Malnutrition is associated with poor trajectories of activities of daily living in geriatric rehabilitation inpatients: RESORT

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\textbf{A B S T R A C T}

Malnutrition is associated with poor functional performance in geriatric rehabilitation inpatients. However, it is unclear if malnourished patients have poor functional trajectories over time. This study aimed to determine the association between (the risk of) malnutrition at admission and trajectories of Activities of Daily Living (ADL) and Instrumental ADL (IADL) from pre-admission to post-discharge in geriatric rehabilitation inpatients. An observational, longitudinal study was conducted in the RESTORing health of acutely unwell adults (RESORT) cohort of geriatric rehabilitation inpatients. A total of 618 patients (mean age 82.1 ± 7.8 years, 57.4 % females) were included. The prevalence of the risk of malnutrition, by Malnutrition Screening Tool (MST) was 41.3 % (n = 255) and malnutrition by the Global Leadership Initiative on Malnutrition (GLIM) and European Society for Clinical Nutrition and Metabolism (ESPEN) criteria were 53.5 % (n = 331) and 13.1 % (n = 81) respectively. Malnutrition by the GLIM criteria but not the ESPEN criteria nor the risk of malnutrition, was associated with ADL trajectories of ‘remained poor’ (OR: 3.33, 95 %CI: 1.21–9.19) and ‘deteriorated’ (OR: 1.68, 95 %CI: 1.13–2.52) compared to the ‘recovered’ trajectory. The risk of malnutrition and malnutrition were not associated with IADL trajectories. Malnutrition at admission was associated with poor ADL trajectories but not IADL trajectories in geriatric rehabilitation inpatients.

1. Introduction

Malnutrition is prevalent among 30–50 % of geriatric rehabilitation patients (Marshall et al., 2016; Clark et al., 2020) and associated with longer length of hospitalization (Marshall et al., 2014; Charlton et al., 2010), higher risk of institutionalization (Neumann et al., 2005; Visvanathan et al., 2004), lower quality of life (Neumann et al., 2005) and mortality (Nicosia et al., 2012; Sullivan et al., 1991). Malnourished geriatric rehabilitation patients have poor performance in activities of daily living (ADL) at admission (Wojzischke et al., 2020) and poor recovery of ADL during hospitalization (Sanchez-Rodriguez et al., 2017) compared to non-malnourished patients. Malnutrition is therefore an important challenge in restoring functional performance in geriatric rehabilitation patients after acute hospitalization.

ADL and instrumental activities of daily living (IADL) trajectories describe the change in functional status over multiple time points. Malnutrition is a predictor of poor ADL trajectories from admission to post-discharge in older hospitalized patients (Chen et al., 2008).

\textbf{Abbreviations: ADL, Activities of Daily Living; IADL, Instrumental ADL; MST, Malnutrition Screening Tool; GLIM, Global Leadership Initiative on Malnutrition; ESPEN, European Society for Clinical Nutrition and Metabolism; CGA, Comprehensive Geriatric Assessment; CCI, Charlson Comorbidity Index; SMI, skeletal muscle index; FFMI, fat-free mass index; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; RUDAS, Rowland Universal Dementia Assessment Scale.}

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However, the evidence is sparse on the associations between malnutrition and trajectories of ADL and IADL from pre-admission to post-discharge in geriatric rehabilitation patients, except for hip fracture patients where the findings are inconclusive and dependent on the tools used to diagnose malnutrition (Goisser et al., 2015; Li et al., 2013). The Global Leadership Initiative on Malnutrition (GLIM) (Cederholm et al., 2019) established diagnostic criteria for malnutrition in adults, which built on the previous criteria published by the European Society for Clinical Nutrition and Metabolism (ESPEN) (Cederholm et al., 2015). Malnutrition diagnosis by ESPEN criteria is limited to the assessment of phenotypic factors whereas the GLIM criteria require the assessment of both phenotypic and etiologic factors of malnutrition.

This study aimed to determine the association between the risk of malnutrition according to the Malnutrition Screening Tool (MST) (Ferguson et al., 1999) and malnutrition diagnosis according to the GLIM and ESPEN criteria at admission, with ADL and IADL trajectories from preadmission to three months post-discharge in geriatric rehabilitation inpatients.

