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ORIGINAL ARTICLE

BEHAVIORAL AND SOCIAL SCIENCES

# Risk factors predicting subtypes of physical frailty incidence stratified by musculoskeletal diseases in community-dwelling older adults: The SONIC study

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**Aim:** This study aims to identify the key risk factors that lead to subtypes of physical frailty assessed by walking speed and grip strength among community-dwelling Japanese individuals, stratified by the presence of musculoskeletal diseases (MSDs) and age group.

**Methods:** We included 302 participants aged 70 or 80 years who did not exhibit subtypes of physical frailty at baseline through the Septuagenarians, Octogenarians, Nonagenarians, Investigation with Centenarians (SONIC) study. Our study was a longitudinal study. The outcome was the incidence of subtypes of physical frailty after 3 years. Subtypes of physical frailty were defined as a weak grip strength or slow walking speed, or both, based on the Japanese version of the Cardiovascular Health Study Index. The risk factors for subtypes of physical frailty incidence were examined by age group and MSD, using multivariate logistic regressions.

**Results:** Of the 302 participants, 110 (36.4%) had MSD. Those with MSD were significantly more likely to have subtypes of physical frailty after 3 years compared with those without MSD. Among all participants, older age was a risk factor of subtypes of physical frailty ($P < 0.05$). Without MSD, older age and dissatisfied financial status were risk factors ($P < 0.05$). With MSD, older age was a risk factor ($P < 0.05$). By age group, in individuals aged 70 years old, a dissatisfied financial status was a risk factor for those without MSD ($P < 0.05$), and a higher BMI was one for those with MSD ($P < 0.05$).

**Conclusions:** Older age was a risk factor for subtypes of physical frailty, but other risk factors differed according to the presence of MSD and age. **Geriatr Gerontol Int 2024; 24: 797–805**.

**Keywords:** community-dwelling older adults, longitudinal study, musculoskeletal diseases, physical frailty.

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## Introduction

Frailty is an important issue in preventing the need for long-term care and extending healthy life expectancy. It is defined as a clinical condition of aging that indicates vulnerability to stressors and multisystem dysfunction.[1] The stage prior to frailty is called pre-frailty.[2] Worldwide, frailty can lead to adverse health outcomes such as falls, disability, and death.[1,3,4] Frailty is a state between robust and disability, and is reversible.[5] Early and accurate screening, as well as appropriate interventions, can help older adults with frailty return to robust and maintain or improve their physical functions.

The Cardiovascular Health Study (CHS) criteria by Fried are commonly used worldwide to assess physical frailty.[1] In Japan, a Japanese version (J-CHS criteria)[6] has been developed and validated.[7] Walking speed and grip strength are two of the elements of this criteria.[6] While frailty assessed by walking speed and grip strength is more accurate, precise, specific, and sensitive than other possible combinations,[8] manifests earlier in the frailty trajectory, and is a better predictor of adverse outcomes,[9] there is no established name for the type of frailty based on these elements. Frailty assessed using them can be labeled as subtypes of physical frailty and may serve as a simple screening method.

Numerous factors associated with physical frailty have been identified, including age, female sex, thinness, education years, falls, and diabetes.[10,11] Furthermore, musculoskeletal diseases (MSDs) such as osteoarthritis, spinal diseases, rheumatoid arthritis, osteoporosis, and fractures are closely associated with physical frailty.[12–14] These are the most common causes of serious long-term pain and disability.[15] Joint disease, fractures, and falls are the top three causes of long-term care needs in Japan, along with frailty.[16]

However, not all individuals with MSD show physical frailty,[17] and the pathways to its incidence remain unclear. The factors contributing to physical frailty may differ depending on the presence of MSD. Additionally, aging is the crucial factor associated with physical frailty,[2] suggesting that risk factors related to the indicence of physical frailty may differ by age. Nevertheless, little is known about the factors related to the incidence of physical frailty stratified by the presence of MSD and age group among people aged 70 years or older.

Therefore, the aim of this study was to identify the key risk factors that lead to subtypes of physical frailty as assessed by walking speed and grip strength among community-dwelling Japanese individuals, stratified by the presence of MSD and age group.

