Determinants of Incident Malnutrition in Community-Dwelling Older Adults: A MaNuEL Multicohort Meta-Analysis

Melanie Streicher, MSc, Judith van Zwienen-Pot, MSc,† Laura Bardon, MSc,‡§ Gabriele Nagel, PhD,¶ Ruth Teh, PhD,‖ Christine Meisinger, PhD,**†† Miriam Colombo, MPH,** Gabriel Torbahn, MPH,* Eva Kiesswetter, PhD,* Marion Flechtner-Mors, PhD,‡‡ Michael Denkinger, PhD,§§ Dietrich Rothenbacher, PhD,¶ Barbara Thorand, PhD,** Karl-Heinz Ladwig, PhD,** Clare A. Corish, PhD,‡‖‖ Michelle Clarke, PhD,‡§ Ngaire Kerse, PhD,*** Marama Muru-Lanning, PhD,*§ Eileen R. Gibney, PhD,‡§ Eibhlís M. O'Connor, PhD,*¶ Marjolein Visser, PhD,¶¶ and Dorothee Volkert, PhD,* on behalf of the MaNuEL consortium*

OBJECTIVES: To identify determinants of incident malnutrition in community-dwelling older adults.

DESIGN: Meta-analysis of 6 community-based longitudinal datasets with follow-up of 1 to 3 years.

SETTING: Datasets from MaNuEL (MalNutrition in the Elderly) partners were included: 3 studies from Germany and 1 each from Ireland, the Netherlands, and New Zealand.

PARTICIPANTS: community-dwelling adults aged 65 and older (N=4,844).

MEASUREMENT: The same definition of incident malnutrition was used for all cohorts (body mass index < 20.0 kg/m^2 at follow-up or weight loss ≥10 % between baseline and follow-up). Twenty-one 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 between each variable, adjusted for specific confounders, and incident malnutrition. Combined odds ratios (ORs) with 95% confidence intervals (CIs) were calculated using random-effects meta-analyses.

RESULTS: Studies included between 209 and 1,841 participants without malnutrition at baseline; mean age ranged from 71.7 to 84.6. Incidence of malnutrition varied from 5.1% and 17.2%. Meta-analyses identified 6 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 than married participants, whereas no association was found for widowed participants. Participants with difficulty walking (OR=1.41, 95% CI=1.06–1.89) or difficulty climbing stairs (OR=1.45, 95% CI=1.14–1.85) and those who were hospitalized before baseline (OR=1.49, 95% CI=1.25–1.76) and during follow-up (OR=2.02, 95% CI=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 with walking and climbing stairs, and hospitalization were identified as

From the *Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Nuremberg, Germany; †Department of Internal Medicine, Nutrition and Dietetics, VU University Medical Center, Amsterdam, The Netherlands; ‡Institute of Food and Health, University College Dublin, Dublin, Republic of Ireland; §School of Agricultural and Food Science, University College Dublin, Dublin, Republic of Ireland; ¶Institute of Epidemiology and Medical Biometry, Ulm University, Germany; ‖Department of General Practice and Primary Health Care, School of Population Health, University of Auckland; **Institute of Epidemiology, Helmholtz Zentrum München, German Research Center for Environmental Health, Neuherberg, Germany; ††Department of Epidemiology, University Center for Health Sciences at the Klinikum Augsburg, Ludwig-Maximilians-Universität München, Augsburg, Germany; ‡‡Division of Sports and Rehabilitation Medicine, Medical Center, University of Ulm, Ulm, Germany; §§Agaplesion Bethesda Hospital, Ulm, Geriatric Research Unit, Ulm University and Geriatric Center Ulm/Alb-Donau, Ulm, Germany; ¶¶Department of Health Sciences, Faculty of Science, Amsterdam Public Health Institute, Vrije Universiteit, Amsterdam, The Netherlands; ‖‖School of Public Health, Physiotherapy and Sports Science, University College Dublin, Dublin, Republic of Ireland; ***School of Population Health, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand; *§James Henare Māori Research Centre, University of Auckland, Auckland, New Zealand; and the *¶Department of Biological Sciences, and Health Research Institute, University of Limerick, Limerick, Ireland.

Address correspondence to: Dorothee Volkert, Friedrich-Alexander-Universität Erlangen-Nürnberg, Institute for Biomedicine of Aging, Kobergerstraße 60, D-90408 Nürnberg, Germany. E-mail: dorothee.volkert@fau.de

[Correction added on October 5, 2018 after online publication: Figure 1 was updated.]

DOI: 10.1111/jgs.15553

0002-8614/18/$15.00

determinants of incident malnutrition. **J Am Geriatr Soc 66:2335–2343, 2018.**

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

Older people are vulnerable to developing malnutrition because of inadequate intake of energy and protein related to age and disease.[1] Further, disease-related malabsorption is a major contributor to malnutrition.[2] The origin of malnutrition is multifactorial, with many factors (e.g., physiological decrease in appetite, chewing and swallowing problems, physical and cognitive impairment, depression, polypharmacy) reducing dietary intake.[3,4] Unintended weight loss is thereby an important indicator of malnutrition, representing a situation in which energy requirements are not met.[5] The outcome of untreated malnutrition is poor and associated with functional impairment, immune dysfunction, poor wound healing, longer hospital stays, higher readmission rates, poorer quality of life, higher healthcare costs, and ultimately greater mortality.[6,7]

