**Determinants of incident malnutrition in community-dwelling older adults: a MaNuEL multi-cohort meta-analysis**

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**Abstract**

**Objective:**  to identify determinants of incident malnutrition in community-dwelling older adults.

**Design:** Meta-analysis of six community-based longitudinal datasets with follow-up durations between 1 and 3 years.

**Setting:** Datasets from MaNuEL (MalNutrition in the Elderly) partners were included: 3 studies from Germany, one from Ireland, The Netherlands and New Zealand, respectively.

**Participants:** 4844 community-dwelling adults aged ≥ 65 years

**Measurement:** The same definition of incident malnutrition was applied for all cohorts: BMI < 20 kg/m² at follow-up or weight loss ≥ 10 % between baseline and follow-up. 21 potential baseline determinants from 7 domains (demographic, nutritional, lifestyle, social, psychological, physical functioning, medical) and 2 follow-up variables (hospitalization, falls) were harmonized for all studies. Binary logistic regression analyses were performed to assess the association of each variable, adjusted for specific confounders, with incident malnutrition. Combined odds ratios (OR, with [95% confidence interval]) were calculated by random effects meta-analyses.

**Results:** Studies included between 209 and 1841 participants without malnutrition at baseline; mean age was between 71.7 and 84.6 years. Incidence of malnutrition varied between 5.1 and 17.2 %. Meta-analyses identified six variables as independent determinants of incident malnutrition: with increasing age, the risk of developing malnutrition increased continuously. Unmarried, separated or divorced participants were more likely to develop malnutrition compared to married participants, whereas no association was found for widowed participants. Participants with difficulties walking (OR 1.41 [1.06-1.89]), difficulties climbing stairs (OR 1.45 [1.14-1.85]) and who were hospitalized before baseline (OR 1.49 [1.25-1.76]) and during follow-up (OR 2.02 [1.41-2.88]) had higher odds of incident malnutrition.

**Conclusion:** In this harmonized meta-analysis based on prospective data of older, community-dwelling adults, age, marital status, limitations of walking or climbing stairs, and hospitalization were identified as determinants of incident malnutrition.

**Key words:** community-dwelling; older; malnutrition; determinants; longitudinal study; meta-analysis

**Short title**

Determinants of incident malnutrition

**Introduction**

Older people are vulnerable to developing malnutrition, due to an age- and/or disease-related inadequate intake of energy and protein (1). Further, disease-related malabsorption is a major contributor to malnutrition (2). The origin of malnutrition is multifactorial as many factors, e.g. physiological decrease in appetite, chewing and swallowing problems, physical and cognitive impairment, depression, and polypharmacy may reduce dietary intake (3,4). Unintended weight loss is thereby an important indicator of malnutrition as it represents a situation where energy requirements are not met (5). The outcome of untreated malnutrition is poor and associated with increased risk of functional impairment, immune dysfunction, poor wound healing, longer hospital stays and higher readmission rates, lower quality of life, higher health care costs, and ultimately with an increased mortality (6,7).

Presently, knowledge on risk factors of malnutrition is mainly based on cross-sectional studies in which reverse causation is always an issue. Knowledge from longitudinal studies is, however, scarce. Previous longitudinal studies in community-dwelling older adults identified poor appetite (8,9), poor self-reported health (10), high age (10), loss of interest in life (8), poor physical function (11), polypharmacy (12), dependence in activities of daily living (13), difficulties walking stairs (9), oral health problems (13), and hospitalization (14) as predictors of malnutrition. The incidence of malnutrition varied between 8.3 and 13.9 % with follow-up durations between 1 and 9 years (8–10). These previous studies used different definitions of malnutrition and considered varying sets of potential determinants and statistical analyses approaches, which makes comparison of results difficult. Due to the poor outcome of malnutrition, it is, however, crucial to identify high risk groups, with a special focus on modifiable risk factors of malnutrition.

This meta-analysis is part of the Joint Action ‘Malnutrition in the Elderly Knowledge Hub’ (MaNuEL) of the European Joint Programming Initiative ‘A Healthy Diet for a Healthy Life’ (JPI-HDHL) (15), with the aim to identify determinants of incident malnutrition in community-dwelling older adults. We individually analyzed longitudinal studies from MaNuEL partners and used a uniform definition of incident malnutrition and a standardized set of potential determinants, covering demographic, social, medical, nutritional, lifestyle, psychological, and physical functioning domains.

