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# Strong Relationship between Malnutrition and Cognitive Frailty in the Singapore Longitudinal Ageing Studies (SLAS-1 and SLAS-2)

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## Abstract

BACKGROUND: Physical frailty is well known to be strongly associated with malnutrition, but the combined impact of physical frailty and cognitive impairment among non-demented older persons (cognitive frailty) on malnutrition prevalence is not well documented.

DESIGN: Cross-sectional cohort study.

Setting and Participants: Community-dwelling older Singaporeans aged ≥55y (n=5414) without dementia in the Singapore Longitudinal Ageing Study (SLAS-1 and SLAS-2).

MEASUREMENTS: The Mini Nutritional Assessment – short form (MNA-SF) and Nutrition Screening Initiative (NSI) Determine Checklist were used to determine their nutritional status. Participants were categorized as cognitive normal (CN) or cognitive impaired (CI) by Mini Mental State Examination (MMSE<=23), as pre-frail (PF) (score=1-2) or frail (F) (score=3-5) using Fried's criteria, and as cognitive pre-frail (PF+CI) or cognitive frail (F+CI).

RESULTS: The prevalence of cognitive frailty was 1.6%, and cognitive pre-frailty was 5.5% (total, 7.1%). The prevalence of MNA malnutrition was 2.4%, and NSI high nutritional risk was 6.3%. The prevalence of MNA malnutrition was lowest among Robust-CN and highest among Frail-CI (0.5% in Robust-CN, 0.6% in Robust-CI, 2.8% in Pre-frail-CN, 7.3% in Pre-frail-CI, 15.4% in Frail-CN, and 23.1% in Frail-CI). Similarly, the prevalence of NSI high nutritional risk was lowest in Robust-CN (3.7%) and highest in Frail-CI (13.6%). Adjusted for sociodemographic and health status, pre-frailty/frailty-CI versus Robust-CN was associated with the highest odds ratio of association with MNA malnutrition (OR=8.16, p<0.001), although not the highest with NSI high nutritional risk (OR=1.48, p=0.017).

CONCLUSIONS: An extraordinary high prevalence of malnutrition was observed among older adults with cognitive frailty who should be specially targeted for active intervention.

*Key words: Cognitive Frailty, Malnutrition, Nutritional Risk.*

## Introduction

Frailty and cognitive impairment are two common geriatric syndromes that increase the risk of adverse health outcomes such as falls, institutionalization, hospitalization, functional disability and mortality. Among older people with both conditions, it is common to observe higher prevalence of malnutrition. Poor nutrition is a major important determinant of both physical frailty (1, 2) and cognitive impairment (3-5). On the one hand, nutrition is a major contributing risk factor for physical frailty, which in turn reportedly increases the risk of cognitive impairment and dementia (6-8). On the other hand, the nutritional health of physically frail or cognitively impaired are more likely to deteriorate as a result of physical and functional decline and neglect of self-care (9, 10).

The prevalence of malnutrition is well documented to be especially high among older people who are very frail or demented, such as in hospitals or nursing homes (11). Population-based studies of community dwelling older persons using the Mini Nutritional Assessment (MNA) and the Fried physical frailty phenotype revealed an overall malnutrition prevalence of 2.3 %, and physical frailty prevalence of 19.1 % (12). These studies revealed that 8.4% of physically frail older adults were identified as malnourished, and 42.7% were at risk of malnutrition. To date, there are no reports of population estimates of the prevalence of malnutrition or high nutritional risk among community-living older persons with cognitive frailty (those who are physically frail or pre-frail and cognitively impaired but without dementia).

Cognitive frailty is an emerging operationalization of age-related cognitive decline present simultaneously with physical frailty. It is defined by the presence of both physical frailty and cognitive impairment, in the absence of dementia (13). Their combined presence has been shown to increase the risk of adverse health outcomes considerably more than either frailty or cognitive impairment alone (14-16). Whether cognitively frail community dwelling older adults have an augmented risk of malnutrition has not been determined. An especially high likelihood of malnutrition among cognitively frail older persons in the population may provide important information for early targeted interventions to improve nutritional health for better functional wellbeing and quality of life, reducing the need for excessive hospitalization and institutionalization.