## Methods

### *Participants*

The study participants were recruited from the Septuagenarians, Octogenarians, Nonagenarians, Investigation with Centenarians (SONIC) study.[18] The narrow age-range cohorts (69–71, 79–81, and 89–91 years at baseline) were designed to minimize confounding by age. The SONIC study began in 2010, and each age group cohort is followed every 3 years. This study was approved by the Ethics Committee of the Osaka University Graduate School of Medicine, Dentistry, and Human Science and the Tokyo Metropolitan Institute of Gerontology (approval numbers: 266, H22-E9, 22 018, and 38, respectively). Details of the SONIC study have been published elsewhere.[18]

This study included 1973 participants (1000 aged 70 ± 1 years and 973 aged 80 ± 1 years) from baseline surveys conducted in 2010 and 2011. We excluded 51 individuals with missing data on MSD and subtypes of physical frailty. Additionally, 1458 individuals with subtypes of physical frailty at baseline and 162 dropouts during the 3-year follow-up were excluded. Finally, 302 participants were included: 186 aged 70 ± 1 (70) years and 116 aged 80 ± 1 (80) years. The participant selection method is shown in Figure 1.

### *Musculoskeletal diseases*

We collected data from surveys and interviews conducted by physicians or nurses at community centers in four cities across Japan (Itami City, Asago City, Itabashi Ward, Nishitama City). MSDs were defined based on the presence of osteoporosis, joint diseases and spinal diseases, rheumatoid arthritis, and fractures.[15] Joint diseases and spinal diseases include knee osteoarthritis, hip osteoarthritis, herniated discs, spinal stenosis, low back pain under treatment, lumbar spondylolisthesis, and cervical spondylolisthesis. The diagnosis of fracture was included for individuals aged 40 years or older who had experienced a fracture, in order to distinguish traumatic fractures and other fractures in non-elderly age groups. If the participants had been diagnosed with a MSD by a physician, we classified participants as "yes".

### *Incidence of physical frailty*

The outcome of this study was the new incidence of subtypes of physical frailty during the 3-year follow-up period. Subtypes of physical frailty were defined as weak grip strength or slow walking speed. Weak grip strength was defined as <26 kg for men and <18 kg for women.[6] Slow walking speed was defined as <1.0 m/s.[6] Participants were classified as having a subtype of physical frailty if they exhibited either slow walking speed or weak grip strength.

Grip strength of the dominant hand was measured twice using a Smedley hand dynamometer (Model YD-100; Yagami, Ltd, Tokyo, Japan). Measurements were taken in a sitting position, with the arms resting against the body. Mean values were calculated and used in the analyses. Walking speed was measured over a 2.44-m walking course. The test was repeated, and the mean speed was used in the analyses.

### *Factor assessment and covariate measurement*

Participants completed questionnaires regarding lifestyle habits, living arrangements, education years, frequency of going outside, self-reported financial status, and health and medical conditions. Education years were classified as <9 and ≥9 years because Japanese compulsory education lasts for 9 years. Frequency of going outside was categorized as at least three times weekly or less than twice. Participants reported their financial status by selecting from five options: "very satisfying", "satisfying", "neutral",


