Association between malnutrition and stages of sarcopenia in geriatric rehabilitation inpatients: RESORT

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1. Introduction

Geriatric rehabilitation following an acute event aims at functional recovery through multidisciplinary interventions [1]. One-third of geriatric rehabilitation patients are diagnosed with malnutrition [2], which is a modifiable risk factor of sarcopenia [3], the age-related low muscle strength and muscle mass [4], being present in 56% of geriatric rehabilitation patients [5]. Malnutrition and sarcopenia are independently associated with functional decline [6,7], lower quality of life [8,9] and higher mortality [10,11] in older adults and can negatively impact functional recovery during geriatric rehabilitation [12,13]. Both conditions may coexist in geriatric rehabilitation patients [14,15] but they remain largely undiagnosed and untreated in routine clinical care [16–18] despite available interventions, such as resistance exercise training in combination with nutritional interventions [19,20].
For early detection and treatment of malnutrition, the Global Leadership Initiative on Malnutrition (GLIM) introduced the GLIM criteria, a three-step approach for the diagnosis of malnutrition [21]. Likewise, the revised definition of the European Working Group on Sarcopenia in Older People (EWGSOP2) proposed a four-step algorithm for the diagnosis of sarcopenia with sarcopenia stages: no sarcopenia, probable sarcopenia, confirmed sarcopenia and severe sarcopenia [4]. Malnutrition and sarcopenia coexist and are associated in one-fourth of hospitalized older adults [22] but this has, up until now, only been shown in one study in geriatric rehabilitation patients [14]. This knowledge is crucial to guide interventions and ultimately improve geriatric rehabilitation patients’ functional recovery.

The aim was to assess the prevalence, the coexistence of, and the association between malnutrition according to GLIM and sarcopenia stages according to EWGSOP2 in geriatric rehabilitation inpatients.

2. Material and methods

2.1. Study design and population

REStORing health of acutely unwell adults (RESORT) is an observational, longitudinal cohort of geriatric rehabilitation inpatients admitted to the Royal Melbourne Hospital (Melbourne, Victoria, Australia). All admitted patients were assessed using a Comprehensive Geriatric Assessment (CGA) [23] within 48 h of admission by physicians, nurses, physiotherapists, occupational therapists and dietitians. The study was approved by the Melbourne Health Human Research Ethics Committee (HREC/17/MH/103).

Patients admitted from 16 October 2017 and discharged by 31 August 2018 (wave 1) were included in the present analysis. Patients were excluded if they were receiving palliative care at admission or if they were incapable of providing informed consent and had no nominated proxy to consent on their behalf. Of the 995 patients admitted, 152 patients were excluded and 150 refused to consent; wave 1 of RESORT therefore included 693 patients, of which 506 were included in the present analysis based on data availability of malnutrition and sarcopenia diagnosis according to the GLIM criteria and EWGSOP2 definition (Fig. 1).

2.2. Patient characteristics

Age, sex, primary reason for hospital admission and length of stay in geriatric rehabilitation were retrieved from medical records. Disease burden was documented by physicians using the 37-point Charlson Comorbidity Index (CCI) [24] and 56-point Cumulative Illness Rating Scale (CIRS) [25], in which higher points indicated higher morbidity. Frailty was measured using the Clinical Frailty Scale and was assessed by a physician on a scale from 1 (very fit) to 9 (terminally ill) [26]. Cognitive impairment was evaluated by the presence of dementia or by a cognitive score below cut-off values of one of following tests: standardized Mini-Mental State Examination (sMMSE) < 24 points [27], Montreal Cognitive Assessment (MoCA) < 26 points [28] or Rowland Universal Dementia Assessment Scale (RUDAS) < 23 points [29]. Anthropometric measurements were performed by nurses. Weight, up to the nearest 0.1 kg, was measured on a calibrated weighing scale, weighing chair or hoist without shoes or heavy clothing. If the patient was able to stand, standing height up to the nearest 0.1 cm, was measured without footwear. If the patient was unable to stand, knee height was measured by a sliding caliper between knee and ankle joints positioned at 90°; the estimated height was then calculated using the LASA equation [30]. The body mass index (BMI) was calculated by body weight divided by height squared (kg/m²). Risk of malnutrition was assessed by nurses with the Malnutrition Screening Tool (MST) on a scale from 0 to 5 with higher scores indicating a higher risk of malnutrition [31]. Functional performance was assessed by occupational therapists using the Katz index for Activities of Daily Living (ADL) [32] and the Lawton and Brody scale for Instrumental Activities of Daily Living (IADL) [33]. Scores of ADLs and IADLs ranged between 0-6 and 0-8 points respectively, with higher scores indicating higher levels of independence.