**Methods**

Within the MaNuEL consortium, studies with high similarity of collected variables and assessment methods, and where a uniform definition of malnutrition could be applied, were selected for this analysis. In total, six studies were identified: ErnSiPP (Nutritional situation of community-dwelling older adults in need of basic care, Germany (16)), ActiFe (Activity and Function in the Elderly, Germany (17)), KORA-Age (Cooperative Health Research in the Region of Augsburg, Germany (18,19)), LASA (The Longitudinal Aging Study Amsterdam, the Netherlands (20)), TILDA (The Irish Longitudinal Study on Ageing Health Assessment, Ireland (21,22)) and LiLACS NZ (Life and Living in Advanced Age, a Cohort Study, New Zealand (23)). A short description of each study with the respective in- and exclusion criteria is presented in the online **Supplemental Text S1**.

Date of baseline data collection for the present analysis was 2010 for ErnSiPP and LiLACS NZ, 2009 for KORA-Age, 1995/96 for LASA, 2009-2011 for TILDA, and 2009/10 for ActiFe. Ethical approval was granted for all studies by the respective Ethics Committees.

*2.2 Participants*

Community-dwelling adults aged 65 years or older, with information on nutritional status at baseline and follow-up were included. Participants with missing values on body mass index (BMI), previous unintended weight loss (WL) and weight at follow-up were excluded as well as participants lost or deceased during follow-up and participants with malnutrition at baseline (**Table 1**). Malnutrition at baseline was defined as either BMI < 20 kg/m² or previous WL according to the pre-defined criteria of each dataset: WL > 3 kg in the last 3 months for ErnSiPP and ActiFe (Mini Nutritional Assessment (MNA) (24)), WL in the past 6 months ≥ 4 kg for LASA and > 5 kg for LiLACS NZ and KORA-Age, and WL ≥ 4.5 kg in the past 12 months for TILDA. Weight and height were measured at baseline in each study to calculate BMI.

For LiLACS NZ, Māori participants were analyzed separately from the main analyses to generate a Caucasian sample similar to the other cohorts. The analysis on determinants of incident malnutrition of the Māori participants is presented in **Supplemental Tables S4a-c**.

*2.3 Definition of incident malnutrition at follow-up*

Incident malnutrition was defined as either having a low BMI (< 20 kg/m²) or WL ≥ 10 % between baseline and follow-up. Body weight was measured at follow-up in LASA, ActiFe, LiLACS NZ, and KORA-Age. In TILDA and ErnSiPP, weight was self-reported. In LASA, ErnSiPP, TILDA and ActiFe, BMI was calculated from height at baseline and weight at follow-up, whereas KORA-Age and LiLACS NZ used measured height and weight at follow-up. The follow-up period was one year for ErnSiPP, two years for TILDA and three years for KORA-Age, LASA, LiLACS NZ and ActiFe.

*2.4 Potential determinants of incident malnutrition*

Information on 21 variables at baseline and two follow-up variables were available in all datasets. The selection of these variables and their classification to a specific domain was based on the results of the systematic literature review by van der Pols-Vijlbrief and colleagues (4). During telephone conferences with all involved researchers, an agreed approach on how to harmonize the variables (continuous or categorical, number of categories, specific cut-off points, etc.) was developed.

**Demographic factors (4 variables)** included age (continuous variable) and sex (male, female). In the TILDA dataset, age was top-coded at 80 for anonymization purposes to ensure older adults could not be identified from the dataset. Marital status was categorized into married, unmarried/separated/divorced and widowed, and education level was categorized into none/primary, secondary and tertiary.

**Social factors (2 variables).** Living alone was dichotomized into yes/no, whereby ‘no’ included living with spouse, partner, children, or others. Receiving social support was ascertained by three different domains: support/help with shopping, cooking or cleaning/household chores. If support was given in one or more of these three domains, social support was categorized as ‘yes’.