2. Methods

2.1. Study design

REStORing health of acutely unwell adulTs (RESORT) is an observational longitudinal inception cohort of geriatric rehabilitation patients admitted to a university-affiliated hospital in Melbourne, Australia. The Geriatric rehabilitation patients are older adults who need further inpatient rehabilitation care to restore functional independence after an acute hospital admission. All patients were assessed using Comprehensive Geriatric Assessment (CGA) by a multidisciplinary team at admission and discharge from geriatric rehabilitation wards, including physicians, nurses, physiotherapists, and occupational therapists (Ellis et al., 2017). Based on individual rehabilitation goals, patients receive medical management, physiotherapy, occupational therapy and are referred to a dietitian if they are at risk of malnutrition. Patients were followed up via phone calls at three months post-discharge. Written informed consent was obtained for all patient by the patient or a nominated proxy. Patients were excluded if they received palliative care at admission. A total of 693 geriatric rehabilitation inpatients, admitted from 16 October 2017 and discharged by 31 August 2018 recruited in wave 1 of RESORT were included in the analysis. The study was approved by the institutional human research ethics committee (HREC/17/MH/103) and follows the ethical guidelines of the Helsinki Declaration, (World Medical Association Declaration of Helsinki, 2001) the National Statement on Ethical Conduct in Human Research (2007) (NHMRC, 2007) and the Guidelines for Good Clinical Research Practice (TGA, 2018).

2.2. Patient characteristics

Age and sex were obtained from the medical records. Information on the living status was obtained from the patient or caregiver or extracted from medical records. Anthropometric and body composition measures were obtained by nurses. Weight (to nearest 0.1 kg) was measured on a calibrated standing scale, weighing chair or hoist. Standing height or knee height was measured dependent on the patients’ ability to stand. The LASA equation for Caucasians was used to estimate the standing height using the knee height (Chumlea et al., 1985). Body mass index (BMI) was calculated as weight divided by height squared (kg/m²).

Comorbidity and the frailty status was assessed by physicians using the Charlson Comorbidity Index (CCI, a higher score indicating more or severe comorbidity) (Charlson et al., 1994) and the Clinical Frailty Scale (9-point scale from 1 indicating very fit to 9 indicating terminally ill) (Rockwood et al., 2005) respectively. Cognitive impairment was defined as dementia diagnosis reported, or a standardised Mini-Mental State Examination (MMSE) (Folstein et al., 1975; Colombo et al., 2004) score < 24 points, or a Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) score < 26 points, or a Rowland Universal Dementia Assessment Scale (RUDAS) score < 23 points. Delirium was defined as delirium diagnosis or risk of delirium defined by the short Confusion Assessment Method (Inouye et al., 1990). The length of stay of the acute admission and geriatric rehabilitation admission were obtained from medical records. The primary reason for hospital admission was extracted from medical records and grouped into musculoskeletal, neurological, cardiorespiratory, infection and other (including gastrointestinal, urology, hematology, ophthalmology, vascular, psychiatry related conditions, cancer and metabolic disorders).

2.3. Malnutrition

Patients were screened at admission for the risk of malnutrition using the MST by a nurse (Ferguson et al., 1999). The MST is a validated screening tool to identify risk of malnutrition in geriatric rehabilitation patients (Marshall et al., 2016b). It includes two questions on unintentional weight loss and reduced food intake due to poor appetite with possible scores from zero to five points. The answers were self-reported. A score ≥ 2 points were considered as at risk of malnutrition. Malnutrition was diagnosed by applying the GLIM and ESPEN criteria. Body composition, included in both the GLIM and ESPEN criteria, was measured using direct-segmental multi-frequency bioelectrical impedance analysis (DSM-BIA, In-Body S10, Biospace Co., Ltd, Seoul, South Korea). BIA is a preferred method to measure body composition in geriatric patients because it can be performed at the bedside, is non-invasive, imposes no radiation exposure, and the measurement is relatively inexpensive (Sipers et al., 2020) and has been validated against Dual Energy X-ray Absorptiometry (Kafri et al., 2014; Ling et al., 2011). Skeletal muscle mass index (SMI) was calculated by dividing skeletal muscle mass (kg) by height squared (m²) (Janssen et al., 2004) and the fat-free mass index (FFMI), dividing the fat-free mass (kg) by height squared (m²).