Knowledge of risk factors for malnutrition is mainly based on cross-sectional studies, in which reverse causation is always an issue; information from longitudinal studies is scarce. Previous longitudinal studies in community-dwelling older adults identified poor appetite,[8,9] poor self-reported health,[10] old age,[10] loss of interest in life,[8] poor physical function,[11] polypharmacy,[12] dependence in activities of daily living,[13] difficulty walking stairs,[9] oral health problems,[13] and hospitalization[14] as predictors of malnutrition. The incidence of malnutrition varied from 8.3% to 13.9% and follow-up duration from 1 to 9 years.[8–10] These previous studies used different definitions of malnutrition and statistical analytical approaches and considered varying sets of potential determinants, which makes comparison of results difficult. Because of poor outcomes with malnutrition, it is crucial to identify high-risk groups, with a special focus on modifiable risk factors for 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 of identifying 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 similar collected variables and assessment methods and providing the opportunity of applying a uniform definition of malnutrition were selected for this analysis. Six studies were identified: Nutritional Situation of Community-Dwelling Older Adults in Need of Basic Care (ErnSiPP, Germany),[16] Activity and Function in the Elderly (ActiFe, Germany),[17] Cooperative Health Research in the Region of Augsburg (KORA-Age, Germany),[18,19] Longitudinal Aging Study Amsterdam (LASA, the Netherlands),[20] The Irish Longitudinal Study on Ageing (TILDA) Health Assessment (Ireland),[21,22] and Life and Living in Advanced Age, a Cohort Study (LiLACS NZ, New Zealand).[23] A short description of each study with the respective inclusion and exclusion criteria is presented in the Supplementary Appendix S1.

Baseline data for the present analysis were from 2010 for ErnSiPP and LiLACS NZ, 2009 for KORA-Age, 1995–96 for LASA, 2009–11 for TILDA, and 2009–10 for ActiFe. The respective ethics committees granted ethical approval for all studies.

Participants

Community-dwelling adults aged 65 and older with information on nutritional status at baseline and follow-up were included. Participants with missing information on body mass index (BMI), previous unintended weight loss, and weight at follow-up were excluded, as were participants who were lost to follow-up or died during follow-up and those with malnutrition at baseline (Table 1). Malnutrition at baseline was defined as a BMI less than 20 kg/m^2 or previous unintended weight loss according to the predefined criteria of each dataset (>3 kg in the last 3 months for ErnSiPP and ActiFe (based on Mini Nutritional Assessment (MNA) question B),[24] ≥ 4 kg in the past 6 months for LASA, > 5 kg in the past 6 months for LiLACS NZ and KORA-Age, and ≥ 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. Analysis of determinants of incident malnutrition of Māori participants is presented in Supplemental Tables S4a-c.

Definition of incident malnutrition at follow-up

Incident malnutrition was defined as low BMI (< 20 kg/m^2) or unintended weight loss of 10% or greater 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 1 year for ErnSiPP; 2 years for TILDA; and 3 years for KORA-Age, LASA, LiLACS NZ, and ActiFe.

Potential determinants of incident malnutrition

Information on 21 variables at baseline and 2 variables at follow-up was available in all datasets. Selection of these variables and their classification in a specific domain was based on results of a systematic literature review.[4] During telephone conferences with all involved researchers, an approach how to harmonize the variables (e.g., continuous or categorical, number of categories, specific cut-off points) was developed.

Table 1. Selection Process for Inclusion of Community-Dwelling Older Adults from Each Study (number of participants)

Process	ErnSiPP	LiLACS NZ	LASA	ActiFe	TILDA	KORA-Age
Participants at baseline	353	937	2,545	1,506	8,504	1,079
Exclusion criteria[a]						
Aged < 65	0	0	1,039	0	4,990	0
Information missing on BMI or previous weight loss at baseline	18	313	27	36	1,156	4
Malnutrition at baseline[c]	46	43	133	17	226	61
Lost to follow-up	35	127	151	N/A[b]	222	159
Died during follow-up	32	105	169	130	N/A[b]	98
Missing BMI or weight at follow-up	6	41	17	532	69	9
Māori participants	N/A	99	N/A	N/A	N/A	N/A
Participants included in analysis	216	209	1,009	791	1841	778

[a]Participants were excluded in presented order.
[b]Participants were removed before the dataset was received for analysis.
[c]Body mass index (BMI) < 20 kg/m^2 or weight loss > 3 kg in the last 3 months (ErnSiPP, ActiFe), ≥ 4 kg (LASA) and > 5 kg LiLACS, (LiLACS NZ, KORA Age) in the past 6 months, and > 4.5 kg in the past 12 months (TILDA) (See text for full study names)
N/A = not applicable

Demographic factors (4 variables) included age (continuous variable) and sex (male, female). In the TILDA dataset, in partcipants aged older than 80 years, an age of 80 years was used for anonymization purposes to ensure that older adults could not be identified from the dataset. Marital status was categorized as married; unmarried, separated, or divorced; or widowed, and education level was categorized as primary or less, secondary, or tertiary.

Social factors (2 variables)

Living alone was dichotomized into yes versus no, with 'no' including living with spouse, partner, children, or others. Receiving social support was assessed regarding three different domains: support or help with shopping, cooking, or cleaning and household chores. If support was received in one or more of these three domains, social support was categorized as 'yes.'