**Lifestyle factors (3 variables).** To describe physical activity three categories were created. In ErnSiPP, the variable was assessed by the question ‘how active is the participant’. Very active (PAL ≥1.6) was categorized as high, active/sometimes active (PAL 1.3-1.4) as moderate and (mostly) inactive (PAL 1.2) as low. LiLACS NZ and KORA-Age assessed physical activity over the past week and ActiFe and LASA over the past two weeks. Study specific tertiles were calculated and used to categorize physical activity. LiLACS NZ used the physical activity scale for the elderly (PASE; score: 0 to 793 points (25)) and study specific tertiles of ≤ 61 indicating low, 62-124 moderate, and ≥ 125 points high activity. KORA also used PASE, with study-specific tertiles: < 96 points indicated low, 96-< 141 moderate, and >= 141 high physical activity. LASA used the LASA Physical Activity Questionnaire (LAPAQ) (26) and categorized < 108 min/day of activities as low, 108-190 min/day as moderate and ≥ 191 min/day as high activity. ActiFe also used the LAPAQ, with study-specific tertiles of < 25 min/day as low, 25-96 min/day as moderate and > 96 min as high. TILDA used the International Physical Activity Questionnaire (IPAQ) (27) and categorized high activity as at least 3 days of vigorous activity or seven days on all activities; moderate activity as 3 or more days of vigorous activity or 30 minutes or more of walking and moderate activity for at least 5 days or spending 5 or more days on any activity; and low activity when none of the other criteria were met (www.ipaq.ki.se, 2005). Current alcohol intake was dichotomized into no/yes, with never alcohol consumers categorized as ‘no’. Smoking was dichotomized into yes and no with never and past smokers categorized as ‘no’.

**Medical factors (6 variables).** The number of chronic diseases were categorized into no/one chronic disease and ≥ 2 chronic diseases. The number of daily-prescribed medications was dichotomized into ‘< 5’ and ‘≥ 5’ to define polypharmacy. Hospitalization during ‘the last year’ or ‘the last 6 months’ (LASA only) before baseline was dichotomized into yes/no. The same variable was assessed at follow-up and dichotomized (not assessed in ActiFe). Pain was assessed by the questions ‘how often were you in pain last week’ (ErnSiPP), ‘are you in pain when standing, changing position, sitting, walking, constantly’ (LASA), ‘are you often troubled with pain’ (TILDA), ‘are you presently in pain’ (ActiFe), ‘pain scale from 0-9, whereas 0 was no pain and 1-9 present pain’ (numerical rating scale, LiLACS NZ), ‘how much pain or discomfort do you have’ (EQ-5D questionnaire, KORA-Age). All categorizes indicating pain were dichotomized into yes. Self-rated health was ascertained in all cohorts by the question ‘how would you describe your health/present physical constitution’, with the categories good, fair, and poor. The variable was dichotomized into good and fair/poor self-rated health.

**Psychological factors (2 variables).** Cognitive impairment was measured with the Mini-Mental State Examination (MMSE; score: 0 - 30) (28)in ErnSiPP, ActiFe, LASA and TILDA. LiLACS NZ used the Modified MMSE (score: 0-100) (29). KORA-Age used the modified Telephone Interview for Cognitive Status (TICS-m; score: 0 - 50) (30). Results were dichotomized into no/yes, a score ≤ 23 (MMSE) or ≤ 31 (TICS-m) indicating cognitive impairment. Depression was measured with the Geriatric Depression Scale (GDS; score: 0-15) (31) in ErnSiPP, KORA-Age and LiLACS NZ; the Center for Epidemiologic Studies Depression Scale (CES-D; score: 0-60) (32) in LASA and TILDA; the Hospital Anxiety and Depression Scale (HADS; score: 0-21) (33) in ActiFe. The scales were dichotomized into no/yes, i.e. GDS ≥ 6 (31), CES-D ≥16 (34) and HADS ≥ 8 (only the questions related to depression were used) indicated depressive symptoms.

