress</b>					Low
	Roberts et al 2007 [43]	Community dwelling Canada N=839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6-13)  Follow-up: 1 year	OR = 1.35	Low	
	<b>Anxiety</b>					Low
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq$ 5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Social support</b>					Low
	Chen et al 2009 [32]	Acute hospital	MNA<17	NS	Low	

		Taiwan N=306 53.27% female Mean age: 71.75(5.62)	Follow-up: six months			
	Roberts et al 2007 [43]	Community dwelling Canada N=839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6-13)  Follow-up: 1 year	NS	Low	
	<b>Residential status</b>					Conflicting
	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17  Follow-up: six months	NS	Low	
	Johansson et al 2009a [34]	Community dwelling Sweden N=579 % female Mean age:	MNA<17  Follow-up: 6 years	NS	Low	

	Jyrkkä et al 2011 [36]	Community dwelling and nursing home  Finland  N=294  69% female  Mean age: 81.9	MNA- Short Form <11  Follow-up: 1,2, 3 years	beta = -1.89 (institution, ref=home)	Low	
	Schilp et al 2011 [44]	Community dwelling  Netherlands  N=1120  51.% female  Mean age: 74.1(5.7)	Weight loss $\geq$ 5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Transport</b>					Low
	Johansson et al 2009b [35]	Community dwelling  Sweden  N=258  % female  Mean age: 74.2(2.55)	MNA<17  Follow-up: 12 years (3 times with 4 year intervals)	NS	Low	
	<b>Loneliness</b>					Low
	Schilp et al 2011 [44]	Community dwelling  Netherlands	Weight loss $\geq$ 5% of body weight in 6 months	NS	Moderate	



		N=1120 51.% female Mean age: 74.1(5.7)	Follow-up: every 3 years over a 9 year period			
	<b>Wellbeing</b>					Low
	Johansson et al 2009a [34]	Community dwelling Sweden N=579 % female: unclear Mean age: unclear	MNA<17  Follow-up: 6 years	NS	Low	
	<b>Meals on wheels</b>					Low
	Johansson et al 2009b [35]	Community dwelling Sweden N=258 % female Mean age: 74.2(2.55)	MNA<17  Follow-up: 12 years (3 times with 4 year intervals)	OR = 21.9 for men; OR = 31.0 for women	Low	
<b>Medication and care</b>	<b>Medication and polypharmacy</b>					Conflicting
	Agostini et al 2004 [28]	Community dwelling, USA M=885	Weight loss≥10 pounds in 1 year	OR = 1.96 for 3-4 medications  OR = 2.78 for 5 or	Moderate	

		72% female Mean age: 81.0(5.2)	Follow up: 1 year	more medications		
	Beck et al 2015 [30]	Nursing home Denmark N=441 80% female Mean age: 85.2(7.5)	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low	
	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17 Follow-up: 6 months	beta = -0.08	Low	
	Jyrkkä et al 2011 [36]	Community dwelling and nursing home Finland N=294 69% female Mean age: 81.9	MNA- Short Form <11 Follow-up: 1,2, 3 years	beta = -0.26 for excessive polypharmacy (10 or more drugs)	Low	
	Knoops et al 2005 [38]	Nursing home Netherlands	BMI	NS	Low	

		N=108 83% female Mean-age: 82.1(7.6)	Follow-up: 24 weeks			
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight  Follow-up: 1 year	NS	Low	
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq$ 5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Hospitalisation</b>					<b>Moderate**</b>
	Alley et al 2010 [29]	Community-dwelling USA N=2690 50.8% female	Weight loss per year in total body mass (DEXA scan) per year	Regression coefficient -0.79	Low	

		Mean age: 73.5(2.9)	Follow-up: 1 year			
	Izawa et al 2014 [33]	Nursing home Japan N=392 77.7% female Mean age: 84.3(7.2)	MNA- Short Form <7  Follow-up: 2 years	OR = 1.8	Low	
	Johansson et al 2009b [35]	Community dwelling Sweden N=258 % female: unclear Mean age: 74.2(2.55)	MNA<17  Follow-up: 12 years (3 times with 4 year intervals)	NS for men; OR = 7.1 for women	Low	
<b>Health</b>	<b>Co-morbidities</b>					Moderate
	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17  Follow-up: 6 months	NS	Low	
	Izawa et al 2014 [33]	Nursing home Japan N=392	MNA- Short Form <7	NS	Low	

		77. 7% female Mean age: 84.3(7.2)	Follow-up: 2 years			
	Jyrkkä et al 2011 [36]	Community dwelling and nursing home Finland N=294 69% female Mean age: 81.9	MNA- Short Form <11  Follow-up: 1, 2, 3 years	NS	Low	
	Knoops et al 2005 [38]	Nursing home Netherlands N=108 83% female Mean-age: 82.1(7.6)	BMI  Follow-up: 24 weeks	NS	Low	
	Okabe et al 2016 [41]	Community dwelling Japan N=197 Mean age:unclear %female unclear	MNA- Short Form <7  Follow-up: 1 year	NS	Moderate	
	Ritchie et al 2000 [42]	Community dwelling USA	Weight loss $\geq 10\%$ of body weight in 1 year	NS	Moderate	