2.3. Malnutrition diagnosis

Malnutrition was diagnosed according to the GLIM criteria [21,34] as previously described [34]. The phenotypic assessment included: low BMI (≤20 kg/m² if < 70 years or ≤22 kg/m² if ≥ 70 years) and/or non-volitional weight loss (1 to >15 kg in the past six months recorded on the MST) and/or reduced muscle mass expressed as skeletal muscle mass index (SMMI ≤10.75 kg/m² and ≤6.75 kg/m² for males and females respectively [35]). The etiologic assessment included three domains: 1) any chronic gastrointestinal condition adversely impacting food assimilation or absorption, identified with the CIRS in patients with a score of ≥3 in one or more CIRS categories, aligning with severe, significant disability or chronic health problems [36]; and/or 2) disease burden and/or an inflammatory condition (acute disease/injury or chronic disease, or moderate to severe inflammation), identified with the CIRS in patients with a score of ≥3 in one or more CIRS categories, aligning with severe, significant disability or chronic health problems [36]; and/or 3) reduced food intake for >2 weeks, identified by answering “yes” to the MST question “Have you been eating poorly because of a decreased appetite?”. Based on these assessments, the patient was indicated as ‘malnourished’ or ‘non-malnourished’. Although the GLIM criteria recommend using a screening tool for malnutrition as a first step in the algorithm, these criteria were applied to all patients independent of the MST as this score has been shown to have low accuracy in geriatric rehabilitation inpatients [34].

2.4. Sarcopenia diagnosis

Muscle strength and physical function were measured by physiotherapists. Handgrip strength was measured with a handheld dynamometer (JAMAR, Sammons Preston, Inc., 119 Bolingbrook, IL, USA). Patients were measured in a sitting position with elbows flexed at 90°, shoulders adducted and forearms in a neutral position without support. Patients were instructed to squeeze the dynamometer as hard as possible, three times for each hand, alternating between the right and the left-hand side [37]. The maximal value was reported in kilograms. The Short Physical Performance Battery (SPPB) was used to assess physical function on a scale ranging from 0 to 12 points with a higher score indicating better physical function [38]. The SPPB consists of three tests: standing balance test, the timed chair stand test and the four-meter walk test (gait speed). For the chair stand test, patients were instructed to raise five times from their chair and the time was recorded in seconds. The gait speed test was repeated two times and the fastest time in seconds was used for analysis and expressed in gait speed per second (m/s).

Muscle mass was measured by direct-segmental multi-frequency bio-electrical impedance analysis (DSM-BIA, InBody 510, Biospace Co., Ltd, Seoul, South Korea) by nurses. DSM-BIA has been validated for assessing segmental and whole-body composition against dual-energy X-ray absorptiometry (DEXA) [39]. DSM-BIA was not performed in patients with 1) electronic internal medical devices or implants such as cardiac pacemakers; 2) plasters or bandages interfering with the placement of the electrodes; 3) amputation or;
4) admission under contact isolation/precautions. Patients were measured in a supine position. Muscle mass was expressed as skeletal muscle mass (SMM, kg) and appendicular lean mass (ALM, kg) [39]. Skeletal muscle index (SMI, kg/m²) was calculated by dividing SMM (kg) by height squared (m²) [39]. ALM index (ALMI) (kg/m²) was calculated by dividing ALM by height squared (m²) [40].

The EWGSOP2 definition and cut-offs was used for sarcopenia diagnosis [4]. Low muscle strength was defined as handgrip strength < 27 kg and < 16 kg for males and females respectively. If handgrip strength was unavailable, the chair stand test was used instead, with low muscle strength defined as failing the pre-test (not able to rise from the chair without using the arms) or a time of > 15 s. Low muscle mass was defined as ALMI < 7.0 kg/m² for males and < 5.5 kg/m² for females. Low physical performance was defined as gait speed ≤ 0.8 m/s or inability to walk. Following the EWGSOP2 algorithm, patients with normal muscle strength were classified with no sarcopenia, patients with low muscle strength but normal muscle mass were classified as probable sarcopenia, patients with low muscle strength and low muscle mass, but normal physical performance were classified as confirmed sarcopenia (non-severe), and patients with low muscle strength, low muscle mass and low physical performance were classified as severe sarcopenia [4]. Although included in the EWGSOP2 algorithm, we did not apply the SARC-F as this screening tool has been shown to have poor specificity and poor accuracy in identifying geriatric rehabilitation inpatients at risk of sarcopenia [41].