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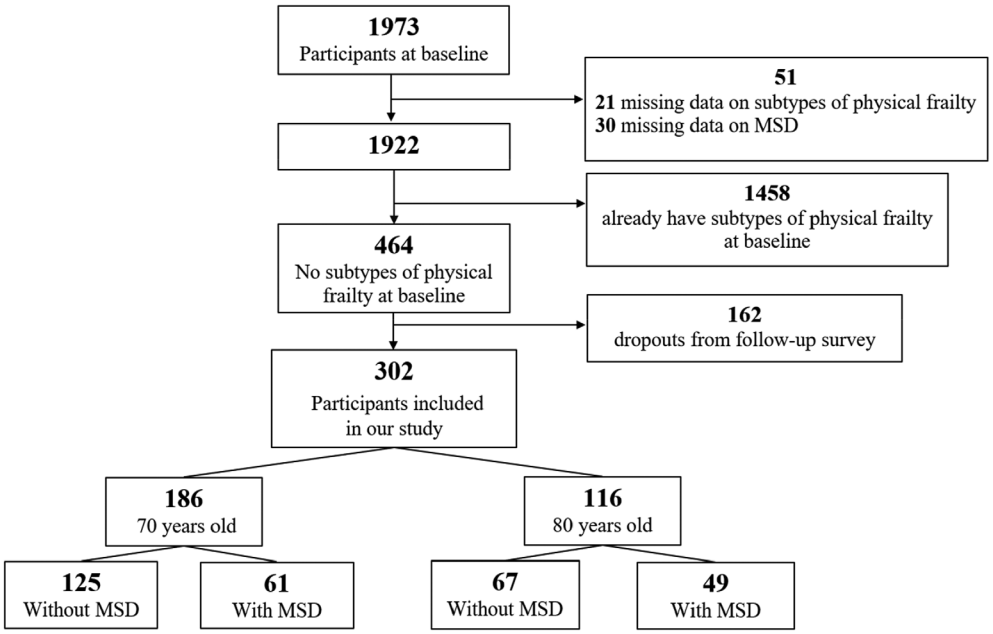


**Figure 1** Participants included in the study. MSD, musculoskeletal diseases; 70 years old, 70 ± 1 years old; 80 years old, 80 ± 1 years old.

"dissatisfying", and "very dissatisfying". Those selecting "very satisfying", "satisfying", or "neutral" were classified as satisfied, while those choosing "dissatisfying" or "very dissatisfying" were classified as dissatisfied. Height, weight, and blood pressure (BP) were measured at the survey venue. Blood samples were also collected. The levels of fasting or casual blood glucose were determined using biochemical examinations. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Hypertension was defined by antihypertensive drug use or BP levels measured at the venue (systolic BP ≥140 or diastolic BP ≥90 mmHg) based on the Japanese Society Hypertension Guidelines on Hypertension in 2019.[19] Diabetes was defined by antidiabetic drug use, hemoglobin A1c levels ≥6.5%, or blood glucose levels ≥200 mg/dL.[20]

### *Statistical analysis*

Continuous variables are reported as the mean (standard deviation, SD) or median (interquartile range, IQR), and categorical variables are reported as a number (%). Descriptive analysis of the participants was performed using Pearson's $\chi^2$ or Fisher's exact test for categorical variables and the independent *t*-test or the Mann–Whitney *U*-test for continuous variables to compare baseline characteristics between those with MSD. Continuous variables were checked a priori to see if they were normally distributed, and the Mann–Whitney *U*-test was used if they were non-normally distributed.

Participants with MSD were stratified, and the risk factors for subtypes of physical frailty incidence were examined in total participants and in each age group using multivariate logistic regressions. In multivariate logistic regression analysis, three models were used with subtypes of physical frailty as dependent variables, and variables that were revealed to be traditional risk factors of physical frailty were used as independent variables. Model 1 included age and sex. Model 2 included BMI and diabetes in addition to the variables in Model 1. Model 3 included living arrangements, education years, frequency of going outside, and self-reported financial status in addition to the variables in Model 2. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. A *P*-value of <0.05 was considered to indicate a significant difference. Statistical analyses were performed using IBM SPSS Statistics version 26 for Windows (IBM Japan, Tokyo, Japan).

## Results

Among the 302 participants followed up, 110 (36.4%) had MSD, and 192 (63.6%) did not. Table 1 shows the sociodemographic characteristics of participants according to MSD by age group. Individuals with MSD were more likely to be female (59.1% vs. 40.6%, $P = 0.002$), to have experienced a fall within the past year (27.3% vs. 9.9%, $P < 0.001$), and to take painkillers (9.1% vs. 2.6%, $P = 0.013$). In individuals aged 70 years old, those with MSD were more likely to be female (60.7% vs. 45.6%, $P = 0.006$), to have <9 years of education (24.6% vs. 11.2%, $P = 0.018$), to have experienced a fall within the past year (23.0% vs. 10.5%, $P = 0.024$), and to be less likely to go outside fewer than three times per week (6.6% vs. 18.4%, $P = 0.044$). In individuals aged 80 years old, those with MSD were more likely to be female (57.1% vs. 31.3%, $P = 0.008$) and to have experienced a fall within the past year (32.7% vs. 9.0%, $P = 0.001$).