		N=563 57.9% female Mean age: unclear, range 70 and over	Follow-up: 1 year			
	Roberts et al 2007 [43]	Community dwelling Canada N=839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6-13)  Follow-up: 1 year	NS	Low	
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq 5\%$ of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Functional health status</b>					Conflicting
Constipation	Beck et al 2015 [30]	Nursing home Denmark N=441 80% female	BMI < 18.5  Follow-up: 6 months and 1 year	NS	Low	

		Mean age: 85.2(7.5)				
Vision & hearing	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17  Follow-up: 6 months	both NS	Low	
Constipation	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight  Follow-up: 1 year	OR = 2.49	Low	
Vision & hearing	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss ≥5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	both NS	Moderate	
	<b>Eating dependency/difficulty feeding</b>					Moderate
	Beck et al 2015 [30]	Nursing home	BMI<18.5	OR = 2.16 for BMI <18.5 but not for	Low	

		Denmark N=441 80% female Mean age: 85.2(7.5)	Follow-up: 6 months and 1 year	the 6 variables related to weight loss		
	Knoops et al 2005 [38]	Nursing home Netherlands N=108 83% female Mean-age: 82.1(7.6)	BMI Follow-up: 24 weeks	beta = 2.51	Low	
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight Follow-up: 1 year	OR = 2.26	Low	
	Shatenstein et al 2001 [46]	Community dwelling and nursing home Canada N=584 59.6% female Mean age: unclear, ranged from 70-90	Weight loss $\geq$ 5% of body weight Follow-up: 5 years	beta = 4.24 in community participants	Low	



	<b>Self-perceived health</b>					<b>Moderate***</b>
	Johansson et al 2009a [34]	Community dwelling Sweden N=579 % female: unclear Mean age: unclear	MNA<17  Follow-up: 6 years	OR = 0.44	Low	
	Johansson et al 2009b [35]	Community dwelling Sweden N=258 % female: unclear Mean age: 74.2(2.55)	MNA<17  Follow-up: 12 years (3 times with 4 year intervals)	OR = 5.1 for men, NS for women	Low	
	Jyrkkä et al 2011 [36]	Community dwelling and nursing home  Finland N=294 69% female Mean age: 81.9	MNA- Short Form <11  Follow-up: 1,2,3 years	NS	Low	
	Roberts et al 2007 [43]	Community dwelling  Canada N=839	Elderly Nutrition Screening (6-13)	OR = 3.30	Low	

		68.7% female Mean age: 79.6	Follow-up: 1 year			
<b>Physical function</b>	<b>ADL, performance or strength</b>					Moderate
	Chen et al 2009 [32]	Acute hospital Taiwan N=306 53.27% female Mean age: 71.75(5.62)	MNA<17  Follow-up: 6 months	beta = 0.17	Low	
	Izawa et al 2014 [33]	Nursing home Japan N=392 77.7% female Mean age: 84.3(7.2)	MNA Short-Form <7  Follow-up: 2 years	OR = 2.62 for ADL 20-50; OR = 2.02 for ADL 0-15	Low	
	Johansson et al 2009b [35]	Community dwelling Sweden N=258 % female: unclear Mean age: 74.2(2.55)	MNA<17  Follow-up: 12 years (3 times with 4 year intervals)	NS for men and women	Low	
	Jyrkkä et al 2011 [36]	Community dwelling	MNA- Short Form	Mary to fix	Low	

		and nursing home Finland N=294 69% female Mean age: 81.9	<11  Follow-up: 1,2,3 years			
	Knoops et al 2005 [38]	Nursing home Netherlands N=108 83% female Mean-age: 82.1(7.6)	BMI  Follow-up: 24 weeks	beta = - 0.11	Low	
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or10% of total body weight  Follow-up: 1 year	OR = 1.79	Low	
	Okabe et al 2016 [41]	Community dwelling Japan N=197 Mean age: unclear %female: unclear	MNA-Short Form <7  Follow-up: 1 year	NS	Moderate	

	Ritchie et al 2000 [42]	Community dwelling USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	OR = 2.27	Moderate	
	Roberts et al 2007 [43]	Community dwelling Canada N=839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6-13)  Follow-up: 1 year	NS	Low	
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq 5\%$ of body weight in 6 months  Follow-up: every 3 years over a 9 year period	HR = 2.5 for difficulties walking stairs,  aged < 75 years	Moderate	
	Serra-Prat et al 2012 [45]	Community dwelling Spain N=254 46.5% female	MNA < 23.5  Follow-up: 1 year	NS	Low	

		Mean age: 78				
	Shatenstein et al 2001 [46]	Community dwelling and nursing home  Canada  N=584  59.6% female  Mean age: unclear, ranged from 70-90	Weight loss $\geq 5\%$ of body weight  Follow-up: 5 years	Mary to fix	Low	
	St Arnaud-McKenzie et al 2010 [48]	Community dwelling  Canada  N=1497  52.3% Female  Mean age: unclear. Ranged from 67-84	Weight loss $\geq 5\%$ of body weight over 2 years  Follow-up: 2 years	Worse baseline physical function predicted both weight loss and weight gain	Moderate	
<b>Lifestyle</b>	<b>Smoking</b>					Moderate
	Ritchie et al 2000 [42]	Community dwelling  USA  N=563  57.9% female  Mean age: unclear, range 70 and over	Weight loss $\geq 10\%$ of body weight in 1 year  Follow-up: 1 year	NS	Moderate	