2.5. Statistical analysis

Descriptive statistics were used to present the patient characteristics. Variables being normally distributed were reported as mean with standard deviation (SD), variables being skewed as median with interquartile range (IQR) and categorical variables as frequency (n) with percentage (%). Multinomial logistic regression analyses of the association between malnutrition and sarcopenia stages included three models: unadjusted, adjusted for age and sex and adjusted for age, sex, CCI and cognitive impairment and were expressed as odds ratios (OR) and 95% confidence intervals (CI). The interaction effect in the association was tested for sex. P-values < 0.05 were considered statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (IBM SPSS Advanced Statistics 25.0, Armonk, NY: IBM Corp.).

3. Results

Table 1 shows the characteristics of geriatric rehabilitation inpatients at admission. The median age was 83.4 years [IQR: 77.5–87.9], 58% were female, 65% had cognitive impairment and the median frailty score was 6 [IQR: 5–6]. The median length of stay in geriatric rehabilitation was 19 days [IQR: 13–29].

According to the GLIM criteria and EWGSOP2 definition, 51% (n = 257) of the patients were malnourished, 49% (n = 250) were diagnosed with probable sarcopenia, 0.4% with confirmed sarcopenia (non-severe) (n = 2) and 19% (n = 94) with severe sarcopenia (Fig. 2). Of the malnourished patients (n = 257), 46% had probable sarcopenia, 0.4% had confirmed sarcopenia (non-severe) and 26% had severe sarcopenia. Of the non-malnourished patients (n = 249), probable sarcopenia, confirmed sarcopenia (non-severe) and severe sarcopenia were present in 53%, 0.4% and 11% respectively. Out of the 506 patients, 23% had both malnutrition and probable sarcopenia, 0.2% had both malnutrition and confirmed sarcopenia.
The prevalence and coexistence of malnutrition according to GLIM and sarcopenia stages according to EWGSOP2 was high among geriatric rehabilitation inpatients. Malnutrition was associated with severe sarcopenia, but not with probable sarcopenia.

4.1. Prevalence and coexistence of malnutrition and sarcopenia

The high prevalence and coexistence of malnutrition and sarcopenia observed in this cohort highlights the importance of diagnosis at admission to geriatric rehabilitation. Despite the coexistence, both malnutrition and sarcopenia diagnostic tools have to be applied due to the likelihood of prevalence of one and not both diagnoses. However, previous research shows diagnosis is currently not implemented in routine clinical care due to a lack of knowledge and diagnostic equipment [17,18]. A study in post-acute care geriatric inpatients reported the coexistence of malnutrition and sarcopenia in 15% of the patients [14], which is comparable to our findings. In a recent systematic review, the coexistence of malnutrition and sarcopenia was present in 23% of hospitalized older adults [22], which is in line with the findings of the present study in geriatric rehabilitation inpatients.

4.2. Association between malnutrition and sarcopenia stages

Malnutrition was found to be associated with sarcopenia in several populations, including hospitalized patients [22] and nursing home residents [42], using different diagnostic criteria. A longitudinal study criteria showed that malnutrition (GLIM) was associated with a threefold higher risk to develop sarcopenia/severe sarcopenia (EWGSOP2) during a four-year follow up period in community-dwelling older adults [3]. The present study shows that malnutrition is associated with severe sarcopenia in geriatric rehabilitation inpatients. This is in line with a previous study in post-acute geriatric inpatients (n = 88), using the European Society of Clinical Nutrition and Metabolism (ESPEN) and first EWGSOP definition [14]. The association between malnutrition and severe sarcopenia could be explained by a lower intake of key nutrients such as protein, vitamin D and calcium, amongst other factors, which affects preservation of muscle mass and subsequently muscle strength and physical performance [43]. However, longitudinal data on nutritional status and dietary intake are required to assess the causal bi-directional relationship between malnutrition and sarcopenia in geriatric rehabilitation. Additionally, one third of the patients diagnosed with severe sarcopenia were non-malnourished, suggesting that malnutrition is not the only risk factor for severe sarcopenia in geriatric rehabilitation patients. Therefore, physical inactivity and other potential causes of sarcopenia should be evaluated to provide targeted interventions [4,44].