2.3.1. GLIM criteria for malnutrition

GLIM has five criteria to diagnose malnutrition in adults in a clinical setting, including three phenotypic criteria and two etiologic criteria. A patient is diagnosed with malnutrition if at least one phenotypic criterion and one etiologic criterion is fulfilled simultaneously. The phenotypic criteria include 1) non-volitional weight loss (>5 % within the past six months, or >10 % beyond six months) 2) low BMI (<20 kg/m² if <70 years, or <22 kg/m² if ≥70 years) and 3) low skeletal muscle mass (SMI ≤ 6.75 kg/m² in females and <10.75 kg/m² in males). The two etiologic criteria include 1) reduced food intake or assimilation (≥50 % of estimated required >1 week, or any reduction for >2 weeks, or any chronic gastrointestinal condition that adversely impacts food assimilation) and 2) an inflammatory condition. The detailed description of the application of the GLIM criteria in RESORT is described elsewhere (Clark et al., 2020).

2.3.2. ESPEN criteria for malnutrition

The ESPEN criteria include two criteria to diagnose malnutrition (Cederholm et al., 2015). A patient is diagnosed with malnutrition if at least one criterion is fulfilled. The criteria include BMI <18.5 kg/m² or unintentional weight loss (>10 % indefinite of time, or >5 % over the past three months) in conjunction with either a low BMI (<20 kg/m² if <70 years old or <22 kg/m² if ≥70 years old) or a low FFMI (females: <15 kg/m², males: <17 kg/m²).

2.4. ADL and IADL

The Katz index (Katz et al., 1963) was used to assess ADLs, with a score ranging from 0 to 6 points and the Lawton and Brody scale (Lawton and Brody, 1969) was used to assess IADLs, with a score ranging from 0 to 8 points, higher scores on both scales indicating higher...
functional independence. Occupational therapists assessed ADL and IADL at admission and discharge from geriatric rehabilitation by observation and information obtained from the patient and/or their carer(s). ADL and IADL at two weeks before hospitalisation was assessed by occupational therapists using information obtained from the patient and/or carer(s). ADL and IADL scores three months post-discharge were assessed by a trained researcher via a telephone interview with the patient and/or carer.

2.5. Statistical analysis

Continuous data were presented as mean and standard deviation (SD) if normally distributed and median and interquartile range (IQR) if skewed. Categorical variables were presented as frequencies and percentages (%).

Latent class growth modelling (LCGM) using R software (R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria) was applied to identify distinct trajectories of ADL and IADL separately from two weeks preadmission to three months post-discharge. Patients who were deceased within the follow-up period were excluded. Starting with a model with one trajectory, k number of distinct latent trajectories was applied using a forward approach and one trajectory at a time was added subsequently, with the shape of the trajectories modelled by adding linear and quadratic terms. The fitness of the models was then assessed after each step by several criteria (Muthen and Muthen, 2000): Bayesian Information Criterion with a decrease of ten points or more recommended as an improvement in the model fit (Raftery, 1995); average posterior probabilities of trajectory membership, with higher than 0.80 as a recommendation (Nagin, 2005) and clinical interpretation and size of the obtained trajectories. Patients were then allocated to their best-fitting trajectory based on the highest posterior probability.