	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq$ 5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Alcohol</b>					Moderate
	Ritchie et al 2000 [42]	Community dwelling USA N=563 57.9% female Mean age: unclear, range 70 and over	Weight loss $\geq$ 10% of body weight in 1 year  Follow-up: 1 year	NS	Moderate	
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq$ 5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	<b>Physical activity</b>					Moderate
	Ritchie et al 2000 [42]	Community dwelling USA	Weight loss $\geq$ 10% of body weight in 1 year	NS	Moderate	

		N=563 57.9% female Mean age: unclear, range 70 and over	Follow-up: 1 year			
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss $\geq$ 5% of body weight in 6 months  Follow-up: every 3 years over a 9 year period	NS	Moderate	
	Stephen and Janssen 2010 [49]	Community dwelling. Canada N=4512 57.1% female Mean age: unclear	Weight loss $\geq$ 10% of body weight  Follow-up: Every year over a 8 year period	NS	Low	
<b>Eating</b>	<b>Appetite/leaves food on plate</b>					Moderate
	Beck et al 2015 [30]	Nursing home Denmark N=441 80% female	BMI<18.5  Follow-up: 6 months and 1 year	OR=2.52	Low	

		Mean age: 85.2(7.5)				
	Knoops et al 2005 [38]	Nursing home Netherlands N=108 83% female Mean-age: 82.1(7.6)	BMI Follow-up: 24 weeks	beta = -2.17	Low	
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight Follow-up: 1 year	NS	Low	
	Schilp et al 2011 [44]	Community dwelling Netherlands N=1120 51.% female Mean age: 74.1(5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	HR = 1.63	Moderate	
	Shatenstein et al 2001 [46]	Community dwelling and nursing home Canada N=584	Weight loss ≥5% of body weight Follow-up: 5 years	beta = -1.52 in community participants	Low	



		59.6% female Mean age: unclear, ranged from 70-90				
	<b>Complaints about taste of food</b>					Moderate
	Beck et al 2015 [30]	Nursing home Denmark N=441 80% female Mean age: 85.2(7.5)	BMI<18.5  Follow-up: 6 months and 1 year	NS	Low	
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or 10% of total body weight  Follow-up: 1 year	NS	Low	
	<b>Nutrient intake and modified texture diets</b>					Moderate
	Knoops et al 2005 [38]	Nursing home Netherlands N=108 83% female	BMI  Follow-up: 24 weeks	NS	Low	

		Mean-age: 82.1(7.6)				
	Okabe et al 2016 [41]	Community dwelling Japan N=197 Mean age: unclear %female unclear	MNA- Short Form <7  Follow-up: 1 year	NS	Moderate	
	Söderström et al 2015 [47]	Community dwelling Sweden N=725 51.6% Female, Mean age 66.7	MNA<17  Follow-up: 10 years	OR= 1.11 for a BMI of <25kg/m2 at baseline	Low	
	<b>Hunger</b>					Low
	Mamhidir et al 2006 [40]	Community dwelling Sweden N=503 72% female Mean age: 86.2(5.5)	BMI<22 and weight of 5% or10% of total body weight  Follow-up: 1 year	NS	Low	
	<b>Thirst</b>					Low
	Knoops et al 2005 [38]	Nursing home Netherlands	BMI	NS	Low	

		N=108 83% female Mean-age: 82.1(7.6)	Follow-up: 24 weeks			
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OR= Odds ratio, HR= Hazard ratio, RR= Risk ratio, NS: Non-significant, BMI: body mass index, MNA: Mini Nutritional Assessment, DEXA: Dual-energy X-ray absorptiometry, ADL: Activities of Daily Living.

\*When studies using the MNA are removed from the analysis, the conflicting evidence for depression being a determinant of malnutrition changes to moderate evidence that depression is not a determinant of malnutrition.

\*\* When studies using the MNA are removed from analysis, the moderate evidence for hospitalisation being a determinant of malnutrition changes to limited evidence that hospitalisation is a determinant of malnutrition.

\*\*\* When studies using the MNA are removed from the analysis, the moderate evidence for self-perceived health being a determinant of malnutrition changes to limited evidence that self-perceived health is a determinant of malnutrition.

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340 **Potentially modifiable determinants**

341 Thirty determinants categorised into seven domains shown in **Table 3**. The results will be  
 342 discussed according to these domains for ease of clarity.