Contrary to our expectations, malnutrition was not associated with probable sarcopenia; i.e. the occurrence of low muscle strength in the absence of low muscle mass. While other studies also found an association between a high risk of malnutrition and lower muscle mass but not with lower muscle strength [45–47]; others did show an association between malnutrition and muscle strength [47–50]. According to the EWGSOP2, muscle strength can be determined by handgrip strength or by the chair stand test but poor agreement has been shown between upper- and lower measures of muscle strength in older adults [51,52], also resulting in different prevalence rates of sarcopenia [53]. Future research should assess the adequacy and agreement between measures of muscle strength to diagnose sarcopenia in geriatric rehabilitation.

Low physical performance is inherently present in geriatric rehabilitation inpatients [1] and resulted in the absence of the confirmed sarcopenia (non-severe) stage in this study as all patients with low muscle strength and low muscle mass but not with lower muscle strength [45–47]; others did show an association between malnutrition and muscle strength [47–50]. According to the EWGSOP2, muscle strength can be determined by handgrip strength or by the chair stand test but poor agreement has been shown between upper- and lower measures of muscle strength in older adults [51,52], also resulting in different prevalence rates of sarcopenia [53]. Future research should assess the adequacy and agreement between measures of muscle strength to diagnose sarcopenia in geriatric rehabilitation.

Data presented as median [IQR] unless otherwise indicated. IQR: interquartile range; ADL: Activities of Daily Living; IADL: Instrumental Activities of Daily Living; SMI: skeletal muscle index; SD: standard deviation; ALMI: appendicular lean mass index; SPPB: Short Physical Performance Battery.

* Hospital admission.
* Length of stay in geriatric rehabilitation.
+ Presence of dementia or sMMSE <24 points or MOCA <26 points or RUDAS <23 points.

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**Table 1**

Patient characteristics at admission to geriatric rehabilitation (n = 506).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>n</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>506</td>
<td>83.4 [77.5–87.9]</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>506</td>
<td>293 (57.9)</td>
</tr>
<tr>
<td>Primary reason for admission*</td>
<td>506</td>
<td></td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neurological</td>
<td>237</td>
<td>(46.8)</td>
</tr>
<tr>
<td>Infection</td>
<td>59</td>
<td>(11.7)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>39</td>
<td>(7.7)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>36</td>
<td>(7.1)</td>
</tr>
<tr>
<td>Other</td>
<td>46</td>
<td>(9.0)</td>
</tr>
<tr>
<td>Length of stay*, days</td>
<td>506</td>
<td>19 [13–29]</td>
</tr>
<tr>
<td>Charlson Comorbidity Index, score</td>
<td>506</td>
<td>2 [1–4]</td>
</tr>
<tr>
<td>Cumulative Illness Rating Scale, score</td>
<td>506</td>
<td>11 [8–14]</td>
</tr>
<tr>
<td>Clinical Frailty Scale, score</td>
<td>455</td>
<td>6 [5–6]</td>
</tr>
<tr>
<td>Cognitive impairment*, n (%)</td>
<td>506</td>
<td>328 (64.8)</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>506</td>
<td>26.2 [22.9–30.8]</td>
</tr>
<tr>
<td>Malnutrition Screening Tool, score</td>
<td>504</td>
<td>1 [0–2]</td>
</tr>
<tr>
<td>Katz-ADL, score</td>
<td>491</td>
<td>2 [1–3]</td>
</tr>
<tr>
<td>Lawton-IADL, score</td>
<td>491</td>
<td>1 [0–2]</td>
</tr>
<tr>
<td><strong>Muscle and physical performance measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip strength, kg, mean ± SD</td>
<td>446</td>
<td>17.3 ± 7.63</td>
</tr>
<tr>
<td>Female</td>
<td>265</td>
<td>13.9 ± 5.62</td>
</tr>
<tr>
<td>Male</td>
<td>181</td>
<td>22.3 ± 7.42</td>
</tr>
<tr>
<td>Unable, n (%)</td>
<td>479</td>
<td>33 (6.89)</td>
</tr>
<tr>
<td>Chair stand test, s</td>
<td>118</td>
<td>21.2 [16.8–29.4]</td>
</tr>
<tr>
<td>Unable, n (%)</td>
<td>502</td>
<td>384 (76.5)</td>
</tr>
<tr>
<td>SMI, kg/m², mean ± SD</td>
<td>497</td>
<td>8.91 ± 1.43</td>
</tr>
<tr>
<td>Female</td>
<td>289</td>
<td>8.52 ± 1.36</td>
</tr>
<tr>
<td>Male</td>
<td>208</td>
<td>9.46 ± 1.34</td>
</tr>
<tr>
<td>ALMI, kg/m², mean ± SD</td>
<td>496</td>
<td>7.21 ± 1.49</td>
</tr>
<tr>
<td>Female</td>
<td>288</td>
<td>6.79 ± 1.45</td>
</tr>
<tr>
<td>Male</td>
<td>208</td>
<td>7.79 ± 1.35</td>
</tr>
<tr>
<td>SPPB, score</td>
<td>501</td>
<td>1 [0–4]</td>
</tr>
<tr>
<td>Gait speed, m/s</td>
<td>327</td>
<td>0.41 [0.28–0.56]</td>
</tr>
<tr>
<td>Unable, n (%)</td>
<td>503</td>
<td>17 [35.0]</td>
</tr>
</tbody>
</table>