Lifestyle factors (3 variables)

Three categories were created to describe physical activity. ErnSiPP asked how active participants were; physical activity level (PAL) 1.2 was categorized as low activity, 1.3 to 1.4 as moderate activity, and 1.5 or more as high activity. LiLACS NZ and KORA-Age assessed physical activity over the past week and ActiFe and LASA over the past 2 weeks. Study-specific tertiles were calculated and used to categorize physical activity. LiLACS NZ used the Physical Activity Scale for the Elderly (PASE; 0–793 points[25]) and study specific tertiles of 61 points or less indicating low activity, 62 to 124 points moderate activity, and 125 points or more high activity. KORA also used PASE, with study-specific tertiles of less than 96 points indicating low activity, 96 to 140 points moderate activity, and 141 points or more high physical activity. LASA used the LASA Physical Activity Questionnaire,[26] with less than 108 min/d of activities categorized as low activity, 108 to 190 min/d as moderate activity, and 191 min/d or more as high activity. ActiFe also used the LASA Physical Activity Questionnaire, with study-specific tertiles of less tha 25 min/d as low activity, 25 to 96 min/d as moderate activity, and more than 96 min/d as high activity. TILDA used the International Physical Activity Questionnaire[27] and categorized high activity as at least 3 days of vigorous activity (at least 1500 MET-minutes/week) or 7 days of combined low, moderate or vigourous-intensity activities; moderate activity as 3 or more days of vigorous activity (at least 20 min/day) or at least 5 days of any combination; and low activity when none of the other criteria were met.[28] Current alcohol intake was dichotomized as no versus yes, with those who had never consumed alcohol categorized as "no". Smoking was dichotomized as yes versus no, with never and past smokers categorized as "no."

Medical factors (6 variables)

The number of chronic diseases were categorized as 1 or fewer versus 2 or more. The number of daily prescribed medications was dichotomized as less than 5 versus 5 or more to define polypharmacy. Hospitalization during the last year or last 6 months (LASA only) was assessed at baseline and follow-up and dichotomized as yes versus no (not assessed in ActiFe). Pain was assessed by asking, "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), and "How much pain or discomfort do you have?" (EQ-5D questionnaire, KORA-Age). All categories indicating pain were summarized into yes. In LiLACS NZ a numerical pain rating scale from 0-9 was used where 0 indicated no pain and 1-9 present pain. Self-rated health was ascertained in all cohorts by asking, "How would you describe your health or present physical constitution" (good, fair, poor)? The variable was dichotomized as good versus fair or poor self-rated health.

Psychological factors (2 variables)

Cognitive impairment was measured using the Mini-Mental State Examination (MMSE; range 0—30)[29] in ErnSiPP, ActiFe, LASA, and TILDA. LiLACS NZ used the modified MMSE (range 0–100).[30] KORA-Age used the modified Telephone Interview for Cognitive Status (TICS-m; score: 0—50).[31] Results were dichotomized as no versus yes

(MMSE score ≤ 23 or TICS-m score ≤ 31 indicating cognitive impairment). Depression was measured using the Geriatric Depression Scale (GDS; range 0–15)[32] in ErnSiPP, KORA-Age and LiLACS NZ; Center for Epidemiologic Studies Depression Scale (CES-D; range 0–60)[33] in LASA and TILDA; and Hospital Anxiety and Depression Scale (HADS; range 0–21)[34] in ActiFe. Responses were dichotomized as no versus yes; a GDS score of 6 or greater,[32] a CES-D score of 16 or greater,[35] and a HADS score of 8 or greater (only questions related to depression were used) indicated depressive symptoms.

Physical functioning factors (5 variables)

Difficulty walking was assessed by asking "Do you have difficulty walking for 5 minutes?" (LASA, ActiFe) or "walking 100 meters?" (TILDA) and "Are you able to walk on even terrain?" (Health Assessment Questionnaire Disability Index,[36] KORA-Age). The answers were categorized as no difficulty versus difficulty (able to walk with difficulty, needs help, cannot walk). ErnSiPP used the question from the Barthel Index[37] "Is the patient immobile, in a wheelchair, walks with help, or independent?" with the first 3 answers being categorized as "difficulty." LiLACS NZ measured normal gait speed at 3 m, and gait speed of 0.8 m/s or less was categprozed as having difficulty walking.[38] Difficulty climbing stairs was assessed by asking, "Do you have difficulty climbing one flight of stairs without resting (TILDA), "Do you have difficulty climbing 5 stairs wihtout resting? (Health Assessment Questionnaire Disability Index,[36] KORA-Age), and "Do you have difficulty walking up and down a staircase of 15 steps?" (LASA, ActiFe). ErnSiPP used the item from the Barthel Index: "Patient is unable to climb stairs, needs help, is independent",[37] and LiLACS NZ asked, "Does your health limit you in climbing several flights of stairs?" All answers indicating that climbing stairs was difficult or not possible or that help was needed were categorized as "difficulty." Falls in the year before baseline was dichotomized as yes versus no. The same question was assessed at follow-up, except for in TILDA, which assessed falls in the last 2 years. The answer was dichotomized as yes versus no. Handgrip strength was measured using a hand dynamometer[39] (kg) in all studies but ErnSiPP, which used a vigorimeter (kPa; KLS Martin Group, Tuttlingen, Germany).[40] Each participant's highest value was used, and the variable was dichotomized as low (< 30 kg or < 66 kPa for men; < 20 kg or < 38 kPa for women) versus normal handgrip.[39,41]

Nutritional factor (1 variable)

Appetite was assessed by asking, "How would you describe your appetite?" and categorized as good versus fair or poor (ErnSiPP, KORA-Age, LiLACS NZ); "Did your appetite decline in the past 3 months? (from the Mini Nutritional Assessment[24]), with no decline considered good, a small decline considered fair, and a severe decline as poor (ActiFe); and "I did not feel like eating; my appetite was poor in the past week" (from the CES-D), with less than 1 day categorized as good, 1 to 2 days as fair, and 3 to 7 days as poor (LASA, TILDA).

Statistical analysis

The respective dataset holder harmonized and analyzed the variables of each dataset locally according to a standardized study protocol and statistical analysis plan. Statistical analyses were performed using SPSS version 24 (IBM Corp., Armonk, NY) in all datasets but ActiFe and KORA-Age, which used SAS version 9.4 (SAS Institute, Inc., Cary, NC). 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 using absolute numbers and proportions (categorical variables) and means and standard deviations (SD) for age and BMI at baseline and follow-up. For each subcategory of the categorical variables, the proportion of incident malnutrition is presented in Supplemental Table S1. Differences in mean BMI between baseline and follow-up were tested using the Wilcoxon signed rank test for paired samples.