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344 **Table 3: Domains of potentially modifiable determinants**

Domain name	Included determinants (n=30)
<b>Oral</b>	1. Dental status 2. Chewing 3. Mouth pain 4. Gum issues 5. Swallowing
<b>Psychosocial</b>	6. Cognitive function 7. Depression/depressive symptomology 8. Psychological distress 9. Anxiety 10. Social support 11. Residential status 12. Transport 13. Loneliness 14. Wellbeing 15. Meals on wheels
<b>Medication and care</b>	16. Medication and polypharmacy 17. Hospitalisation
<b>Health</b>	18. Co-morbidities 19. Functional health status 20. Eating dependency/difficulty feeding 21. Self-perceived health
<b>Physical function</b>	22. Activities of daily living, performance or strength
<b>Lifestyle</b>	23. Smoking 24. Alcohol 25. Physical activity
<b>Eating</b>	26. Appetite / leaves food on plate 27. Complaints about taste of food 28. Dietary factors – nutrient intake and modified texture diets 29. Hunger 30. Thirst

345

346 **Oral domain**

347 A total of 13 studies [30-33, 38-45, 50] studies examined 5 potential determinants in the oral  
348 domain.

349

350 Dental status

351 Dental status (denture use, having teeth) was assessed by six studies [38-43]. Measurement of  
352 dental status varied significantly across studies. Five studies [38-40, 42, 43] used single item  
353 yes/ no questions: One study [40] used a yes/no response to some or all natural teeth lost and  
354 not using dentures; one study [38] assessed whether dental status was complete or  
355 incomplete; one study [39] assessed if participants had any remaining natural teeth; one study  
356 [43] assessed the presence or absence of dental problems. One study [42] scored participants  
357 based on number of dentures, no teeth or presence of natural teeth.

358

359 Chewing difficulties

360 Chewing difficulties was assessed by seven studies [30, 33, 38-40, 42, 44]. Five studies [30,  
361 38-40, 42] used single item yes/no questions on able or unable to chew or presence or  
362 absence of chewing problems. One study [33] categorized chewing difficulties into three  
363 categories: difficulty chewing even soft food items (poor), difficulty chewing harder foods  
364 (fair), and no difficulty chewing harder foods (good). Only one study [44] assessed biting and  
365 chewing with a question 'Are you able to bite or chew hard food?' and categorised  
366 participants into 'almost never', 'some of the time', no problem, 'often' or 'most of the time'.

367

368 Mouth pain

369 Mouth pain was assessed by three studies [39, 40, 42] using a single item yes/no question on  
370 the presence or absence of mouth pain.

371

372 Gum issues

373 Gum issues (inflammation, bleeding, periodontal disease) were assessed by three studies [30,  
374 42, 50]. One study [30] used a single item yes/no answer question to the presence or absence  
375 of inflamed, swollen or bleeding gums. One study [42] assessed the number of participants  
376 with gum bleeding, and percentage of sites with this bleeding.

377 Two studies assessed the effect of periodontal disease [42, 50]. One study [50] measured  
378 mean depth and attachment loss, percentage of pockets with at least 6mm probing depth. The  
379 other study [42] used a single item yes/no question to assess the presence or absence of  
380 periodontal disease.

381 One study [32] assessed a combination of oral health factors together, and could not be  
382 categorised under any one determinant. This study used the 12-item General Oral Health  
383 Assessment Index to assess oral health.

384

385 Swallowing

386 Swallowing was assessed by six studies [30, 31, 38, 40, 41, 45]. Measurement of swallowing  
387 varied significantly across studies. Two studies [31, 45] used the volume viscosity test. Three  
388 studies [30, 38, 40] used single item yes/no questions from The Resident Assessment  
389 Instrument - Minimum Data Set (RAI-MDS) to the presence or absence of swallowing  
390 problems. One study [41] used cervical auscultation to assess swallowing problems.

391 There is conflicting evidence that dental status, periodontal disease and swallowing are  
392 determinants of malnutrition.

393 There is moderate quality evidence that chewing difficulties, mouth pain and gum issues are  
394 not determinants of malnutrition.

395

396 **Psychosocial domain**

397 A total of ten studies [32, 34-37, 40-44, 46] examined ten determinants in the psychological  
398 domain.

399

400 Cognitive function

401 Cognitive function was assessed by nine studies [32, 34, 35, 37, 40-43, 46]. Five studies [32,  
402 34, 35, 43, 46] used a Mini-Mental State Examination (MMSE) measure to assess cognitive  
403 capacity, one study [46] used the modified MMSE (3MS); one study [32] used the 11-item  
404 MMSE, two studies [34, 35] used the full MMSE; one study [43] used the Adult Lifestyle  
405 and Function Interview MMSE (ALFI-MMSE). The Clinical Dementia Rating Scale and  
406 Cognitive Performance Scale were used by two studies [40, 41], respectively. One study [37]  
407 used a single item yes/no question on the presence of dementia, and the MNA 2 subscore on  
408 cognitive status. Another study [42] assessed mental status subjectively by getting the  
409 interviewer to judge the participants' presence or absence of mild confusion. Memory  
410 impairment affecting ADL function was assessed by one study [34] using a single item  
411 yes/no question; "Do you believe you are having memory problems that have an impact on  
412 your daily life?".

413

414 Depression and depressive symptomology

415 Depression and/or depressive symptomology was assessed by six studies [32, 40, 42, 44, 46].  
416 Measures of depression varied significantly across studies. One study [40] used the  
417 Depression Rating Scale. One study [32] used the Geriatric Depression Scale Short-Form.  
418 One study xx used the Geriatric Depression Long-Form. One study [44] used the Center for  
419 Epidemiological Studies Depression Scale while another [46] used the Cambridge Mental  
420 Disorders of the Elderly Examination questionnaire and a single item yes/no question on loss

421 of interest in life. Only one study [42] used a single item question “How often have you felt  
422 downhearted and blue?”