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sarcopenia (non-severe) and 13% had both malnutrition and severe sarcopenia.

Figure 3 shows the association between malnutrition and sarcopenia stages. There was no effect modification for sex. Patients with malnutrition had higher odds of having severe sarcopenia (OR = 2.07, 95% CI = 1.13–3.81, p = 0.019) compared to patients without malnutrition. No association was observed between malnutrition and probable sarcopenia (OR = 0.91, 95% CI = 0.58–1.42, p = 0.674). The association between malnutrition and confirmed sarcopenia (non-severe) was not assessed given the insufficient number of inpatients in this sarcopenia stage.
guidelines on clinical nutrition and hydration in geriatrics, as well as the GLIM criteria, recommend nutritional interventions to be part of a multimodal approach including physio- and occupational therapy as well as pharmacological agents [21,57]. Likewise, the EWGSOP2 definition recommends a combination of nutrition and exercise interventions to treat sarcopenia [4]. The prevalence of malnutrition in half of the geriatric rehabilitation inpatients indicates that most patients are likely to require nutritional support with adequate amounts of protein and energy intake. This is supported by a recent study in geriatric rehabilitation patients showing that protein intake was <0.8 g/(kg/day) in 46% and <1.2 g/(kg/day) in 92% of the patients [15], whereas the recommended protein intake for older people with acute or chronic disease is between 1.2 and 1.5 g/(kg/day) [58]. While the efficacy of nutritional and exercise interventions on clinical outcomes in geriatric rehabilitation inpatients needs to be further established, protein supplementation can increase protein intake [59] and muscle mass in older adults [20,60].

### 4.3. Strengths and limitations

This is the first study investigating the association between malnutrition and sarcopenia in geriatric rehabilitation inpatients using the most recent definitions. All measurements were conducted by a multidisciplinary team as part of a CGA, which promotes the standardization of assessments and utilizes adequate methodology for older patients. There are also some limitations. Firstly, the use of the MST as a proxy to identify reduced food intake and weight loss for the GLIM criteria could have introduced bias as the MST questions do not address a specific time frame of reduced food intake and weight loss and rely on self-reported information. Secondly, muscle mass was measured with BIA, which could not be performed in patients with pacemakers and other electronic...
implants and amputations. BIA measurements can also be influenced by hydration status [61].

5. Conclusion

In geriatric rehabilitation inpatients, the prevalence of malnutrition and sarcopenia was high, and both conditions coexisted frequently. Malnutrition was associated with severe sarcopenia according to EWGSOP2, but not with probable sarcopenia. The present findings warrant the implementation of diagnosis of both conditions at admission to geriatric rehabilitation. Also, further research is needed to evaluate feasible and efficient interventions to counteract both conditions in geriatric rehabilitation inpatients to improve rehabilitation outcomes.

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Author contributions

EMR and ABM were responsible for the conceptualization. JP, EMR and ABM were responsible for the data curation. LMGV was responsible for the conceptualization. JP, JPvW, CGMM and ABM were responsible for reviewing the manuscript.

Conflict of interest

A.B. Maier reports grants from Danone Nutricia Research, outside the submitted work; J.P. van Wijngaarden reports that she is an employee of Danone Nutricia Research. The other authors declare that they have no conflicts of interest.

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