### *Physical frailty incidence*

Figure 2 presents the incidence of subtypes of physical frailty in the 3-year follow-up survey. A total of 122 participants (40.4%) developed subtypes of physical frailty. The incidence of subtypes of physical frailty during the 3 years was significantly higher in participants with MSD than in those without MSD, among total participants (48.2% vs. 35.9%, $P = 0.037$) and those aged 80 years old (65.3% vs. 46.3%, $P = 0.042$). The incidence of subtypes of physical frailty in those aged 80 years old was significantly higher than in those aged 70 years old, regardless of the presence of MSD.

In total, 96 participants (31.8%) had slow walking speed, 41 (37.3%) from participants with MSD and 55 (28.6%) from those without MSD. A total of 46 participants (15.2%) had weak grip strength, 24 (21.8%) from participants with MSD and

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**Table 1** Characteristics of the participants

| | Total participants ($n = 302$) | | | Those aged 70 years old ($n = 186$) | | | Those aged 80 years old ($n = 116$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | All ($n = 302$) | Without MSD ($n = 192$) | With MSD ($n = 110$) | All ($n = 186$) | Without MSD ($n = 125$) | With MSD ($n = 61$) | All ($n = 116$) | Without MSD ($n = 67$) | With MSD ($n = 49$) |
| Age†, 80 years old | 116 (38.4) | 67 (34.9) | 49 (44.5) | - | - | - | - | - | - |
| Female† | 143 (47.4) | 78 (40.6) | 65 (59.1)* | 94 (50.5) | 57 (45.6) | 37 (60.7)* | 49 (42.2) | 21 (31.3) | 28 (57.1)* |
| Current Smoking†,‡, yes | 22 (7.4) | 18 (9.5) | 4 (3.7) | 19 (10.2) | 15 (12.2) | 4 (6.7) | 3 (2.6) | 3(4.5) | 0 |
| Alcohol‡, ex-drinker | 11 (3.7) | 6 (3.2) | 5 (4.6) | 9 (4.8) | 4 (3.3) | 5 (8.3) | 2 (1.7) | 2(3.0) | 0 |
| BMI§, kg/m$^2$ | 22.9 ± 2.8 | 22.9 ± 2.9 | 22.9 ± 2.6 | 23.2 ± 2.8 | 23.0 ± 2.9 | 23.6 ± 2.6 | 22.4 ± 2.8 | 22.8 ± 3.0 | 22.0 ± 2.3 |
| Living arrangements†, alone | 40 (13.2) | 22 (11.5) | 18 (16.4) | 18 (9.7) | 11 (8.8) | 7 (11.5) | 22 (19.0) | 11(16.4) | 11(22.4) |
| Education†, <9 years | 54 (17.9) | 30 (15.6) | 24 (21.8) | 29 (15.6) | 14 (11.2) | 15 (24.6)* | 25 (21.6) | 16(23.9) | 9(18.4) |
| Frequency of going outside†,‡, <3 days/week | 46 (15.2) | 33 (17.2) | 13 (11.8) | 27 (14.5) | 23 (18.4) | 4 (6.6)* | 19 (16.4) | 10(14.9) | 9(18.4) |