423

#### 424 Psychological distress

425 Psychological distress was assessed by one study [43] using L’Indice de détresse  
426 psychologique de Santé Québec (IDPESQ-14) questionnaire.

427

#### 428 Anxiety

429 Anxiety was assessed by one study [44] using the anxiety subscale of the Hospital Anxiety  
430 and Depression Scale.

431

#### 432 Social support

433 Social support was assessed by two studies [32, 43]. One study [32] used the six-item Social  
434 Support Questionnaire-Short Form. The second study [43] used a single item yes/no question  
435 on satisfaction with social support.

436

#### 437 Residential status

438 Residential status was assessed by four studies [32, 34, 36, 44]. Two studies [32, 34] used a  
439 single item yes/no question on living alone or not. One study [36] assessed whether  
440 participants were living at home or in sheltered accommodation. The final study [44] assessed  
441 whether participants were independent in living, receiving home care, or not independent  
442 (including institutionalised).

443

#### 444 Transport



445 Use of special transport services was assessed by one study [35] using a single item yes/no  
446 question on the use of special transport services.

447

#### 448 Loneliness

449 Loneliness was assessed by one study [44] using the Dutch validated loneliness scale.

450

#### 451 Wellbeing

452 Wellbeing was assessed by one study [34] using the Philadelphia Geriatric Centre Multilevel  
453 Assessment Instrument.

454

#### 455 Meals on wheels

456 Meals on wheels was assessed by one study [35] using a single item yes/no question on use  
457 of meals and wheels.

458

459 There is conflicting evidence that cognitive function, depression and residential status are  
460 determinants of malnutrition.

461 Low evidence suggests that loss of interest in life and access to meals and wheels are  
462 determinant of malnutrition.

463 There is also low evidence showing that psychological distress, anxiety, residential status,  
464 loneliness, access to transport and wellbeing are not determinants of malnutrition.

465 Furthermore, there is low evidence that access to meals and wheels is a determinant of  
466 malnutrition.

467

#### 468 **Medication and care domain**

469 A total of ten studies [28-30, 32-34, 36, 38, 40, 44] examined two determinants in the  
470 medication and care domain.

#### 471 Medication and/or polypharmacy

472 Medication and/or polypharmacy was assessed by seven studies [28, 30, 32, 36, 38, 40, 44].  
473 One study [30] assessed prescription medications, and polypharmacy was defined as the  
474 consumption of over five prescription medications per day. The second study [36] defined  
475 excessive polypharmacy as the use of ten or more drugs, polypharmacy as the use of six to  
476 nine drugs, and non-polypharmacy as the use of five or less drugs concomitantly. A third  
477 study [28] recorded all medication reported taken by participants on a regular basis, and  
478 categorized participants into no medication use, 1 or 2, 3 or 4, or 5 or more drugs taken daily.  
479 The fourth study [40] assessed the number of medications reported taken in the last seven  
480 days. One study [44] assessed medication through three categories: no medication use; the  
481 use of one or two medications; and the use of three or more medications. Another study [32]  
482 assessed the number of prescriptions and over the counter medication that were taken  
483 currently by participants. Finally one study [38] assessed the frequency of medication use and  
484 type of medicines reported taken.

485

#### 486 Hospitalisation

487 Hospitalisation was assessed by three studies [29, 33, 35]. Two studies used a single item  
488 yes/no question to hospitalisation over a 2 year period [33], and hospital stay during the last 2  
489 months [35]. One study [29] assessed total days hospitalized in a given year and categorised  
490 participants into no hospitalisation, 1-3 days hospitalised, 4-7 days hospitalised, or 8 or more  
491 days hospitalised.

492

493 There is conflicting evidence that medication intake and/or polypharmacy is a determinant of  
494 malnutrition while moderate evidence suggests that hospitalisation is a determinant of  
495 malnutrition.

496

#### 497 **Health domain**

498 A total of twelve studies [30, 32-36, 38, 40-44] examined four determinants in the health  
499 domain.

500

#### 501 Co-morbidities

502 Co-morbidity was assessed by **eight** studies. Two studies [33, 41] used the Charlson  
503 Comorbidity Index. Four studies [32, 38, 42, 44] assessed number and type of  
504 diagnosis/disease. One study [43] used the chronic disease score while another study [36]  
505 used the Functional Comorbidity Index.

506

#### 507 Functional health status

508 Visual and hearing impairments were individually assessed by two studies [32, 44]. Two  
509 categories were created: 'none' and 'one or two items with some difficulty'. Constipation was  
510 individually assessed by two studies [30, 40] using a single item yes/no question on the  
511 presence of constipation.

512

#### 513 Eating dependency/Difficulty feeding

514 Eating dependency was assessed by four studies [30, 38, 40, 46]. Two studies [30, 40] used  
515 the single item yes/no question on eating dependency (whether the person was classified as  
516 independent in eating and drinking) from the Resident Assessment Instrument-Minimum  
517 Data Set (RAI-MDS). One study [38] used a single item yes/no question on able/not able to

518 bring food to mouth. The last study [46] categorised ability to eat unaided into, completely  
519 unable, with some help, or without help.