Univariate logistic regression analyses were performed for each independent variable to identify risk factors for incident malnutrition (yes or no) (Supplemental Table S2). Then, each variable was adjusted for age, sex, education, and its own fixed set of specific confounders. Confounders were selected based on the literature, and a Delphi method was used with all researchers of the working group (n=12) 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.) 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 difficulty walking and climbing stairs (phi coefficient=0.26–0.61), so only living alone and difficulty walking were considered as confounders in the relevant models. Because none of the participants without social support (ErnSiPP), none with difficultu climbing stairs (ActiFe), and none with 1 or fewer chronic diseases (LiLACS NZ) developed malnutrition at follow-up, these variables were not adjusted and were not used as potential confounders in the respective studies. Because 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 between cognitive impairment and incident malnutrition.

Odds ratios (ORs) of the individually adjusted regression analyses were combined in random-effects meta-analyses in R (R Foundation for Statistical Computing, Vienna, Austria) using the meta-package 'metagen'; $p<.05$ 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 the I^2 test and τ (Tau)^2, with I^2 of 75% or greater[42] indicating 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), 1,009 (LASA), 791 (ActiFe), 1,841 (TILDA), and 778 (KORA-Age)

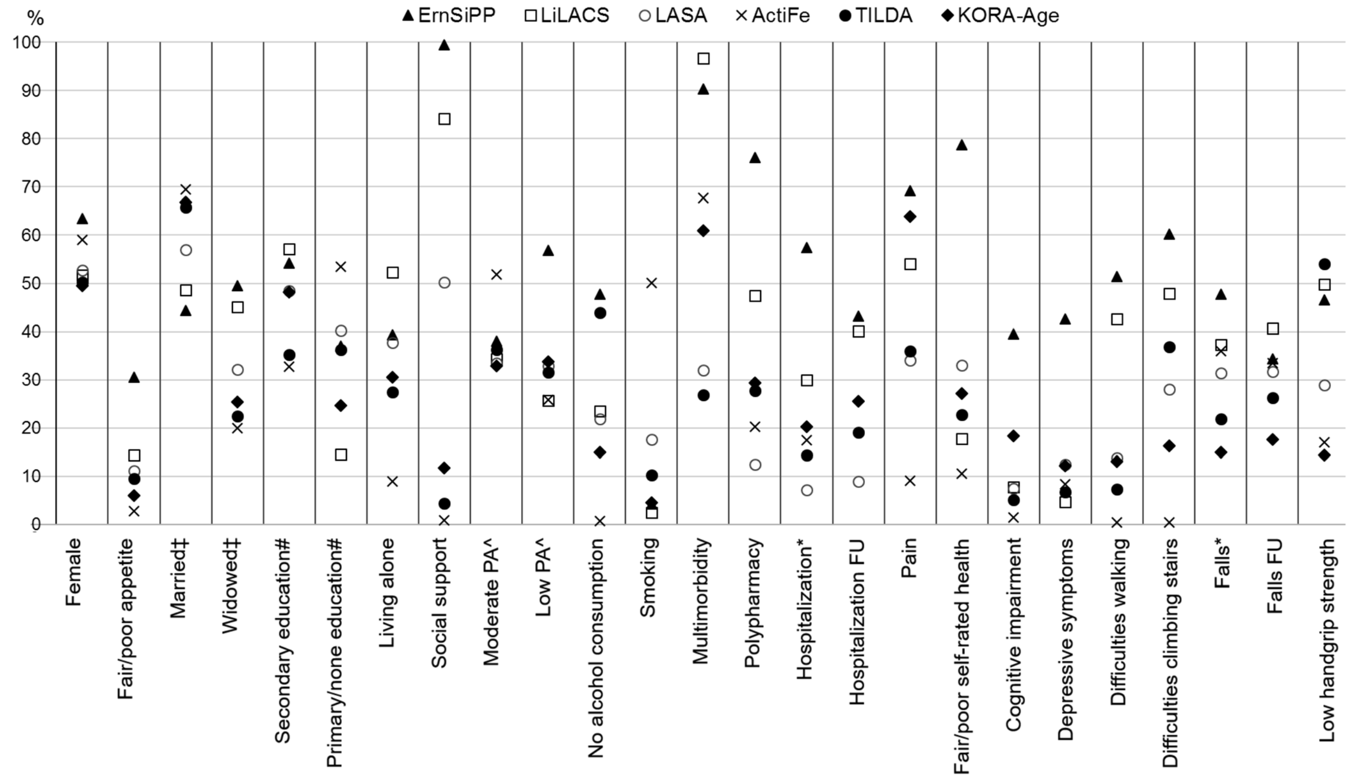


Figure 1. Prevalence of potential determinants of incident malnutrition, separated according to study. ‡Third category 'unmarried/divorced' is not presented—all three categories add up to 100%. #Third category 'tertiary education' is not presented—all three categories add up to 100%. ^Third category 'high physical activity' is not presented—all three categories add up to 100%. *Before baseline. FU = follow-up; PA = physical activity.

community-dwelling adults aged 65 and older were included in the analyses. The participant selection process 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 from 71.7 ± 5.0 (TILDA) to 84.6 ± 0.5 (LiLACS NZ) and mean BMI at baseline from 27.1 ± 3.6 kg/m^2 (LiLACS NZ) to 29.4 ± 6.3 kg/m^2 (ErnSiPP). In all studies, mean BMI was statistically significantly lower at follow-up than baseline (data not shown).