**Physical functioning factors (5 variables).** Difficulties walking was assessed by the questions ‘do you have difficulties doing a 5 minute walk’ (LASA, ActiFe); walking 100 meters’ (TILDA) and ‘are you able to take a walk on even terrain’ (HAQ-DI questionnaire (35), KORA-Age). The answers were categorized into ‘no difficulties’ and ‘difficulties’ (able to walk with difficulties, needs help, cannot walk). ErnSiPP used the question from the Barthel-Index (36): ‘is the patient immobile, in a wheelchair, walks with help, or independent’ with the first three answers being categorized as ‘difficulties’. LiLACS NZ measured normal gait speed at 3 meters and gait speed ≤ 0.8 m/sec was interpreted as having difficulties walking (37). Difficulties climbing stairs was assessed by the questions ‘do you have difficulties climbing one flight of stairs without resting (TILDA); 5 stairs’ (HAQ-DI questionnaire (35), KORA-Age) and ‘do you have difficulties walking up and down a staircase of 15 steps’ (LASA, ActiFe). ErnSiPP used the question from the Barthel-Index: ‘patient is unable to climb stairs, needs help, is independent’ (36), and LiLACS NZ: ‘does your health limit you in climbing several flight of stairs’. All answers indicating that climbing stairs was difficult, not possible or that help was needed were categorized as ‘difficulties’. Falls in the past year before baseline was dichotomized into yes/no. The same question was assessed at follow-up, except for TILDA, which assessed falls in the last two years. The answer was dichotomized into yes/no. Handgrip strength was measured with the hand dynamometer (38) in kg in all studies but ErnSiPP, which used the Martin Vigorimeter (in kPa) (39). The participant’s highest value was used and the variable was dichotomized into low (< 30 kg or < 66 kPa for men and < 20 kg or <38 kPa for women) and normal handgrip (38,40).

**Nutritional factor (1 variable).** Appetite was categorized into good or fair/poor, obtained by the questions ‘how would you describe your appetite’ (ErnSiPP, KORA-Age, LiLACS NZ), ‘did your appetite decline in the past 3 months (from the Mini Nutritional Assessment (24))’ whereby no decline was considered ‘good’, small decline ‘fair’ and severe decline ‘poor’ (ActiFe), and ‘I did not feel like eating; my appetite was poor in the past week’ (from the CES-D), whereby less than 1 day was categorized into good, 1-2 days into fair, and 3-4 and 5-7 days into poor (LASA, TILDA).

*2.6 Statistical analysis*

The variables of each dataset were harmonized and analyzed locally by the respective dataset holder according to a standardized study protocol and statistical analysis plan. Statistical analyses were performed with SPSS Version 24 (IBM Corp., Armonk, NY, USA) in all datasets but ActiFe and KORA-Age, who used SAS software Version 9.4 (SAS Institute Inc., Cary, NC, USA). For the analyses, missing values of potential determinants were imputed using the interactive Markov chain Monte Carlo method and 20 imputation models were created.

Participant characteristics are described by absolute numbers and proportions (categorical variables), and by mean and standard deviation (SD) for age and BMI at baseline and follow-up. For each subcategory of the categorical variables, the proportion of incident malnutrition is presented **(Supplemental Table S1)**.Differences in mean BMI between baseline and follow-up were tested with Wilcoxon Signed Rank Test for paired samples.

For each independent variable, univariate logistic regression analyses were performed to identify risk factors of incident malnutrition (yes or no) **(in Supplemental Table S2 only)**. Then, each variable was adjusted for age, sex and education and for its own fixed set of specific confounders. The selection of confounders was based on literature and a Delphi method was employed with all researchers (n=12) of the working group to finalize the list of confounders. Variables were considered as confounders for a specific determinant when at least 75 % of all researchers agreed **(see Supplemental Table S3 for the list of confounders)**. The variables age and sex were not adjusted for confounders. Correlations between all variables were tested to check for multicollinearity between independent variables. Stronger correlations were found between marital status and living alone (Phi coefficient 0.72 – 0.90) and difficulties walking and difficulties climbing stairs (Phi coefficient 0.26 – 0.61) and thus only ‘living alone’ and ‘difficulties walking’ were considered as confounders in the relevant models. As none of the participants without social support (ErnSiPP), none with difficulties climbing stairs (ActiFe) and none with no/one chronic disease (LiLACS NZ) developed malnutrition at follow-up, these variables were not adjusted and were not used as potential confounder in the respective studies. As the TICS-m score (used for assessment of cognitive impairment) was already adjusted for education, education was not used as confounder in the KORA-Age study to adjust the association of cognitive impairment and incident malnutrition.

Odds ratios of the individually adjusted regression analyses were combined in random-effects meta-analyses in R (41) using meta-package ‘metagen’; *p*< 0.05 was considered to be statistically significant. The weight for each cohort was calculated based on the number of included participants of the cohort and the number of events. Heterogeneity between cohorts was explored using I² test and τ (Tau)², with I² ≥ 75 % (42) showing considerable heterogeneity between cohorts. The results of the meta-analysis were visualized using forest plots that illustrate the results of the individual studies and the summary effect.