520

### 521 Self-perceived health

522 Self-perceived health was assessed by four studies [34-36, 43]. Two studies [34, 35] used the  
523 Nottingham Health Profile. One study [36] used a five-point scale and classified participants  
524 into three health status categories: good (very good/good), moderate and poor (fairly poor).  
525 One study [43] assessed current health status by getting participants to rate their own health  
526 as very good, excellent or poor, and their current health status (worse, same, better) compared  
527 to their own health one year earlier.

528

529 There is moderate evidence that co-morbidity, visual and hearing impairments are not  
530 determinants of malnutrition.

531 There is also moderate evidence that eating dependency and poor self-perceived health are  
532 determinants of malnutrition.

533 Conflicting evidence suggests constipation is a determinant of malnutrition.

534

### 535 **Physical function domain**

536 Physical function was assessed by 13 studies [32-34, 36, 38, 40-46, 48]. Measures focussed  
537 on ADL, performance, and strength. Three studies [33, 34, 46] used the 0-100 ADL Index.  
538 One study [40] used a 4-18 ADL score. Another study [38] used the Zorg index (Care Index  
539 Questionnaire). A third study [43] summed the number of reported physical problems in the  
540 past year (problems with balance, feet, ankles). Finally, one study [36] used an eight point  
541 instrumental ADL tool.

542

543 One study [42] used a single yes/no question on independent/dependent in ADLs of walking,  
544 bathing, dressing, toileting, transferring, and getting outside. Three studies [32, 41, 45] used  
545 the Barthel Index. Two studies [44, 48] used a series of performance tests. One study [44]  
546 used three performance tests (chair stands, tandem stand, walk tests, and difficulty walking  
547 stairs), and rated performance on a scale, and the other study [48] used eight performance  
548 tests: handgrip, bicep strength, quadriceps strength, chair stand test, two gait speed tests,  
549 timed up and go test, and the one leg stand test.

550

551 There is moderate evidence that physical function is a determinant of malnutrition.

552

### 553 **Lifestyle domain**

554 A total of three studies [42, 44, 49] examined three determinants in the lifestyle domain.

555

#### 556 Smoking

557 Smoking status was assessed by two studies [42, 44]. One study [42] used a single item  
558 yes/no question to the smoking or chewing of tobacco, and categorised participants into  
559 current smoker, former smoker or those who had never smoked. The second study [44]  
560 categorised participants into 3 categories: current smoker, former smoker, or never a smoker.

561

#### 562 Alcohol

563 Alcohol use was assessed by two studies [42, 44]. One study [44] assessed alcohol use on the  
564 number of days per week drinking alcohol, and the number of alcohol consumptions each  
565 time, and categorized participants into four categories: no alcohol, light, moderate, and (very)  
566 excessive use of alcohol. The second study [42] assessed alcohol use using a yes or no single  
567 item yes/no question on drinking alcohol 5 or more days per week.

568

569 Physical activity

570 Physical activity was assessed by three studies [42, 44, 49]. One study [42] defined physical  
571 activity by whether participants walked one or more blocks each day. A second study [44]  
572 assessed physical activity in the previous two weeks using the Longitudinal Aging Study  
573 Amsterdam Physical Activity Questionnaire which included information on frequency and  
574 duration of walking, cycling, household activities, and sport activities. The third study [49]  
575 asked participants whether they had engaged in common leisure activities in the previous 2  
576 weeks, including walking, hiking, jogging, cycling, dancing, aerobics, bowling, golfing,  
577 calisthenics, and swimming. Each activity was assigned a per-minute caloric expenditure  
578 value, which was summed over all minutes of activity over the week.

579

580 There is moderate evidence that smoking status, alcohol consumption and physical activity  
581 levels are not determinants of malnutrition.

582

583 **Eating domain**

584 A total of eight studies [30, 34, 38, 40, 41, 44, 46, 47] examined five determinants in the  
585 eating domain.

586

587 Appetite/leaves food on plate

588 Appetite/leaving food on plate was measured by five studies [30, 38, 40, 44, 46]. Four studies  
589 [30, 38, 40, 46] used a single item yes/no question on loss of appetite/leaves 25% of food on  
590 plate or not. The other study [44] used the question ‘I did not feeling like eating, my appetite  
591 was poor’ from the Center for Epidemiologic Studies Depression Scale, and participant had  
592 to rate on a 4-point scale.

593

594 Complaints about taste of food

595 Complaints about taste was assessed by two studies [30, 40]. Both studies used the single  
596 item yes/no question on complaint/no complaint about taste of food from the RAI-MDS.

597

598 Dietary factors: Nutrient intake and modified texture diets

599 Two studies [38, 47] assessed energy and/or nutrient intake. One study [38] recorded  
600 participant food and beverage consumption in diaries, and energy and nutrient intake (protein,  
601 fat, carb) was calculated using the Dutch food composition database. The second study [47]  
602 used a questionnaire assessing dietary intake, with a particular focus on fat, and the different  
603 types of fat.

604 One study [41] assessed the effect of a modified texture diet (whether the diet was minced  
605 into small pieces, pureed, or mixed in a blender).