Data for the MST, GLIM and ESPEN criteria were missing at random (Little’s test p > 0.05) and therefore imputed using the multiple imputation method pooling five imputation datasets (Rubin, 1987; Little, 1988). Multinomial logistic regression analyses were used to determine the association between MST, GLIM and ESPEN criteria and the ADL and IADL trajectories. Two models were used: a crude model and a model adjusted for age, Charlson Comorbidity Index score, median (IQR) and cognitive impairment. The results were presented as odds ratios (OR) and 95% confidence intervals (CI). The analysis was performed by Statistical Package for the Social Sciences (SPSS) (IBM SPSS Advanced Statistics 25.0, Armonk, NY, IBM Corp). A p-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Patient characteristics

Table 1 shows the patient characteristics at admission. Seventy-five patients (10.3%) died during hospitalization or within three months post-discharge, leaving 618 patients with a mean age of 82.1 (SD 7.8) years and 355 (57.4%) females included in the analyses. Cognitive impairment was present in 396 (64.1%) patients. The most frequent primary reason for hospital admission was musculoskeletal (n = 301, 48.7%). The median acute and geriatric rehabilitation LOS were 7 [4–11] and 20 [13–29] days respectively.

3.2. Malnutrition

The number of missing data (at random) for the MST and GLIM and ESPEN criteria were 10 (1.6%), 109 (17.6%) and 146 (23.6%) respectively and data was therefore imputed for these patients. The risk of malnutrition was prevalent in 255 (41.3%) and malnutrition according to GLIM and ESPEN criteria was prevalent in 331 (53.5%) and 81 (13.1%) patients, respectively.

Table 1: Characteristics of geriatric rehabilitation inpatients at admission.

| Characteristic | N    | Total |
|---------------|------|-------|
| Age, years, mean (SD) | 618  | 82.1 (7.8) |
| Female, n (%) | 618  | 355 (57.4) |
| Living alone, n (%) | 612  | 250 (40.5) |
| Body mass index, kg/m², mean (SD) | 618  | 27.4 (6.7) |
| Charlson Comorbidity Index, score, median (IQR) | 618  | 2 [1–4] |
| Cognitive impairment, n (%) | 618  | 396 (64.1) |
| Acute hospitalization LOS, days, median (IQR) | 618  | 7 [4–11] |
| Geriatric rehabilitation LOS, days, median (IQR) | 618  | 20 [13–29] |

Primary reason for hospital admission

| Malnutrition | MST risk of malnutrition, n (%) | 618  | 255 (41.3) |
| GLIM criteria for malnutrition, n (%) | 618  | 331 (53.5) |
| ESPEN criteria of malnutrition, n (%) | 618  | 81 (13.1) |

SD: standard deviation; IQR: interquartile range; LOS: Length of stay; MST: Malnutrition Screening Tool; GLIM: Global Leadership Initiative on Malnutrition; ESPEN: European Society for Clinical Nutrition and Metabolism.

* Include gastroenterology, urology, hematology, ophthalmology, vascular, psychiatry related conditions, cancer and metabolic disorders.

3.3. ADL and IADL trajectories

Three distinct trajectories were identified for both ADL and IADL from two weeks preadmission to three months post-discharge (Table 2); patients with low pre-admission ADL/IADL scores that showed no improvement (‘remained poor’, ADL: n = 41 (6.6%), IADL: n = 260 (42.0%)), patients with high pre-admission ADL/IADL scores that showed no recovery (‘deteriorated’, ADL: n = 204 (33.0%), IADL: n = 142 (23.0%)) and patients with high pre-admission ADL/IADL scores and showed good recovery (‘recovered’, ADL: n = 373 (60.4%), IADL: n = 216 (35.0%)).

Patient characteristics at admission and ADL and IADL scores at different time points stratified by ADL and IADL trajectories are given in Supplementary Table 1. Patients in the ‘remained poor’ ADL and IADL trajectories were older, had more comorbidities, were more often cognitively impaired and were fatter than the patients in the ‘deteriorated’ or ‘recovered’ ADL and IADL trajectories.

Fig. 1 shows the prevalence of (the risk of) malnutrition at admission and the ADL and IADL trajectories from two weeks preadmission to three months post-discharge. The percentage of patients at risk of malnutrition and malnourished according to the GLIM and ESPEN criteria was the highest within the ‘remained poor’ ADL trajectory group (48.8%, 75.6% and 19.5% respectively). The prevalence of severe malnutrition was higher than moderate malnutrition in the ‘remained poor’ ADL trajectory group (41.5% vs 34.1%) whereas the prevalence of moderate malnutrition was higher than severe malnutrition in other ADL and IADL trajectories.