**Results**

Data from 216 (ErnSiPP), 209 (LiLACS NZ), 1009 (LASA), 791 (ActiFe), 1841 (TILDA), and 778 (KORA-Age) community-dwelling adults aged 65 years or older were included in the analyses. The selection process of participants is described in **Table 1**. In **Figure 1**, the prevalence of the 21 potential baseline determinants and 2 follow-up variables is presented (for more details see **Supplemental Table S1**). At least half of participants were female in all studies, mean age varied between 71.7 (SD 5.0) years in TILDA and 84.6 (SD 0.5) years in LiLACS NZ, and mean BMI at baseline between 27.1 (SD 3.6) kg/m² in LiLACS NZ and 29.4 (SD 6.3) kg/m² in ErnSiPP. In all studies, mean BMI was statistically significantly lower at follow-up compared to baseline (data not shown).

As displayed in **Figure 2**, the 3-year incidence of malnutrition was 4.6 % in KORA-Age, 5.1 % in LASA, 5.9 % in ActiFe and 17.2 % in LiLACS NZ, the 2-year incidence was 10.7 % in TILDA and the 1-year incidence was 8.8 % in ErnSiPP. Being malnourished at follow-up was mostly due to weight loss ≥ 10 % alone, whereas a BMI < 20 kg/m² alone or the combination of low BMI and weight loss were less common.

Six variables were identified in the meta-analysis as determinants of incident malnutrition **(Figure 3)**. With increasing age, the risk of developing malnutrition increased continuously. Unmarried, separated or divorced participants were more likely to develop malnutrition compared to married participants, whereas no association was found for widowed compared to married participants. Participants with difficulties walking (OR [95% CI] 1.41 [1.06-1.89]) and difficulties climbing stairs (1.45 [1.14-1.85]) had higher odds of being malnourished at follow-up. A higher chance of incident malnutrition was also found for participants who were in hospital before baseline and those who were hospitalized during follow-up (2.02 [1.41-2.88]). Heterogeneity between studies was low for all these determinants except for hospitalization during follow-up, with a moderate heterogeneity (I²) of 49 %.

Variables from the social, lifestyle, psychological, nutrition, and medical (except for hospitalization) domain were not associated with incident malnutrition in the meta-analysis. Heterogeneity of the random effects meta-analysis of these variables was low or moderate, except for chronic diseases with a high heterogeneity **(Table 2)**.

Eight variables (appetite, smoking, living alone, social support, polypharmacy, difficulties walking, difficulties climbing stairs, falls before baseline) were consistently not significantly associated with malnutrition in all studies, whereas results of the other 15 variables were rather more inconsistent between studies. For difficulties walking and difficulties climbing stairs, the combined effect sizes reached significance. Individual study results and combined odds ratios of determinants not significantly associated with incident malnutrition after adjustment for confounders are presented in **Supplemental Figures S1-20**.

The following describes findings specific for older Māori, indigenous Polynesian people in New Zealand (n=99). Being widowed and having a low physical activity at baseline were associated with higher odds of incident malnutrition in univariate analyses. These associations, however, were attenuated after adjustment for confounders **(Supplemental Table S4b & c)**.

**Discussion**

To our knowledge, this is the first multi-cohort, harmonized meta-analysis to identify determinants of incident malnutrition in community-dwelling adults aged 65 years or older. Besides age and marital status, having difficulties walking and climbing stairs, prior hospitalization and hospitalization during follow-up were identified as determinants of incident malnutrition, indicating that these variables should be addressed in the screening to identify older adults at high risk of developing malnutrition. Identification of these variables may also indicate potential targets for preventive interventions, e.g. improving the care of unmarried older people or improving functional capabilities by specific exercise or physical therapies.