606

607 Hunger

608 Hunger was assessed by one study [40] using a single item yes/no question from the RAI-  
609 MDS on feeling hungry or not.

610

611 Thirst

612 Thirst was assessed by one study [38] by asking participants whether their thirst was  
613 increased, normal or diminished.

614

615 There is moderate evidence that poor appetite is a determinant of malnutrition.

616 Moderate evidence suggests that complaints about taste of food and specific nutrient intake  
617 are not determinants of malnutrition.

618 There is also low evidence that modified texture diets is a determinant of malnutrition.

619 Low evidence suggests that hunger and thirst are not determinants of malnutrition.

620 ***Results when studies using the MNA are removed***

621 Removing the ten studies [31-37, 41, 45, 47] which used the MNA as a indicator of

622 malnutrition changed the results for certain domains, because potential determinants are

623 included as part MNA. The conflicting evidence for depression changed to moderate

624 evidence that depression is not a determinant. The current moderate evidence for self-

625 perceived health and hospitalisation being determinant changed to limited evidence for both.

626 The evidence for the other potential determinants stayed the same.

627



628 **Discussion**

629 This systematic review provides moderate evidence that hospitalisation, eating dependency,  
630 poor self-perceived health, poor physical function and poor appetite are determinants of  
631 malnutrition.

632

633 There is moderate quality evidence that chewing difficulties, mouth pain, gum issues co-  
634 morbidity, visual and hearing impairments, smoking status, alcohol consumption and  
635 physical activity levels, complaints about taste of food and specific nutrient intake are not  
636 determinants of malnutrition.

637

638 Low evidence suggests that loss of interest in life, access to meals and wheels, and modified  
639 texture diets are determinants of malnutrition.

640 Furthermore, low evidence suggests that psychological distress, anxiety, loneliness, access to  
641 transport and wellbeing, hunger and thirst are not determinants of malnutrition.

642

643 There is conflicting evidence that dental status, swallowing, cognitive function, depression,  
644 residential status, medication intake and/or polypharmacy, constipation, periodontal disease  
645 are determinants of malnutrition. The findings of this systematic review are broadly in line  
646 with previous systematic reviews conducted on determinants of malnutrition in older adults  
647 [14, 21, 22], but vary on the quality assessment of studies and the balance of evidence for  
648 certain determinants. Two of these reviews [14, 22] state that certain factors, for example,  
649 depression, swallowing, excessive polypharmacy are determinants of malnutrition, whereas  
650 we have found that there is conflicting evidence for these potential determinants.

651

652 The results of this systematic review should be interpreted with caution due to the identified  
653 limitations of the included studies. While prospective cohort studies are regarded as Level 1a  
654 evidence, observational studies are often flawed by residual and unmeasured confounding.  
655 The definitions and criteria used for malnutrition varied across studies, even within the same  
656 domain (e.g. oral domain). Using the MNA as an outcome measure of malnutrition could  
657 potentially lead to an overestimate of the impact of certain factors which are already in the  
658 MNA. This aspect does not seem to be considered by authors of the included studies. We  
659 examined if removal of the MNA studies would change the results and found that the items  
660 which are part of the MNA (e.g cognition, depression, physical function) were overestimated  
661 in terms of their impact on determining malnutrition.

662

663 There is still no consensus on whether low BMI, malnutrition screening tools instead of  
664 MNA, and percent weight loss, are equally valid and sensitive for measuring  
665 malnutrition.[51-53]. **Another consideration is that malnutrition not only includes**  
666 **undernutrition and underweight, it also includes overweight or obesity.[53, 54].**  
667 **Therefore, the fact to consider only low BMI for example, could underestimate**  
668 **malnutrition.[53, 54].** It is imperative that future research examines these considerations  
669 carefully, as a better understanding of the best definition, is likely to significantly progress  
670 the quality of our studies, and the overall malnutrition field [9, 55].

671

672 **There is strong evidence that the prevalence of malnutrition varies across settings [2, 5,**  
673 **6]. The vast majority of studies included in this review focus on the community setting.**  
674 **Due to the paucity of literature focussing on the nursing home and acute hospital**  
675 **setting, it is difficult to state with any certainty if different determinants of malnutrition**  
676 **are more relevant in specific settings. Studies that examine the same determinants**

677 **across multiple setting are needed to enable any conclusions about setting-specific**  
678 **determinants.**

679

680 Measurement of determinants across available studies varied significantly. Although  
681 subjective complaints may be more relevant with regards to eating problems, most studies  
682 poorly described the assessment of their determinants, and used single-item subjective  
683 questions of questionable validity to measure determinants which may warrant objective  
684 measurement (e.g. oral health, physical activity). Similar to the definition of malnutrition,  
685 there is no consensus on what best defines cut-offs for certain determinants; for example,  
686 good oral health, polypharmacy, cognitive function, etc. Research needs to better examine  
687 what are the best definitions and measurements of these individual determinants.

688

689 There is a paucity of literature on certain determinants like hunger, physical activity, anxiety,  
690 loneliness, social support, etc with only one to two studies examining these factors; this  
691 limited data means we cannot draw inference on these factors and malnutrition.