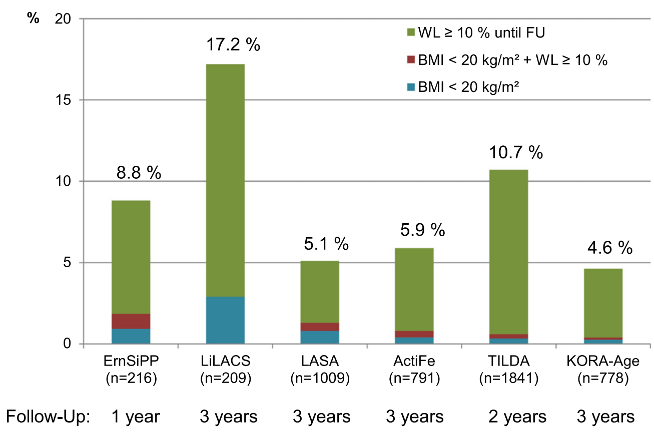


Figure 2. Incidence of malnutrition in each cohort. Malnutrition was defined as body mass index (BMI) < 20 kg/m^2 or unintended weight loss (WL) ≥ 10% until follow-up (FU). (see text for full study names)

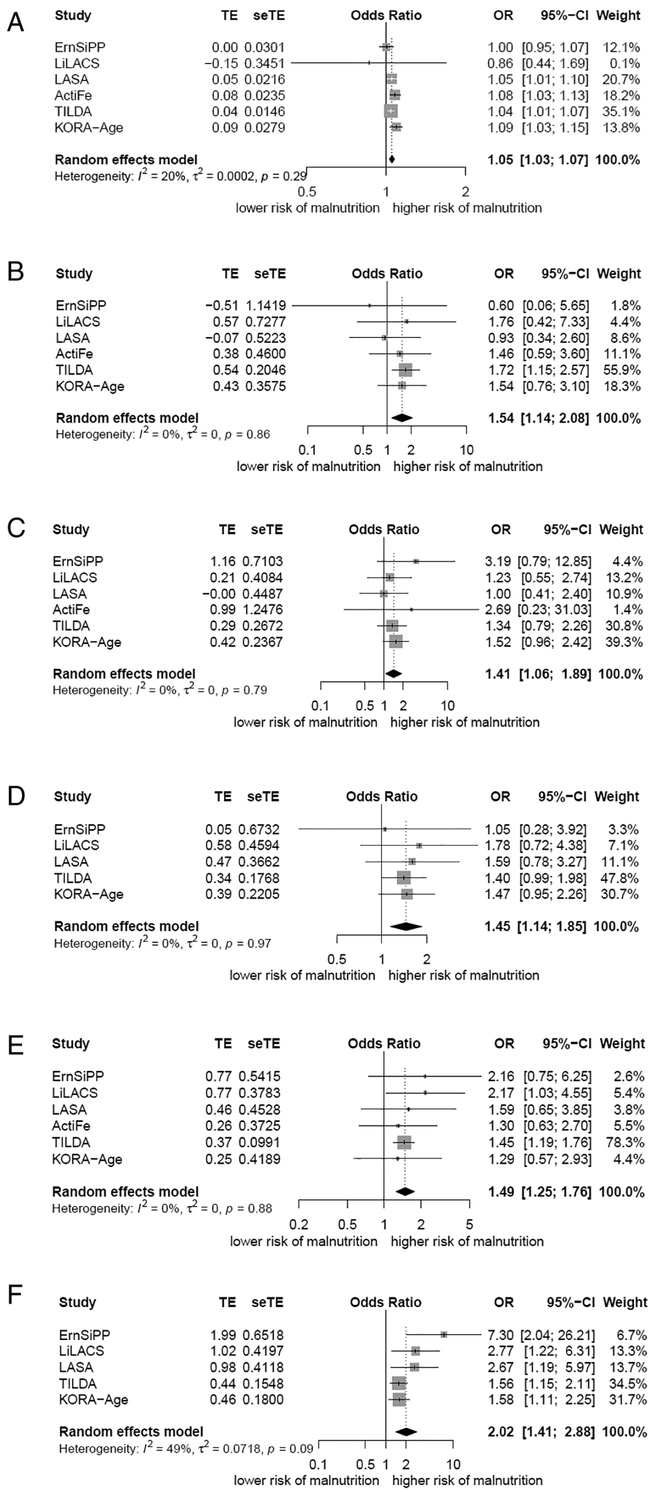
Three-year incidence of malnutrition was 4.6% in KORA-Age, 5.1% in LASA, 5.9% in ActiFe, and 17.2% in LiLACS NZ; 2-year incidence was 10.7% in TILDA, and 1-year incidence was 8.8% in ErnSiPP (Figure 2). Being malnourished at follow-up was mostly because of weight loss of 10% or more, whereas BMI less than 20 kg/m^2 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 than married participants, whereas no difference was found between widowed and married participants. Participants with difficulty walking (OR=1.41, 95% confidence interval (CI)=1.06–1.89) or climbing stairs (OR=1.45, 95% CI=1.14–1.85), those who were in the hospital before baseline (OR=1.49, 95% CI=1.25–1.76) and those who were hospitalized during follow-up (OR=2.02, 95% CI=1.41–2.88) had higher odds of being malnourished at follow-up. Heterogeneity between studies was low for all these determinants except for hospitalization during follow-up, which had moderate heterogeneity (I^2=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, which had high heterogeneity (Table 2).

Eight variables (appetite, smoking, living alone, social support, polypharmacy, difficulty walking, difficulty climbing stairs, falls before baseline) were consistently not significantly associated with malnutrition in all studies, whereas results of the other 15 variables were less consistent between studies. For difficulty walking and climbing stairs, the combined effect sizes reached significance. Individual study results and combined ORs of determinants not significantly associated with incident malnutrition after adjustment for confounders are presented in Supplemental Figures S1 to S20.