In the current study, the same definition of malnutrition was applied to all cohorts; this harmonization is important to eliminate the impact of differences in the definitions on the incidence rate. The incidence of malnutrition in the included studies varied between 4.6 and 17.2 %. This variation might have occurred due to differences in the study populations and follow-up durations. In the ErnSiPP study, for example, participants were community dwelling but all received homecare. These participants might have had a higher risk of developing malnutrition compared to participants in the other studies. Further, participants in the ErnSiPP and LiLACS NZ study had a higher mean age (80.4 and 84.6 years, respectively) compared to participants from the other studies (ranged between 74.1 and 75.1 years), which might partly explain the higher incidence of malnutrition in these two cohorts. In TILDA, mean age was lowest (71.7 years), but the incidence of malnutrition was surprisingly high compared to the other population-based studies LASA, ActiFe and KORA-Age. Reasons for the much higher proportion of participants with weight loss > 10 % in TILDA are unclear. As age was top-coded at 80 in the TILDA cohort and 12.2 % of the participants were >= 80 years, it is however unknown to what extent mean age was underestimated.

The results of our meta-analyses are in line with results of previous longitudinal studies that identified difficulties climbing stairs (9), higher age (10,43) and hospitalization (14) as determinants of malnutrition. This is also consistent with the result of a ‘moderate to strong evidence’ for an association of hospitalization with malnutrition in the systematic review by van der Pols-Vijlbrief et al. (2014) which considered a combination of cross-sectional and longitudinal studies (4). This association might be explained by illness or acute stress with increased energy demands but also by poor absorption and/or low intake due to pain, nausea, poor appetite, and low quality of hospital food (4). As hospitalization before and during follow-up were both associated with higher odds of malnutrition, our results show that hospitalization may represent a short and long-term risk factor for the development of malnutrition.

Poor appetite and poor self-reported health were not associated with incident malnutrition in our study. These results are unexpected as the systematic review by van der Pols-Vijlbrief et al. found ‘strong evidence’ for an association between poor appetite and malnutrition and ‘moderate to strong evidence’ for poor self-reported health (4). The conclusion on the latter variable is however only based on cross-sectional studies and thus, the long-term effect of poor self-rated health on the development of malnutrition might be rather small.

Living alone, education, smoking, alcohol consumption, multimorbidity, and depressive symptoms did not predict incident malnutrition, which is consistent with the findings of the systematic review by van der Pols-Vijlbrief and colleagues (4). For living alone, education and smoking, calculated associations were consistently not significant in all cohorts, whereas the results of the other determinants differed slightly: only in the ErnSiPP cohort that consisted of participants in home care, alcohol consumption remained significant after adjustment for confounders. A possible explanation could be that participants drinking alcohol were in better health than participants who did not (or not anymore) drink alcohol and thus had a lower chance of developing malnutrition. In LASA, multimorbidity remained a significant determinant of incident malnutrition after adjustment for confounders. In LASA and KORA-Age, having depressive symptoms was significantly associated with malnutrition but in an opposite direction.

For low physical activity, inconclusive evidence for an association with malnutrition was found by van der Pols-Vijlbrief et al. (4). In our meta-analysis, significant univariate associations were found in TILDA and KORA-Age, but these associations were attenuated after adjustment for confounders. Thus, one possible explanation for the inconclusive results of the systematic review could be that we adjusted for more confounders than the previous studies in the systematic review.

**Strengths and limitations**

Our analysis has several strengths. We had access to six longitudinal cohort studies conducted in older persons across Europe and beyond. We standardized our data analyses using a fixed protocol, a uniform definition of incident malnutrition and a large number of harmonized variables as potential determinants and covered a wide range of relevant domains. Furthermore, each variable was adjusted for the same set of confounders.

Our work, however, also has some limitations. Only datasets from MaNuEL partners with a uniform set of variables could be considered and thus, other additional determinants not available in these datasets, e.g. food intake, swallowing and chewing problems, might not have been identified. These additional variables could also not be considered as potential confounders. Variables were harmonized, but different methods and tools were originally used to assess the variables. Heterogeneity, however, was generally low and thus, we do not expect the results of the meta-analyses to be strongly influenced by the use of different tools. Further, a high variability was discovered in some study characteristics, e.g. the prevalence of social support ranged from 0.9% in ActiFe to 99.5% in ErnSiPP, as a result of different research focus in the original study and different in- and exclusion criteria (see online supplemental material for a short description of the included studies). It is however striking that despite these large study differences, the associations were quite similar. Due to the need to harmonize potential determinants, categories for most variables had to be reduced to a few, or to only two categories (e.g. alcohol consumption yes/no, depressive symptoms yes/no, cognitive impairment yes/no), which might have resulted in a loss of information as well as in loss of power.