692

693 While we are interested in progressing our knowledge of malnutrition in older adults,  
694 focussing on older adults with a mean age of 74 is also a significant limitation. Participants in  
695 the included studies had high levels of co-morbidities at baseline, and the possibility that  
696 malnutrition could have been present at baseline cannot be ruled out. Fifty years of age and  
697 older has been defined as the new age bracket for older adults by some groups, so potentially  
698 we need future research in older adults earlier in this range to track determinants and  
699 malnutrition more closely over regular follow-ups, to give us a clearer understanding of the  
700 true determinants of malnutrition in this population. Results may also be influenced by the  
701 type of participants. We compared cohorts of different age, different settings, and different

702 health status so the determinants could change depending on the group under investigation.  
703 Long term prospective studies are need recruiting participants from young old group before  
704 they become malnourished to truly identify determinants of malnutrition. Future research in  
705 specific age brackets, different settings and health status need to be conducted with  
706 appropriate follow-ups to advance our understanding of the determinants of malnutrition in  
707 different subgroups and settings as certain determinants are more relevant/specific depending  
708 on the setting they are assessed in.

709

710 Analysing the effect of single determinants in isolation may have limitations. The emerging  
711 international consensus on malnutrition is that it is a complex multidimensional problem  
712 where determinants from different domains (e.g. oral, psychosocial, physical, lifestyle,  
713 health, and eating ) interact with each other, may vary from individual to individual, or over  
714 time depending how strong the determinant is [56-60]. Treatments targeting a range of these  
715 factors seem promising [61]. If determinants are not mutually exclusive, the utility of further  
716 prospective studies analysing one determinant in isolation should be called into question.  
717 Studies measuring the cumulative risk of different determinants may provide us with better  
718 insights. Interactions between determinants should also be explored (for example, lack of  
719 cooking skills might only be a determinant of malnutrition in older community dwelling men  
720 when they are recently widowed) which may be pertinent in different settings/genders.  
721 Further research into multidimensional screening tools that measure cumulative risk across  
722 multiple domains may be a useful way forward. It may then be worth examining if stratifying  
723 or individualising care based on the dominant modifiable determinants for each individual  
724 can provide superior outcomes over one size fits all usual care approaches for malnutrition.

725

726 Strengths of this review are that it was systematically performed by two independent  
727 reviewers, and only prospective cohort studies were included. We acknowledge some  
728 limitations. (1) Our definition of a potentially modifiable determinant is open to  
729 interpretation. Currently, we lack the data to confirm which determinants are modifiable. For  
730 example, cognitive status, hospitalisation, medication, for a number of reasons, may not be  
731 modifiable. We also do not know what underlying determinants influence the success of an  
732 [nutritional] intervention, e.g. dental condition, ability to masticate and swallow food with  
733 ease and mediate treatment response. However, placing more attention on factors that are  
734 likely to be more modifiable, and treatable malnutrition, are important research and clinical  
735 priorities (2). The way we categorised domains and determinants is subjective in nature.  
736 Certain determinants (e.g swallowing, self-reported health, dependency) are multifaceted in  
737 nature, and so could also be placed in a different domain, as we do not understand the factors  
738 that underlie these individual determinants. However, a previous review on this topic used a  
739 similar categorisation approach [21]. [21][21][21][21]We included studies with a wide  
740 variety of settings, determinants, definitions, follow-up periods, and measurements, so it is  
741 difficult to synthesise this heterogeneous evidence. However we did use a descriptive  
742 synthesis [27] to give a best evidence approach. Furthermore, definitions and measurements  
743 vary widely in clinical practice. Lastly, the total number of presently available studies,  
744 especially when taking into account the substantial heterogeneity between studies together  
745 with their inconsistent results, is too limited to draw firm conclusions.

746

## 747 **Conclusion**

748 This systematic review of prospective studies provides moderate evidence that  
749 hospitalisation, eating dependency, poor self-perceived health, physical function, poor  
750 appetite are determinants of malnutrition. Moderate quality evidence suggest that chewing

751 difficulties, mouth pain, gum issues co-morbidity, visual and hearing impairments, smoking  
752 status, alcohol consumption and physical activity levels, complaints about taste of food and  
753 specific nutrient intake are not determinants of malnutrition. The review displays low  
754 evidence that loss of interest in life, access to meals and wheels, and modified texture diets  
755 are determinants of malnutrition, and low evidence that psychological distress, anxiety,  
756 loneliness, access to transport and wellbeing, hunger and thirst are not determinants of  
757 malnutrition. Finally, there is conflicting evidence that dental status, swallowing, cognitive  
758 function, depression, residential status, medication intake and/or polypharmacy, constipation,  
759 periodontal disease is a determinant of malnutrition. Overall multiple factors contribute to  
760 malnutrition. However, strong robust evidence is lacking for many determinants. Better  
761 prospective cohort studies are required. With an increasingly aging population, targeting  
762 modifiable factors will be crucial to the effective treatment and prevention of malnutrition.

763

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777

## 778 **STATEMENT OF AUTHORSHIP**

779 MV, DV and EMOC conceived the idea for the review. MOK and MK performed the  
780 database searches and analyses. MOK wrote the manuscript. All authors edited the  
781 manuscript. All authors have read and approved the final manuscript.

782

## 783 **CONFLICT OF INTEREST**

784 The authors declare no conflict of interest.

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