In this study, we examined the prevalence of malnutrition among older adults in the Singapore

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Longitudinal Ageing Study cohort by their physical frailty and cognitive status. The Mini Nutritional Assessment is the most common tool used to assess nutritional status, and categorizes subjects as normal nutritional status, at risk of malnutrition, and malnourished (11, 17). However, its components include neuropsychological problems (mild dementia and dementia or depression) which conflate its association with cognitive impairment and cognitive frailty. On the other hand, the Nutrition Screening Initiative (NSI, also called DETERMINE Your Nutritional Health) does not include any neuropsychological measurement components, and categorizes participants as having good nutrition, moderate nutritional risk, and high nutritional risk (18-20). In this study, therefore, we used both the MNA and the NSI to estimate the prevalence of malnutrition and nutritional risk among cognitively frail older persons.

## Methods

### *Participants*

The SLAS is a population-based longitudinal study of aging and health of two cohorts (SLAS-1 and SLAS-2) of community dwelling Singaporeans aged 55 and older, excluding individuals who were unable to participate because of severe physical or mental disability (16, 21, 22). The first cohort (SLAS 1 baseline, N = 2804) recruited residents in the southeast region of Singapore between 2003 and 2005, and the second cohort (SLAS 2 baseline, N = 3270) used identical methodologies to recruit residents in the southwest and south central regions of Singapore between 2010 and 2013. Baseline data collected included demographic, medical, behavioral, biological, mental, and nutritional characteristics collected from extensive questionnaire interviews and assessments. The study was approved by the National University of Singapore Institutional Review Board, and written informed consent was obtained from all the participants.

In this cross-sectional study, we examined the combined baseline data of 6074 participants recruited from SLAS-1 and SLAS-2. Participants with missing frailty score (n=431), missing MMSE score (n=12), and those who reported a history of dementia, Parkinson's disease, other neurodegenerative disorders (n=23), and history of stroke (n=194) were excluded, resulting in 5414 older adults for cross-sectional analysis.

### *Baseline Measurements*

#### *Cognitive Impairment*

Participants' cognitive status was assessed using Mini Mental State Examination (MMSE) with a total of 30 points (higher score indicating better cognition) (23). In this study, we used a score of 24 or more to define normal cognition, and score of 23 and below as cognitive impairment.

### *Frailty*

In this study, frailty was assessed based on 5 criteria used in the Cardiovascular Health Study (CHS): shrinking, weakness, slowness, exhaustion and physical inactivity (24). To assess weakness and slowness, we used the Performance Oriented Mobility Assessment (POMA) (25) measures of balance and gait that were available in both SLAS-1 and SLAS-2, although knee extension strength and gait speed from six-meter walk were available in SLAS-2. The two versions of the physical frailty index have good agreement (weighted kappa was 0.63), and were equally and strongly predictive of adverse health outcomes (7, 16, 21, 22). We have shown in previous studies that this modified CHS physical frailty index predicts depression, IADL-ADL dependency, hospitalization, and poor quality of life (16, 21, 22).

1. Unintentional shrinking was defined as body mass index (BMI) of less than 18.5 kg/m2 and/or unintentional weight loss of 4.5 kg (10 pounds) or more in the past 6 months.
2. Weakness was assessed by the lowest quintile of POMA performance on rising from chair test in the sitting position with arms folded.
3. Slowness was defined by POMA gait performance score (range, 0-12) of 8 or lower, in which subjects walked 6 meters and returned to the starting point quickly.
4. Exhaustion was defined by their response ("not at all") to the question from the SF-12 quality of life scale: "Do you have a lot of energy?"
5. Low activity was defined by "none" self-report of participation in any physical activity (walking or recreational or sports activity).

One-point score was assigned for the presence of each frailty component, and the summed scores were derived to categorize participants as frail (score = 3-5), pre-frail (score = 1-2), and robust (score=0).

Cognitive frailty is defined as the simultaneous presence of both physical frailty and cognitive impairment, cognitive pre-frailty is defined as the simultaneous presence of both physical pre-frailty and cognitive impairment, both excluding concurrent dementia or other dementias.

### *Nutrition Screening Initiative (NSI)*

Nutrition risk score was assessed by a 10-item questionnaire in the Nutrition Screening Initiative (NSI, also called DETERMINE Your Nutritional Health). The summed weighted scores range from 0 to 21, with a higher score indicating poorer nutritional status: 6 or more was used to categorize participants with high nutritional risk, 3 to 5 indicated moderate nutritional risk, and 0 to 2 indicated good nutrition (20).