In older Māori, indigenous Polynesian people in New Zealand (n=99), being widowed and having low physical activity at baseline were associated with higher odds of incident malnutrition in univariate analyses, but these associations were attenuated after adjustment for confounders (Supplemental Tables S4b, c).



DISCUSSION

To our knowledge, this is the first multicohort, harmonized meta-analysis to identify determinants of incident malnutrition in community-dwelling adults aged 65 and older. In addition to age and marital status, difficulty 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 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 care of unmarried older people, improving functional capabilities using 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 effect of differences in definitions on incidence rate. The incidence of malnutrition in the included studies ranged from 4.6% to 17.2%. This variation might have occurred because of differences in the study populations and follow-up durations. In the ErnSiPP study, for example, participants were community dwelling, but all received home care. These participants might have been at higher risk of developing malnutrition than those in the other studies. Furthermore, ErnSiPP and LiLACS NZ participants had a higher mean age (80.4 and 84.6, respectively) than those from the other studies (range 74.1–75.1), which might partly explain the higher incidence of malnutrition in these 2 cohorts. Mean age was lowest in TILDA (71.7), but the incidence of malnutrition was surprisingly higher than in the other population-based studies (LASA, ActiFe, KORA-Age). Reasons for the much higher proportion of participants with weight loss greater than 10% in TILDA are unclear. Because age was top-coded at 80 in the TILDA cohort, and 12.2% of participants were aged

Figure 3. Forrest plots presenting odds ratios (ORs) and corresponding 95% confidence intervals (CIs) of random-effects meta-analyses of determinants significantly associated with incident malnutrition after adjustment for indicated confounders: (A) Age, continuous. (B) Unmarried vs married (adjusted for age, sex, education, depressive symptoms, alcohol consumption). (C) Difficulty walking and (D) difficulty climbing stairs (yes vs no) (adjusted for age, sex, education, cognitive impairment, body mass index, handgrip strength, physical activity, self-rated health, depressive symptoms, medication, chronic diseases, pain, falls before baseline). (E) Hospitalized before baseline (yes vs no) (adjusted for age, sex, education). (F) Hospitalized during follow-up (yes vs no) (adjusted for age, sex, education, handgrip strength, difficulties walking, chronic diseases, self-rated health, medication, cognitive impairment, hospitalization before baseline, falls before baseline, pain). Meta-analysis based on 6 longitudinal cohort studies with 216 (ErnSIPP), 209 (LiLACS NZ), 1,009 (LASA), 791 (ActiFe), 1,841 (TILDA), and 778 (KORA-Age) participants. (See text for full study names)

Table 2. Random-Effects Meta-Analyses of All Adjusted Potential Determinants Not Significantly Related to Incidence of Malnutrition

Determinant	Odds Ratio (95% Confidence Interval)	Heterogeneity	
		I^2, %	Tau^2
Female	1.25 (0.97–1.63)	20	0.02
Appetite fair to poor (reference good)	1.12 (0.72–1.72)	35	0.10
Married (reference widowed)	0.97 (0.71–1.33)	41	0.06
Education (reference tertiary)			
Secondary	0.79 (0.59–1.06)	4	0.01
≤Primary	0.73 (0.52–1.03)	14	0.03
Living alone	0.98 (0.71–1.33)	30	0.05
Social support	1.13 (0.74–1.71)	36	0.08
Physical activity (reference high)			
Moderate	1.30 (0.95–1.80)	21	0.03
Low	1.05 (0.68–1.61)	45	0.12
Alcohol consumption	0.88 (0.57–1.38)	58	0.15
Smoking	1.07 (0.78–1.46)	0	0.00
≤1 chronic diseases	1.16 (0.64–2.12)	93	0.40
< 5 medications	1.13 (0.91–1.41)	0	0.00
Pain	1.08 (0.88–1.34)	0	0.00
Self-rated health fair or poor (reference very good or good)	1.23 (0.87–1.73)	37	0.06
Cognitive impairment	1.37 (0.95–1.97)	17	0.04
Depressive symptoms	1.03 (0.59–1.79)	53	0.22
Falls before baseline	1.10 (0.86–1.40)	0	0.00
Falls during follow-up	1.18 (0.86–1.61)	46	0.07
Handgrip strength low (reference normal)	1.09 (0.68–1.73)	70	0.21

Meta-analysis is based on 6 longitudinal cohort studies with 216, 209, 1,009, 1,841, 791, and 778 participants, respectively.
List of confounders used to adjust the associations presented in Supplemental Table S3.

80 and older, it is 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 difficulty climbing stairs,[9] older age,[10,43] and hospitalization[14] as determinants of malnutrition. This is also consistent with the result of moderate to strong evidence for an association between hospitalization and malnutrition in a systematic review that considered a combination of cross-sectional and longitudinal studies.[4] Illness or acute stress, with greater energy demands, but also poor absorption or low intake because of pain, nausea, poor appetite, and low quality of hospital food might explain this association.[4] Because hospitalization before and during follow-up were associated with greater odds of malnutrition, our results indicate that hospitalization is a short- and long-term risk factor for malnutrition.

Poor appetite and poor self-reported health were not associated with incident malnutrition. These results are unexpected because the systematic review found strong evidence of an association between poor appetite and malnutrition and moderate to strong evidence of an association between poor self-reported health and malnutrition.[4] The conclusion regarding the latter variable is based only on cross-sectional studies, and thus, the long-term effect of poor self-rated health on malnutrition might be 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.[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 those who did not (or not anymore) 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, albeit in the opposite direction.