| Self-reported financial status†, dissatisfied | 53 (17.5) | 33 (17.2) | 20 (18.2) | 38 (20.4) | 26 (20.8) | 12 (19.7) | 15 (12.9) | 7(10.4) | 8(16.3) |
| Falling within the past year†, yes | 49 (16.3) | 19 (9.9) | 30 (27.3)** | 27 (14.5) | 13 (10.5) | 14 (23.0)* | 22 (19.0) | 6(9.0) | 16 (32.7)* |
| Taking painkillers†,‡, yes | 15 (5.0) | 5 (2.6) | 10 (9.1)* | 6 (3.2) | 2 (1.6) | 4 (1.8) | 9 (7.8) | 3(4.5) | 6(12.2) |
| Comorbidities, yes | | | | | | | | | |
| Hypertension† | 213 (72.2) | 136 (73.1) | 77 (70.6) | 117 (62.9) | 79 (66.4) | 38 (63.3) | 96 (82.8) | 57(85.1) | 39(79.6) |
| Diabetes†,‡ | 34 (11.8) | 18 (9.8) | 16 (15.2) | 23 (13.2) | 14 (11.9) | 9 (16.1) | 11 (9.6) | 4 (6.2) | 7 (14.3) |
| History of stroke‡ | 9 (3.1) | 7 (3.9) | 2 (1.9) | 5 (2.7) | 4 (3.3) | 1 (1.7) | 4 (3.4) | 3 (5.3) | 1 (2.1) |
| Heart disease† | 40 (13.5) | 28 (14.8) | 12 (11.1) | 19 (10.2) | 13 (10.5) | 6 (10.0) | 21 (18.1) | 15 (23.1) | 6 (12.5) |
| MSD | | | | | | | | | |
| Rheumatoid arthritis | 3 (1.0) | - | 3 (2.7) | 2 (1.1) | - | 2 (3.3) | 1 (0.9) | - | 1 (2.0) |
| Osteoporosis | 36 (11.9) | - | 36 (32.7) | 18 (9.7) | - | 18 (29.5) | 18 (15.5) | - | 18 (36.7) |
| Joint diseases and spinal diseases | 54 (17.9) | - | 54 (49.5) | 32 (17.2) | - | 32 (53.3) | 22 (19.0) | - | 22 (44.9) |
| Fracture | 49 (16.2) | - | 49 (44.5) | 26 (14.0) | - | 26 (42.6) | 23 (19.8) | - | 23 (46.9) |
| Albumin§, g/dL | 4.4 ± 0.3 | 4.4 ± 0.3 | 4.4 ± 0.3 | 4.5 ± 0.3 | 4.5 ± 0.3 | 4.5 ± 0.3 | 4.4 ± 0.2 | 4.4 ± 0.3 | 4.4 ± 0.2 |
| Gait speed¶, m/s | 1.1 (1.1–1.2) | 1.1 (1.1–1.2) | 1.1 (1.1–1.2) | 1.1 (1.1–1.3) | 1.1 (1.1–1.3) | 1.1 (1.1–1.3) | 1.1 (1.0–1.2) | 1.1 (1.0–1.2) | 1.1 (1.1–1.2) |
| Grip strength¶, kg | | | | | | | | | |
| Male ($n = 159$) | 32.3 (30.0–36.3) | 32.3 (29.7–37.5) | 32.3 (30.3–34.6) | 34.1 (30.5–39.3) | 35.5 (30.5–39.9) | 32.8 (30.3–35.7) | 31.3 (28.8–33.5) | 30.9 (28.7–33.6) | 31.5 (30.0–33.6) |
| Female ($n = 143$) | 21.5 (19.0–23.8) | 21.8 (19.6–24.0) | 21.0 (19.0–23.6) | 22.1 (19.9–24.1) | 22.3 (20.4–24.8) | 22.0 (19.1–24.0) | 20.0 (18.6–22.4) | 20.0 (18.6–22.6) | 20.5 (18.6–22.3) |

70 years old, 70 ± 1 years old; 80 years old, 80 ± 1 years old; BMI, body mass index; MSD, musculoskeletal diseases.

*$P < 0.05$; **$P < 0.01$; for statistical significance.

†Number (%) with Pearson's chi-square test.

‡Number (%) with Fisher's exact test.

§Mean ± standard deviation with the independent t-test.

¶Median (IQR) with the Mann–Whitney *U*-test.