**Conclusion**

In this harmonized meta-analysis based on data from six longitudinal studies, increased age, marital status, functional limitations, and hospitalization were identified as independent determinants of incident malnutrition in community-dwelling older adults. These factors seem to be relevant for malnutrition screening and prevention but need to be confirmed in future analyses . For hospitalization, the acute event with probably increased energy requirements, anorexia, eating difficulties, and poor intake may be the underlying reason for the development of malnutrition.

As harmonization of variables was needed due to the use of different methods and tools, more standardized data collection in future studies would increase the comparability of study results.

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**Statement of Authorship**

MS coordinated data analysis, performed meta-analyses and drafted the manuscript. MS, JZP, LB, GN, RT, CM performed individual data analyses. MS, JZP, LB, GN, RT, CM, MC, GT, EK, EG, MV and DV developed the standardized study protocol, statistical analysis plan and list of confounders. DV and MV are the co-coordinators of the MaNuEL project. All authors read the manuscript, contributed comments to its revision and approved the final version.

**Conflict of Interest Statement**

All authors declared no conflict of interest.

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**Legends**

**Figure 1:** Prevalence of potential determinants of incident malnutrition, separated by study

‡Third category ‘unmarried/divorced’ is not presented – all three categories add up to 100 %; #Third category ‘tertiary education’ is not presented – all three categories add up to 100 %; ^Third category ‘high physical activity’ is not presented – all three categories add up to 100 %; \*before baseline; FU= follow-up; PA= physical activity

**Figure 2:** Incidence of malnutrition of each cohort

Malnutrition was defined as either having BMI < 20 kg/m² or WL ≥ 10 % until follow-up.

BMI=body mass index; FU= follow-up; WL= weight loss

**Figures 3:** Forrest plots presenting odds ratios (OR) and corresponding 95% confidence intervals (CI) of random effects meta-analyses of determinants significantly associated with incident malnutrition after adjustment for indicated confounders:

A: Age, continuously

B: Unmarried vs. Married\*

C: Difficulties walking: yes vs. no\*\*

D: Difficulties climbing stairs: yes vs. no\*\*

E: Hospitalization before baseline: yes vs. no#

F: Hospitalization during follow-up: yes vs. no‡

Meta-analysis is based on six longitudinal cohort studies with 216 (ErnSiPP), 209 (LiLACS NZ), 1009 (LASA), 791 (ActiFe), 1841 (TILDA) and 778 (KORA-Age) participants.

\* adjusted for age, sex, education, depressive symptoms, alcohol consumption)

\*\*adjusted for age, sex, education, cognitive impairment, BMI, handgrip strength, physical activity, self-rated health, depressive symptoms, medication, chronic diseases, pain, falls before baseline

# adjusted for age, sex, education

‡ adjusted for age, sex, education, handgrip strength, difficulties walking, chronic diseases, self-rated health, medication, cognitive impairment, hospitalization before baseline, falls before baseline, pain

**Online Supplemental Material**

Supplemental Text S1: Short description of the respective studies

Supplemental Table S1: Baseline potential determinants and incidence of malnutrition (IMN)\* for all subcategories of all 6 cohorts

Supplemental Table S2: Odds ratios (OR) with 95 % confidence interval (CI) of the univariate associations of all potential determinants at baseline, and hospitalization and falls within follow-up with incident malnutrition\* in all 6 cohorts

Supplemental Table S3: List of confounders

Supplemental Table S4a: Overview on mean age and BMI of Māori participants

Supplemental Table S4b: Baseline variables and percentage of incident malnutrition (IMN) for all subcategories for the indigenous older adults in NZ

Supplemental Table S4c: Odds ratios (OR) with 95 % confidence interval (CI) of the multivariate associations of all potential determinants with incident malnutrition (3 years follow-up) for the indigenous older adults in NZ

Supplemental Figures S1- 20: Forrest plots present odds ratios (OR) and corresponding 95% confidence intervals (CI) of random effects meta-analyses of determinants not significantly associated with incident malnutrition after adjustment for confounders. Meta-analysis is based on six longitudinal studies with 216 (ErnSiPP), 209 (LiLACS NZ), 1009 (LASA), 791 (ActiFe), 1841 (TILDA) and 778 (KORA-Age) participants.