**Table 1.** Socio-demographic Characteristics and Prevalence of Malnutrition/Nutritional Risk and Physical and Cognitive Frailty in the SLAS total cohorts

| Characteristics | | n/ Mean | %/ SD |
|---|---|---|---|
| No. of participants | | N=6074 | |
| Age (years) | | 66.4 | 7.80 |
| Male | | 2259 | 37.2 |
| Education Levels | | 6063 | |
| No Education | | 1216 | 20.0 |
| Primary | | 2314 | 38.2 |
| Secondary/higher | | 2533 | 41.8 |
| Housing Status | | 6056 | |
| 1-2 room public housing | | 937 | 15.5 |
| 3-5 room public housing | | 4047 | 66.8 |
| High end public and private housing | | 1072 | 17.7 |
| Race (Non-Chinese) | | 615 | 10.1 |
| Single/divorced/widowed | | 1907 | 31.5 |
| Living Alone | | 730 | 12.1 |
| | | | |
| Mini Nutritional Assessment (MNA) | | 5791 | |
| Normal nutrition (12-14) | | 4097 | 70.8 |
| At risk of malnutrition (8-11) | | 1554 | 26.8 |
| Malnourished (0-7) | | 140 | 2.40 |
| Nutrition screening index (NSI) | | 6037 | |
| Good nutrition (0-2) | | 4167 | 69.0 |
| Moderate nutritional risk (3-5) | | 1490 | 24.7 |
| High nutritional risk (≥6) | | 380 | 6.29 |
| | | | |
| Blood Nutritional Biomarkers # | | | |
| Anaemia | | 976 | 17.3 |
| Low albumin | | 1142 | 20.1 |
| Low total cholesterol | | 620 | 11.0 |
| Low lymphocyte | | 368 | 6.58 |
| | | | |
| Physical Frailty | | 5643 | |
| Robust | | 3186 | 56.5 |
| Pre-frail | | 2279 | 40.4 |
| Frail | | 178 | 3.15 |
| | | | |
| MMSE Status | | 6053 | |
| Cognitively Intact | | 5395 | 89.1 |
| Cognitively Impaired | | 658 | 10.9 |
| | | | |
| Physical and Cognitive Frailty Status | | 5631 | |
| Cognitively Normal (N=5060) | Robust | 3006 | 53.4 |
| | Pre-frail † | 1962 | 34.8 |
| | Frail † | 88 | 1.56 |
| Cognitively Impaired (N=577) | Robust | 177 | 3.14 |
| | Pre-frail ¶ | 310 | 5.51 |
| | Frail ¶ | 88 | 1.56 |

† Represents participants who were physically pre-frail or frail without cognitive impairment; ¶ Represents participants with cognitive frailty (physical pre-frailty or frailty with cognitive impairment, without dementia). # Anaemia: haemoglobin <12 g/dL in female, <13 g/dL in male; low albumin: <40 g/L; low total cholesterol: <4.14 mmol/L; low lymphocyte: $<1.2\times10^9$/L.

## *Mini Nutritional Assessment (MNA)*

Mini Nutritional Assessment – short form (MNA – SF), a widely used nutrition screening scale (17) was also converted from available data from our study (detailed in Supplementary Table 1). The summed score was 14 in total, with a higher score indicating better nutritional status: 12 to 14 indicated normal nutritional status, 8 to 11 indicated at risk of malnutrition (at-risk), and 7 or less meant malnourished.

## *Covariates*

Sociodemographic data included age, gender, race, education, housing type (an indicator of socioeconomic status), marital status, and living arrangement. The self-report of a medical disorder diagnosed and treated by a physician was recorded for 22 named diagnoses and other disorders. The number of comorbidities was estimated from the total count of medical disorders in the past 1 year. Polypharmacy was defined as the use of 5 or more medications. Depressive symptoms were measured by the Geriatric Depression Scale (GDS), which has been validated for use in local Chinese, Malay, and Indian participants (26). The summed score is 15 points, with a higher score indicating more depressive symptoms, and a score of more than 5 is suggestive of a clinically significant level of depressive symptoms. Functional dependency was assessed by self-reported difficulty and requiring help on 1 or more ADL/IADL activities. Hospitalization was determined by self-report of new hospitalizations for any medical conditions over the past year. Quality of life was measured using the Medical Outcomes Study SF12-PCS and SF12-MCS of quality of life. Blood nutritional biomarkers, including hemoglobin, albumin, total cholesterol, and lymphocytes, were measured using standard clinical laboratory methods in the National University Hospital National Reference Laboratory.