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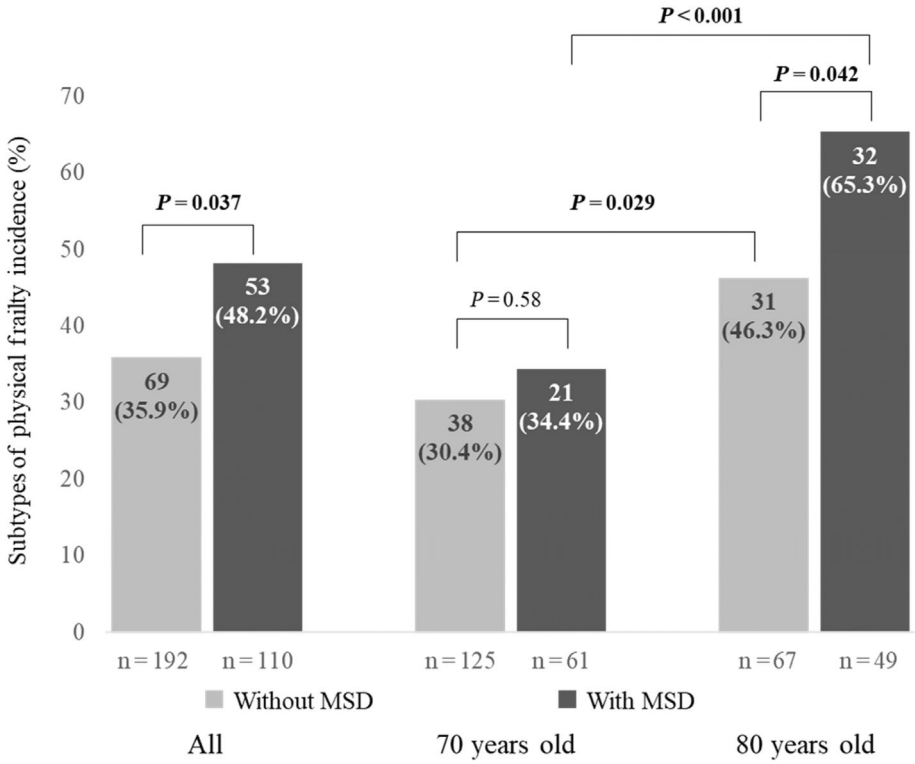


**Figure 2** Subtypes of physical frailty incidence over the 3-year follow-up. MSD, musculoskeletal diseases; 70 years old, 70 ± 1 years old; 80 years old, 80 ± 1 years old.

22 (11.5%) from those without MSD. The rate of weak grip strength was significantly higher in participants with MSD ($P = 0.016$).

### *Risk factors associated with physical frailty incidence*

Table 2 presents the results of the logistic regression analysis examining the risk factors associated with the incidence of subtypes of physical frailty. Among all participants, the incidence of subtypes of physical frailty increased with older age (OR = 2.86, 95% CI = 1.70–4.80). In individuals without MSD, older age and dissatisfied financial status were risk factors for the incidence of subtypes of physical frailty (OR = 2.18, 95% CI = 1.10–4.30; OR = 2.53, 95% CI = 1.13–5.69, respectively). In contrast, in individuals with MSD, older age was the only risk factor (OR = 6.04, 95% CI = 2.22–16.46).

Table 3 shows the risk factors associated with the incidence of subtypes of physical frailty in individuals aged 70 years old. Among all participants, diabetes was a risk factor for subtypes of physical frailty in Model 2, but not in Model 3. Dissatisfied financial status was a risk factor in participants without MSD (OR = 3.77, 95% CI = 1.46–9.73) (Model 3). A higher BMI was a risk factor in participants with MSD (OR = 1.36, 95% CI = 1.00–1.81) (Model 3).

No significant risk factors were found overall or for the presence or absence of MSD in individuals aged 80 years old (Table S1).

## Discussion

Our study revealed that the incidence of subtypes of physical frailty was significantly higher in individuals with MSD than in those without. Aging was a risk factor for subtypes of physical frailty with or without MSD. In individuals without MSD, a dissatisfied financial status was independently associated with the incidence of subtypes of physical frailty in those aged 70 years old. In individuals with MSD, a higher BMI was a risk factor in those aged 70 years old.