For low physical activity, inconclusive evidence of an association with malnutrition was found in the systematic review.[4] In our meta-analysis, significant univariate associations were found in TILDA and KORA-Age, but these associations were attenuated after adjustment for confounders. One possible explanation for the inconclusive results of the systematic review could be that we adjusted for more confounders than the studies in the systematic review.

STRENGTHS AND LIMITATIONS

Our analysis has several strengths. We had access to 6 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. Each variable was adjusted for the same set of confounders.

Our work 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, although heterogeneity was generally low, so we do not expect the use of different tools to have strongly influenced the results of the meta-analyses. Furthermore, high variability was discovered in some study characteristics (e.g., prevalence of social support ranged from 0.9% in ActiFe to 99.5% in ErnSiPP) as a result of different research focuses in the original study and different inclusion and exclusion criteria. (See online supplemental material for a short description of the included studies.) Despite these large study differences, the associations were quite similar. Because of the need to harmonize potential determinants, categories for most variables had to be reduced to a few or only 2 categories (e.g., alcohol consumption, yes/no; depressive symptoms, yes/no; cognitive impairment, yes/no), which might have resulted in a loss of information and a loss of power.

CONCLUSION

In this harmonized meta-analysis based on data from 6 longitudinal studies, older 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. Regarding hospitalization, the acute disease with probably increased energy requirements, anorexia, eating difficulties, and poor intake may be the underlying reason for the development of malnutrition.

Because variables needed to be harmonized because different methods and tools were used, more-standardized data collection in future studies would increase comparability of study results.

ACKNOWLEDGMENTS

We would like to thank all research collaborators of the underlying studies.

TILDA thanks Lauren Power for her support.

LiLACS NZ wishes to acknowledge participants, their families, and whanau for supporting the study. We thank Te RōpuKaitiaki o ngā tikanga Māori for their guidance. We acknowledge the community partners in LiLACS NZ who engaged with participants and collected data (Western Bay of Plenty Primary Health Organisation, Ngā Matāpuna Oranga Kaupapa Māori Primary Health Organisation, Te Korowai Aroha Trust, Te Rūnanga o Ngati Pikiao, Rotorua Area Primary Health Services, Ngati Awa Research and Archives Trust, Te Rūnanga o Ngati Irapuaia, Te Whanau a Apanui Community Health Centre).

This work was presented in a MaNuEL symposium at the 39th Congress of the European Society for Clinical Nutrition and Metabolism (ESPEN) in The Hague, Netherlands, and at the 13th Congress of the European Union Geriatric Medicine Society (EUGMS) in Nice, France, both in September 2017.

The KORA study was initiated and financed by the Helmholtz Zentrum München—German Research Center for Environmental Health, which is funded by the German Federal Ministry of Education and Research (BMBF) and by the State of Bavaria.

The KORA-Age project was financed by the German Federal Ministry of Education and Research (BMBF FKZ 01ET0713 and 01ET1003A) as part of the 'Health in Old Age' program.

The MaNuEL knowledge hub supported the preparation of this article. This work is supported by the Joint Programming Initiative Healthy Diet for a Healthy Life. The funding agencies supporting this work are (in alphabetical order of participating Member State): Germany: German Federal Ministry of Food and Agriculture through the Federal Office for Agriculture and Food (Grants 2815ERA10E (FAU) and 2815ERA08E (UUlm)); Ireland: Department of Agriculture, Food and the Marine and Health Research Board Project Reference 15/HDHL/2 MANUEL; The Netherlands: The Netherlands Organisation for Health Research and Development (ZonMw 50-52905-98-499).

Conflict of Interest: All authors declare no conflict of interest.

Author Contributions: MS data analysis, meta-analyses, drafted manuscript. MS, JZP, LB, GN, RT, CM: individual data analyses. MS, JZP, LB, GN, RT, CM, MC, GT, EK, EG, MV, DV: standardized study protocol, statistical analysis plan, 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.

Sponsor's Role: The sponsors played no role in this study.

REFERENCES

1. Allison SP. Malnutrition, disease, and outcome. Nutrition 2000;16:590–593.
2. Bolin T, Bare M, Caplan G, Daniells S, Holyday M. Malabsorption may contribute to malnutrition in the elderly. Nutrition 2010;26:852–853.
3. McMinn J, Steel C, Bowman A. Investigation and management of unintentional weight loss in older adults. BMJ 2011;342:d1732.
4. van der Pols-Vijlbrief R, Wijnhoven HAH, Schaap LA, Terwee CB, Visser M. Determinants of protein–energy malnutrition in community-dwelling older adults: A systematic review of observational studies. Ageing Res Rev 2014;18:112–131.
5. Pirlich M, Lochs H. Nutrition in the elderly. Best Pract Res Clin Gastroenterol 2001;15:869–884.
6. Norman K, Pichard C, Lochs H, Pirlich M. Prognostic impact of disease-related malnutrition. Clin Nutr 2008;27:5–15.
7. Correia M, Waitzberg D. The impact of malnutrition on morbidity, mortality, length of hospital stay and costs evaluated through a multivariate model analysis. Clin Nutr 2003;22:235–239.
8. Shatenstein B, Kergoat MJ, Nadon S. Weight change, nutritional risk and its determinants among cognitively intact and demented elderly Canadians. Can J Public Health Rev Can Sante Publique 2001;92:143–149.
9. Schilp J, Wijnhoven HAH, Deeg DJH, Visser M. Early determinants for the development of undernutrition in an older general population: Longitudinal Aging Study Amsterdam. Br J Nutr 2011;106:708–717.
10. Roberts KC, Wolfson C, Payette H. Predictors of nutritional risk in community-dwelling seniors. Can J Public Health 2007;98:331–336.
11. St-Arnaud-McKenzie D, Payette H, Gray-Donald K. Low physical function predicts either 2-year weight loss or weight gain in healthy community-dwelling older adults. The NuAge Longitudinal Study. J Gerontol A Biol Sci Med Sci 2010;65B:1362–1368.