## *Statistical analysis*

Stata 12.0 (StataCorp LP, Texas, USA) was used to analyze data in our study. Categorical variables were presented as percentages and numbers (%, n), and means ± standard deviation was applied for continuous variables. Differences in the distribution of categorical variables among frailty/cognitive impairment/nutrition groups were tested for significance by Chi-square test. For continuous variables, the ANOVA F test or Kruskall-Wallis test was used for comparison of different groups. Multinomial logistic regression was performed to calculate the odds ratio (OR) and 95 % confidence intervals (CI) between frailty-cognitive status and malnutrition/nutritional risk. An acceptable level of significance was established as $p < 0.05$.

**Table 2.** Prevalence of Malnutrition/Nutritional Risk by Physical Frailty-Cognition Status

| | Numbers | | | | | | Proportions (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cognitive Normal | | | Cognitive Impaired | | | Cognitive Normal | | | Cognitive Impaired | | |
| | Robust | Pre-frail | Frail | Robust | Pre-frail | Frail | Robust | Pre-frail | Frail | Robust | Pre-frail | Frail |
| Mini Nutritional Assessment (MNA) | 2928 | 1868 | 65 | 168 | 286 | 65 | 100 | 100 | 100 | 100 | 100 | 100 |
| Normal nutrition (12-14) | 2441 | 1166 | 27 | 99 | 112 | 18 | 83.4 | 62.4 | 41.5 | 58.9 | 39.2 | 27.7 |
| At risk of malnutrition (8-11) | 473 | 649 | 28 | 68 | 153 | 32 | 16.1 | 34.7 | 43.1 | 40.5 | 53.0 | 49.2 |
| Malnourished (0-7) | 14 | 53 | 10 | 1 | 21 | 15 | 0.48 | 2.84 | 15.4 | 0.60 | 7.34 | 23.1 |
| At-risk and Malnourished | 487 | 702 | 38 | 69 | 174 | 47 | 16.6 | 37.6 | 58.5 | 41.1 | 60.8 | 72.3 |
| | | | | | | | | | | | | |
| Nutritional Screening Index (NSI) | 2929 | 1877 | 65 | 168 | 288 | 66 | 100 | 100 | 100 | 100 | 100 | 100 |
| Good nutrition (0-2) | 2244 | 1240 | 28 | 99 | 187 | 31 | 76.6 | 66.1 | 43.1 | 58.9 | 64.9 | 47.0 |
| Moderate nutritional risk (3-5) | 578 | 524 | 26 | 56 | 70 | 26 | 19.7 | 27.9 | 40.0 | 33.3 | 24.3 | 39.4 |
| High nutritional risk (≥6) | 107 | 113 | 11 | 13 | 31 | 9 | 3.65 | 6.02 | 16.9 | 7.74 | 10.8 | 13.6 |
| Moderate and High nutritional risk | 685 | 637 | 37 | 69 | 101 | 35 | 23.4 | 33.9 | 56.9 | 41.1 | 35.1 | 53.0 |
| | | | | | | | | | | | | |
| Blood Nutritional Biomarkers | | | | | | | | | | | | |
| Anaemia | 383 | 318 | 27 | 32 | 82 | 23 | 13.6 | 17.7 | 44.3 | 20.7 | 30.8 | 41.1 |
| Low albumin | 443 | 404 | 28 | 45 | 110 | 26 | 15.6 | 22.4 | 45.9 | 28.5 | 40.7 | 46.4 |
| Low total cholesterol | 955 | 203 | 11 | 16 | 30 | 14 | 9.02 | 11.3 | 18.0 | 10.2 | 11.2 | 25.0 |
| Low lymphocyte | 151 | 133 | 6 | 9 | 20 | 5 | 5.38 | 7.48 | 10.0 | 5.84 | 7.55 | 9.26 |