The incidence of subtypes of physical frailty over the 3-year period was significantly higher in individuals with MSD than in those without MSD, among total participants and those aged 80 years old. Our findings support previous studies.[13,14] Musculoskeletal disorders can cause limitations in movement, resulting in decreased muscle strength and endurance and a limited range of motion of joints.[21] In addition, pain, one of the symptoms of MSD, limits daily activities.[15] Therefore, individuals with MSD may be at an increased risk of frailty owing to limited activities of daily living (ADL).

For all participants, older age was a risk factor for subtypes of physical frailty incidence. The rate of physical frailty increases with age-related physical changes and a decline in physiological functioning.[22] The results of this study support the findings of previous studies.

Our study found that dissatisfied financial status was a risk factor for subtypes of physical frailty in 70-year-olds without MSD, expanding findings of previous studies.[11] These results indicate an association between dissatisfied financial status and physical frailty even in those without MSD. Income dissatisfaction increases malnutrition risk and inappropriate food intake,[23] which are established risk factors of frailty owing to micronutrient deficits.[24] Therefore, nutritional status might mediate the association between financial status and physical frailty incidence. Although financial issues are very difficult to resolve through interventions, we propose providing information about social security systems to

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**Table 2** Risk factors associated with incidence of subtypes of physical frailty

| | All | | | Without MSD | | | With MSD | | |
|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) |
| Age, 80 years old (ref. 70 years old) | 2.63 (1.62–4.26)*** | 2.76 (1.67–4.56)*** | 2.86 (1.70–4.80)*** | 1.97 (1.06–3.66)* | 1.96 (1.04–3.70) | 2.18 (1.10–4.30)* | 3.72 (1.37–8.29)** | 5.92 (2.30–15.25)*** | 6.04 (2.22–16.46)** |
| Sex, female (ref. male) | 1.31 (0.81–2.11) | 1.32 (0.81–2.17) | 1.43 (0.84–2.41) | 1.00 (0.54–1.84) | 0.94 (0.50–1.78) | 0.99 (0.50–1.94) | 1.65 (0.73–3.72) | 2.14 (0.87–5.23) | 2.21 (0.81–6.02) |
| BMI, kg/m$^2$ | - | 1.00 (0.92–1.10) | 1.00 (0.92–1.10) | - | 0.95 (0.85–1.05) | 0.95 (0.85–1.06) | - | 1.22 (1.01–1.48)* | 1.19 (0.99–1.44) |
| Diabetes, yes (ref. no) | - | 2.00 (0.95–4.23) | 1.87 (0.88–3.98) | - | 1.34 (0.48–3.75) | 1.16 (0.40–3.36) | - | 3.32 (0.97–11.43) | 3.41 (0.94–12.34) |
| Living arrangement, alone (ref. not alone) | - | - | 0.83 (0.39–1.79) | - | - | 0.89 (0.31–2.55) | - | - | 0.73 (0.20–2.64) |
| Education years, <9 years (ref. ≥9 years) | - | - | 1.49 (0.80–2.78) | - | - | 1.24 (0.52–2.92) | - | - | 1.96 (0.66–5.84) |
| Frequency of going outside, <3 days/week (ref. ≥3 days/week) | - | - | 1.20 (0.61–2.36) | - | - | 0.99 (0.43–2.29) | - | - | 2.39 (0.56–10.25) |
| Self-reported financial status, dissatisfied (ref. satisfied) | - | - | 1.43 (0.75–2.71) | - | - | 2.53 (1.13–5.69)* | - | - | 0.53 (0.16–1.73) |

Model 1 included age and sex; Model 2 included variables in Model 1, diabetes, and BMI; Model 3 included variables in Model 2, living arrangement, education years, frequency of going outside, and self-reported financial status as covariates.

70 years old, 70 ± 1 years old; 80 years old, 80 ± 1 years old; BMI, body mass index; CI, confidence interval; MSD, musculoskeletal disease; OR, odds ratio.

*$P$ < 0.05; **$P$ < 0.01; ***$P$ < 0.001.