12. Agostini JV, Han L, Tinetti ME. The relationship between number of medications and weight loss or impaired balance in older adults. J Am Geriatr Soc 2004;52:1719–1723.
13. Ritchie CS, Joshipura K, Silliman RA, Miller B, Douglas CW. Oral health problems and significant weight loss among community-dwelling older adults. J Gerontol A Biol Sci Med Sci 2000;55:M366–M371.
14. Alley DE, Koster A, Mackey D, et al. Hospitalization and change in body composition and strength in a population-based cohort of older persons. J Am Geriatr Soc 2010;58:2085–2091.
15. Visser M, Volkert D, Corish C et al. Tackling the increasing problem of malnutrition in older persons: The Malnutrition in the Elderly (MaNuEL) Knowledge Hub. Nutr Bull 2017;42:178–186.
16. Kiesswetter E, Pohlhausen S, Uhlig K, et al. Prognostic differences of the Mini Nutritional Assessment short form and long form in relation to 1-year functional decline and mortality in community-dwelling older adults receiving home care. J Am Geriatr Soc 2014;62:512–517.
17. Denkinger MD, Franke S, Rapp K, et al. Accelerometer-based physical activity in a large observational cohort-study protocol and design of the activity and function of the elderly in Ulm (ActiFE Ulm) study. BMC Geriatr 2010; 10:50.
18. Peters A, Döring A, Ladwig K-H, et al. Multimorbidität und erfolgreiches altern: Ein blick auf die bevölkerung im rahmen der KORA-Age-Studie. Z Für Gerontol Geriatr 2011;44:41–54.
19. Holle R, Happich M, Löwel H, Wichmann H. KORA—a research platform for population based health research. Gesundheitswesen 2005;67:19–25.
20. Hoogendijk EO, Deeg DJH, Poppelaars J et al. The Longitudinal Aging Study Amsterdam: Cohort update 2016 and major findings. Eur J Epidemiol 2016;31:927–945.
21. Cronin H, O'Regan C, Finucane C, Kearney P, Kenny RA. Health and aging: Development of The Irish Longitudinal Study on Ageing health assessment. J Am Geriatr Soc 2013;61:S269–278.
22. Whelan BJ, Savva GM. Design and methodology of The Irish Longitudinal Study on Ageing. J Am Geriatr Soc 2013;61:S265–S268.
23. Hayman KJ, Kerse N, Dyall L et al. Life and living in advanced age: A cohort study in New Zealand-Te Puāwaitanga o Nga Tapuwae Kia Ora Tonu, LiLACS NZ: Study protocol. BMC Geriatr 2012;12:33.
24. Rubenstein LZ, Harker JO, Salvà A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: Developing the Short-Form Mini-Nutritional Assessment (MNA-SF). J Gerontol A Biol Sci Med Sci 2001;56A: M366–M372.
25. Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): Development and evaluation. J Clin Epidemiol 1993; 46:153–162
26. Stel VS, Smit JH, Pluijm SM, Visser M, Deeg DJ, Lips P. Comparison of the LASA Physical Activity Questionnaire with a 7-day diary and pedometer. J Clin Epidemiol 2004;57:252–258.
27. Craig CL, Marshall AL, Sjöström M, et al. International Physical Activity Questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35:1381–1395.
28. International Physical Activity Questionnaire (online). Available at www.ipaq.ki.se Accessed July 26th, 2018.
29. Folstein MF, Folstein SE, McHugh PR. 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–198.
30. Teng EL, Chui HC. The Modified Mini-Mental State (3MS) examination. J Clin Psychiatry 1987;48:314–318.
31. Cook SE, Marsiske M, McCoy KJM. The use of the Modified Telephone Interview for Cognitive Status (TICS-M) in the detection of amnestic mild cognitive impairment. J Geriatr Psychiatry Neurol 2009;22:103–109.
32. Yesavage JA, Brink TL, Rose TL et al. Development and validation of a geriatric depression screening scale: A preliminary report. J Psychiatr Res 1982;17:37–49.
33. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. Appl Psychol Meas 1977;1:385–401.
34. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. Acta Psychiatr Scand 1983;67:361–370.
35. Berkman LF, Berkman CS, Kasl S et al. Depressive symptoms in relation to physical health and functioning in the elderly. Am J Epidemiol 1986;124:372–388.
36. Fries JF, Spitz P, Kraines RG, Holman HR. Measurement of patient outcome in arthritis. Arthritis Rheum 1980;23:137–145.
37. Mahoney FI, Barthel DW. Functional evaluation: The Barthel Index. Md State Med J 1965;14;61–65
38. Abellan van Kan G, Rolland Y, Andrieu S et al. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. J Nutr Health Aging 2009;13:881–889.
39. Lauretani F, Russo CR, Bandinelli S et al. Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. J Appl Physiol 2003;95:1851–1860.
40. Thorngren K-G, Werner CO. Normal grip strength. Acta Orthop Scand 1979;50:255–259.
41. Phillips P. Grip strength, mental performance and nutritional status as indicators of mortality risk among female geriatric patients. Age Ageing 1986; 15:53–56.
42. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–560.
43. Johansson Y, Bachrach-Lindström M, Carstensen J, Ek A-C. Malnutrition in a home-living older population: Prevalence, incidence and risk factors. A prospective study. J Clin Nurs 2008;18:1354–1364.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

Appendix S1: Short description of the respective studies

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

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

Table S3: List of confounders

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

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

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

Figures S1-S20: 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.