**Table 3.** Association of Malnutrition/Nutritional Risk with Physical Frailty-Cognitive Impairment Categories in Multinomial Logistic Regression Analysis

| | Mini Nutritional Assessment (MNA) | | | | | | Nutritional Screening Initiative (NSI) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | At Risk of Malnutrition | | Malnourished | | At Risk/ Malnourished | | Moderate Nutritional Risk | | High Nutritional Risk | | Moderate and High Risk | |
| | OR (95 % CI) | p | OR (95 % CI) | p | OR (95 % CI) | p | OR (95 % CI) | p | OR (95 % CI) | p | OR (95 % CI) | p |
| Robust without CI * | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Robust with CI | 4.19 (2.83-6.20) | <0.001 | NE | NE | 4.07 (2.75-6.02) | <0.001 | 2.27 (1.48-3.48) | <0.001 | 1.54 (0.66-3.62) | 0.321 | 2.14 (1.42-3.23) | <0.001 |
| Pre-frailty without CI | 2.77 (2.37-3.23) | <0.001 | 7.90 (4.13-15.1) | <0.001 | 2.92 (2.50-3.39) | <0.001 | 1.53 (1.30-1.80) | <0.001 | 1.67 (1.22-2.28) | 0.001 | 1.55 (1.33-1.81) | <0.001 |
| Pre-frailty with CI | 7.23 (5.18-10.1) | <0.001 | 30.2 (12.4-73.6) | <0.001 | 7.88 (5.69-10.9) | <0.001 | 1.30 (0.90-1.89) | 0.163 | 1.87 (1.04-3.36) | 0.037 | 1.42 (1.01-2.00) | 0.047 |
| Frailty without CI | 3.48 (1.86-6.52) | <0.001 | 43.1 (15.0-124) | <0.001 | 4.70 (2.63-8.41) | <0.001 | 2.84 (1.47-5.47) | 0.002 | 1.67 (1.22-2.28) | 0.001 | 2.95 (1.57-5.54) | 0.001 |
| Frailty with CI | 7.99 (3.78-16.9) | <0.001 | 116 (36.8-365) | <0.001 | 11.3 (5.57-23.0) | <0.001 | 2.03 (1.00-4.13) | 0.050 | 2.23 (0.79-6.32) | 0.132 | 2.07 (1.05-4.09) | 0.036 |
| | | | | | | | | | | | | |
| Robust without CI | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Robust with CI | 4.17 (2.82-6.18) | <0.001 | NE | NE | 4.03 (2.73-5.97) | <0.001 | 2.25 (1.46-3.45) | 0.001 | 1.52 (0.65-3.58) | 0.334 | 2.12 (1.41-3.19) | <0.001 |
| Pre-frailty / frailty without CI | 2.78 (2.39-3.25) | <0.001 | 8.46 (4.45-16.1) | <0.001 | 2.95 (2.53-3.43) | <0.001 | 1.55 (1.31-1.82) | <0.001 | 1.70 (1.25-2.32) | 0.001 | 1.57 (1.35-1.83) | <0.001 |
| Pre-frailty / frailty with CI | 7.27 (5.30-9.99) | <0.001 | 35.1 (15.3-80.4) | <0.001 | 8.16 (5.99-11.1) | <0.001 | 1.38 (0.98-1.95) | 0.064 | 1.85 (1.07-3.21) | 0.028 | 1.48 (1.07-2.04) | 0.017 |

* CI: Cognitive impairment. Adjusted for age, gender, race, marital status, living status, education levels, housing status, co-morbidities, FEV1/FVC<70%, ADL/IADL disability, anaemia, hypertension, diabetes, cardiac disease, history of kidney failure, depressive symptoms, hospitalization, polypharmacy, hearing loss, visual impairment. NE: Not estimated because of small number.