Table 3 shows the association between (the risk of) malnutrition at admission and the ADL and IADL trajectories from two weeks preadmission to three months post-discharge. The reference group was defined as patients with a ‘recovered’ trajectory for ADL and IADL. Malnutrition by the GLIM criteria was associated with ‘remained poor’ (OR: 3.33, 95% CI: 2.04–5.39).

Table 2: Activities of daily living (ADL) and instrumental ADL (IADL) trajectories from two weeks pre-admission to three months post-discharge in geriatric rehabilitation patients (n = 618).

| Trajectory   | ADL, n (%) | IADL, n (%) |
|--------------|------------|-------------|
| Remained poor | 41 (6.6)   | 260 (42.0)  |
| Deteriorated  | 204 (33.0) | 142 (23.0)  |
| Recovered     | 373 (60.4) | 216 (35.0)  |
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1.21–9.19) and ‘deteriorated’ (OR: 1.68, 95 % CI: 1.13–2.52) ADL trajectories compared to the ‘recovered’ ADL trajectory in both the crude and adjusted models. Malnutrition by the GLIM criteria was not associated with IADL trajectories. Malnutrition by the ESPEN criteria and the risk of malnutrition by the MST was not associated with ADL trajectories and IADL trajectories.

### Table 3
Association between (the risk of) malnutrition at admission and activities of daily living and instrumental activities of daily living trajectories from two weeks pre-admission to three months post-discharge in geriatric rehabilitation patients.

| Risk of malnutrition/ malnutrition | ADL trajectories |                      | IADL trajectories |                      |
|------------------------------------|-----------------|---------------------|-------------------|---------------------|
|                                    | Recovered n = 373 | Deteriorated n = 204 | Remained poor n = 41 | Recovered n = 216 | Deteriorated n = 142 | Remained poor n = 260 | p |
|------------------------------------|-----------------|---------------------|-------------------|-------------------|
| MST Crude OR (95 % CI)             | 1               | 1.23 (0.87–1.74)    | 0.24               | 1                 | 1.01 (0.65–1.58)     | 0.94 (0.92–1.97)       | 12 |
| Adj OR (95 % CI)                   | 1               | 1.69 (1.16–2.48)    | 0.007              | 1                 | 1.18 (0.75–1.88)     | 0.47 (0.89–1.92)        | 17 |
| GLIM Crude OR (95 % CI)            | 1               | 1.27 (0.66–2.46)    | 0.46               | 1                 | 1.69 (0.86–3.34)     | 0.13 (0.56–2.11)        | 80 |
| Adj OR (95 % CI)                   | 1               | 1.68 (0.63–2.49)    | 0.51               | 1                 | 1.72 (0.86–3.46)     | 0.13 (0.52–2.11)        | 90 |
| ESPEN Crude OR (95 % CI)           | 1               | 1.25 (0.69–4.44)    | 0.76               | 1                 | 1.25 (0.65–4.36)     | 0.28 (0.56–2.11)        | 80 |
| Adj OR (95 % CI)                   | 1               | 1.68 (0.69–4.44)    | 0.28               | 1                 | 1.72 (0.86–3.46)     | 0.28 (0.56–2.11)        | 90 |

ADL: Activities of Daily Living; IADL: Instrumental ADL; MST: Malnutrition Screening Tool; GLIM: Global Leadership Initiative on Malnutrition; ESPEN: European Society for Clinical Nutrition and Metabolism.

Adj OR: Adjusted Odds Ratio - adjusted for age, Charlson Comorbidity Index score and cognitive impairment. Bold p-values indicate statistical significance (p < 0.05).

### Discussion

Malnutrition by GLIM criteria at admission was associated with poor ADL trajectories from two weeks pre-admission to three months post-discharge in geriatric rehabilitation inpatients, but not with IADL trajectories. The risk of malnutrition and malnutrition according to ESPEN criteria was not associated with ADL and IADL trajectories.