## Results

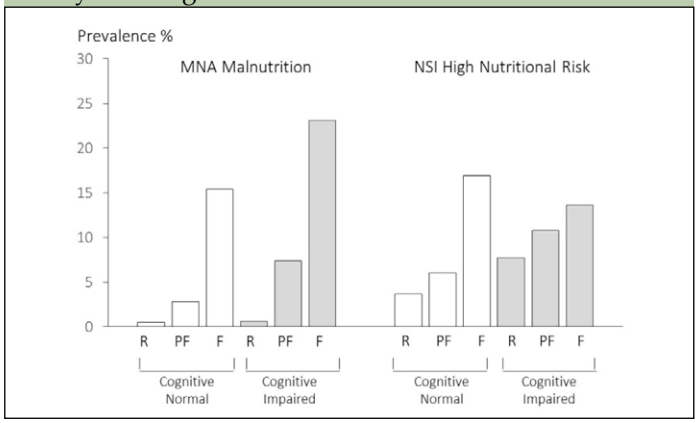
The mean age of the study cohort was 66.4 ± 7.8 years (range: 54 - 97.6 years), 37.2% were male, 58.2% had primary or lower education, 15.5% were living in low-end (1-2 room) public housing, 89.9% were Chinese, and 12.1% were living alone (Table 1).

In total, 3.2% of the study participants were frail, and 40.4% were pre-frail; 10.9% were cognitively impaired (MMSE score < 24). The prevalence of co-existing frailty and cognitive impairment (cognitive frailty) was 1.6%, and the prevalence of cognitive pre-frailty was 5.5%.

The prevalence of MNA malnourishment was 2.4%, and 26.8% were at risk of malnutrition. The prevalence of NSI high nutritional risk was 6.3% and moderate nutritional risk was 24.7%.

The prevalence of MNA and NSI malnutrition and nutritional risk by categories of physical frailty and cognitive impairment are shown in Table 2 and Figure 1. The prevalence of MNA at-risk and malnutrition was lowest among the cognitive normal (CN) who were robust (R-CN) at 16.6%; the presence of cognitive impairment increased the prevalence to 41.1% among R-CI, and the presence of pre-frailty (PF) and frailty (F) increased the prevalence to 37.6% among PF-CN and 58.5% among the F-CN respectively. The prevalence was highest among the frail-cognitive impaired (F-CI) at 72.3%. Similar trends were observed with the prevalence of NSI moderate and high nutritional risk. The prevalence of anaemia, low albumin, low cholesterol and low lymphocyte also partially reflected this trend of relationship, being lowest among the R-CN and highest among the F-CI.

**Figure 1.** Prevalence of Nutritional Status by Physical Frailty and Cognitive Status




The estimates of association of malnutrition/nutritional risk with frailty-cognitive status derived from multinomial logistic regression analysis are shown in Table 3. These estimates were adjusted for variables which were found to be associated with physical frailty, cognitive impairment or malnutrition/nutritional risk (see Supplementary Table 2): age, gender, race, marital status, living status, education levels, housing status, co-morbidities, FEV1/FVC<70%, ADL/IADL disability, anaemia, hypertension, diabetes, cardiac disease, history of kidney failure, depressive symptoms, hospitalization, polypharmacy, hearing loss, visual impairment. With reference to R-CN group, the presence of cognitive impairment among the R-CI was associated with an increased OR of 4.03 ($p<0.001$) for MNA at-risk/malnutrition and OR of 2.12 ($p<0.001$) for NSI moderate and high nutritional risk. The presence of pre-frailty/frailty among the PF/F-CN was associated with an increased OR of 2.95 ($p<0.001$) for MNA at-risk/malnutrition and OR of 1.57 ($p<0.001$) for NSI moderate and high nutritional risk. Pre-frailty/frailty with cognitive impairment (PF/F-CI) was associated with the highest OR for MNA at-risk/malnutrition (OR=8.16, $p<0.001$), although not for NSI moderate and high nutritional risk (OR=1.48, $p=0.017$).

## Discussion

Physical frailty, cognitive impairment and malnutrition are related but distinct geriatric syndromes (12, 27). They are individually associated with similarly increased risk of health and functional decline, loss of independence, hospital costs, and increased mortality. They also share many sociodemographic, physical, psychological and cognitive risk factors (see Supplementary Table 2). In this study, we recapitulate the higher prevalence of malnutrition associated with physical frailty and cognitive impairment that have been summarized in previous reports (1-5). We show further that the prevalence of malnutrition was exaggerated when physical frailty and cognitive impairment were present together in the same individuals. Cognitive frailty has been shown in some prior studies to predispose older persons to especially higher risks of adverse health outcomes mentioned above (14-16). The combined impact of cognitive impairment and physical frailty among non-demented older persons on malnutrition prevalence is highlighted in this study.

There are already strong recommendations based on good evidence that in clinical and institutional settings, older persons should be screened, assessed and treated for physical frailty and malnutrition (28, 29). Frail and malnourished patients should be identified for interventions to prevent future disability and other adverse health outcomes. In ageing societies, the identification of such vulnerable older people should extend to all specialists, primary and community care providers, incorporating into routine practice simple screening tools which are already available. From a population health and prevention perspective, it is appropriate that community-dwelling pre-frail elderly who are at risk of malnutrition should be considered as intervention groups for early identification and amenable interventions in community-based and primary care settings. In this study population, only about 47% of older persons were robust and not at-risk/malnourished by MNA (43% by NSI). The others included 18% who were both physically pre-frail/frail and at-risk/malnourished by MNA (15% by NSI), the remaining proportions being either pre-frail/frail alone or at-risk/malnourished alone.

In this study population, 43.5% were pre-frail or frail, and the overall prevalence of cognitive pre-frailty/frailty was 7.1%. The prevalence of at-risk/malnutrition by MNA among the pre-frail/frail overall was 42%, and the prevalence among the cognitive pre-frailty/frailty was 63%. This isolated group of highly vulnerable older individuals are thus most likely to be malnourished.

These estimates provide useful information for decision-making strategies in planning programs for community-based and primary care interventions targeting physical frailty, cognitive impairment and malnutrition together.

It should be mentioned that the estimates of physical frailty, cognitive impairment and malnutrition/ nutritional risk in this study population are lower compared to estimates in Western studies because of the younger age of the cohort. The mean age was 66 years, whereas in a meta-analysis of 10 studies (12), the mean age was 77 years. The overall prevalence of frailty (3.2%) and pre-frailty (40.4%), is therefore lower in comparison to reported prevalence of 19.1% physical frailty and 51.6% pre-frailty in those Western studies. The prevalence of cognitive frailty in our cohort, 1.6 %, is also lower than that in a Japanese study (mean age = 71 years) which reported 2.7 % prevalence of cognitive frailty (30). The overall prevalence of malnutrition and risk of malnutrition measured by MNA are 2.4% and 26.8%. Although of the same magnitude as in the pooled results of 2 recent meta-analysis studies (6, 15), they actually represent a comparatively higher prevalence of malnutrition and risk of malnutrition given the younger age. In the meta-analysis by Verlaan et al, 8.4% of physically frail community dwelling older adults were identified as malnourished by MNA, and 42.7% were at risk of malnutrition. In comparison, we found a higher prevalence of MNA malnutrition (19%) and at risk of malnutrition (46%) among overall frail older adults in this study population, indicating a greater contribution of malnutrition to physical frailty in this Asian population.

There are methodological difficulties in using appropriate nutritional measurement tools in a study of malnutrition in relation to physical frailty and cognitive impairment. It is widely acknowledged that there is no ideally accurate measurement of malnutrition (31). The MNA assessment tool is the most widely used instrument used for screening and assessing nutritional status, but it includes questions that overlap with frailty and cognitive impairment components. Two-third of the MNA items in the long form, such as weight loss and immobility, are closely associated with frailty (32), and the inclusion of neuro-psychological problems overlap with cognitive impairment. The estimated associations of malnutrition with physical frailty and cognitive impairment may be viewed as being conflated. On the other hand, the NSI (DETERMINE Your Nutritional Health) does not include any neuropsychological measurement components, and measures a relatively greater contribution of inadequate dietary intake and nutritional deficiency due to change of eating behavioral, social-economic status, with less phenotypic overlap with the frailty and cognition criteria (Supplementary Table 3). We thus used both the MNA and the NSI as parallel measurements to detect malnutrition and nutritional risk in this study. The results were generally in consonance, but the NSI tended to reveal weaker associations compared to MNA. We also used in parallel, blood measurement indicators of malnutrition including anaemia, low albumin, low cholesterol and low lymphocyte count, which showed consistent results of association with those obtained from MNA and NSI.

## Conclusion

We observed an extraordinarily high prevalence of malnutrition and nutritional risk among older adults with cognitive frailty. This further validates the relevance and importance of the cognitive frailty construct, and underlines the importance of nutritional interventions in the prevention and treatment of cognitive frailty.

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