The association of (the risk of) malnutrition with poor ADL function has been described at admission, (Neumann et al., 2005) discharge...
ADL are basic, predominantly physically demanding, daily tasks whereas IADL are complex activities such as handling finances, administering medications, shopping, preparing meals, housekeeping and managing transportation, that demand cognitive function (Fong and Gleason, 2015). Malnutrition leads to decreased muscle mass and body cell mass resulting in diminished physical function (Cederholm et al., 2017). Therefore, malnutrition might influence the physically demanding ADL tasks more directly compared to the cognitively demanding IADL tasks. Furthermore, IADL function prior to the patients’ hospitalisation was considerably lower, making a recovery of IADL during rehabilitation and post-discharge unlikely and therewith the influence of malnutrition less likely.

Low muscle mass is associated with ADL dependency in hospitalized geriatric patients (Meskers et al., 2019). In older patients with hospital-associated deconditioning, chronic disease-related malnutrition was associated with lower ADL at discharge (Wakabayashi and Sashika, 2014). Unintentional weight loss is also associated with poor ADL at discharge (Wakabayashi and Sashika, 2014; Villafane et al., 2016) and its change from admission to discharge (Goto et al., 2016; Nishioka et al., 2016, 2018) in geriatric rehabilitation patients. The association between malnutrition and functional trajectories from pre-admission to post-discharge has only been reported in geriatric hip fracture patients (Goisser et al., 2015; Li et al., 2013). Malnutrition diagnosed by the Mini Nutrition Assessment (MNA) at discharge was associated with worse ADL and IADL trajectories from discharge up to twelve months post-discharge (Li et al., 2013). This finding is consistent with the results of the present study, even though that cohort was younger (mean age 78.1 years), more independent in ADL and IADL before hip fracture compared to the RESORT cohort and excluded patients with severe cognitive impairment and morbidity. In another cohort of 97 geriatric hip fracture patients demographically and clinically more comparable to the RESORT cohort, no association was found between pre-fracture nutritional status assessed by MNA and the trajectories of ADL from pre-fracture to six months post-discharge (Goisser et al., 2015).

The malnutrition prevalence in the present study is consistent with previous findings in geriatric patients (Charlton et al., 2012; Bell et al., 2013; Rojer et al., 2016). The higher prevalence of severe malnutrition in the ‘remained poor’ ADL trajectory group compared to the other groups can be explained by the characteristics of the patients at admission, with a higher frailty score and highest prevalence of cognitive impairment. The disparity observed in the prevalence of the risk of malnutrition identified by the MST and malnutrition diagnosed by the GLIM and ESPEN criteria has been previously reported (Clark et al., 2020).

5. Strengths & limitations

This is the first study to report on the association between malnutrition and functional trajectories from pre-admission to post-discharge in a large cohort of geriatric rehabilitation inpatients using validated methods appropriate for older patients. Moreover, the RESORT cohort is representative of geriatric rehabilitation inpatients as no exclusion criteria were applied for the level of cognition, morbidity or physical function of patients.

The number of patients in the ‘remained poor’ ADL trajectory was low leading to possible power problems to estimate the effect size. The accuracy of the self-reported information on poor appetite and weight loss history in MST may be limited by the cognitive impairment and recall bias in this cohort. The self-reported information on ADL and IADL performance three months post-discharge from geriatric rehabilitation might under or over estimated. The accuracy of the body composition measurement by BIA may be influenced by the hydration status of the patients. The observational study design limits the ability to establish a causal relationship between malnutrition and poor ADL trajectories.

6. Conclusions

Malnutrition diagnosed by the GLIM criteria at admission was associated with poor ADL trajectories from two weeks preadmission to three months post-discharge in geriatric rehabilitation inpatients but not with IADL trajectories. The results favour the use of the GLIM criteria as a diagnostic tool for malnutrition, compared with the ESPEN criteria in geriatric rehabilitation inpatients to help predict ADL trajectories. Future studies should focus on the effect of nutrition intervention on functional recovery in malnourished geriatric rehabilitation patients. It is also important to explore the impact of nutritional therapy and occupational therapy during and post-discharge on malnutrition and ADL and IADL function of geriatric rehabilitation inpatients.

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Declaration of Competing Interest

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.mad.2021.111500.

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