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**Table 3** Risk factors associated with subtypes of physical frailty incidence in those aged 70 years old.

| | All | | | Without MSD | | | With MSD | | |
|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) | OR (95%CI) |
| Sex, female (ref. male) | 1.13 (0.61–2.09) | 1.13 (0.59–2.17) | 1.18 (0.60–2.31) | 0.82 (0.38–1.76) | 0.79 (0.35–1.76) | 0.83 (0.36–1.92) | 2.05 (0.66–6.35) | 3.06 (0.81–11.52) | 2.36 (0.57–9.69) |
| BMI, kg/m$^2$ | - | 1.04 (0.93–1.17) | 1.05(0.93–1.18) | - | 0.97(0.84–1.11) | 0.96 (0.83–1.11) | - | 1.38 (1.04–1.83)* | 1.36(1.00–1.81)* |
| Diabetes, yes (ref. no) | - | 2.58 (1.04–6.41)* | 2.29 (0.90–5.86) | - | 2.70 (0.85–8.58) | 2.37 (0.68–8.24) | - | 2.11 (0.40–11.17) | 3.26 (0.51–20.80) |
| Living arrangement Alone (ref. not alone) | - | - | 0.73 (0.23–2.30) | - | - | 0.45 (0.09–2.41) | - | - | 4.57(0.37–56.17) |
| Education years <9 years (ref. ≥9 years) | - | - | 2.13 (0.90–5.07) | - | - | 2.18 (0.59–8.01) | - | - | 2.49 (0.56–11.08) |
| Frequency of going outside <3 days/week (ref. ≥3 days/week) | - | - | 0.81 (0.31–2.09) | - | - | 0.78 (0.26–2.36) | – | – | 0.35 (0.02–6.35) |
| Self-reported financial status Dissatisfied (ref. Satisfied) | - | - | 1.71 (0.78–3.76) | - | - | 3.77 (1.46–9.73)** | - | - | 0.23 (0.02–1.84) |

Model 1 included sex; Model 2 included variables in Model 1, diabetes, and BMI; Model 3 included variables in Model 2, living arrangement, education years, frequency of going outside, and self-reported financial status as covariates.

70 years old, 70 ± 1 years old; BMI, body mass index; CI, confidence interval; MSD, musculoskeletal disease; OR, odds ratio.

*$P < 0.05$, **$P < 0.01$.

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ensure that support reaches those in need, and using the power of local communities through volunteers or non-profit organizations.

While the association between a lower BMI and frailty is well established, our study revealed that a higher BMI was a risk factor among individuals aged 70 years with MSD. Generally, a higher BMI often signals more adipose tissue, potentially weakening muscles and reducing physical function. Adipose tissues also release inflammatory proteins such as CRP, TNF-α, IL-6, and IL1β, promoting chronic inflammation and muscle atrophy.[25] This can worsen muscle weakness, physical function, and the risk of frailty. Based on our research, we propose helping individuals aged 70 years with MSD to manage their BMI as a strategy to prevent frailty. However, this approach may not be as effective for those aged 80 years, as higher BMI did not seem to be a risk factor at that age. Kuzuya highlighted the necessity of tailored preventive measures for individuals under 75, and individualized measures require either preventing overnutrition to avoid lifestyle-related diseases or preventing undernutrition to avoid the need for nursing care and frailty.[26] Therefore, it is suggested that BMI control is advisable for individuals under 75, whereas for those over 75, intervention may not always be necessary.

When classified by the presence or absence of MSD, no specific risk factors were found among individuals aged 80 years old. Given that aging is a risk factor for the incidence of subtypes of physical frailty and that those with MSD had a significantly higher incidence of subtypes of physical frailty than those without MSD among individuals aged 80 years, our results suggest that older age and having MSD play an important role in subtypes of physical frailty for those aged 80 years old.

One strength of our study is that it is part of the SONIC study, which is a longitudinal study involving community residents within a narrow age range of 70 ± 1 and 80 ± 1 years old. This allowed us to examine differences in the effects of aging on the association between risk factors for subtypes of physical frailty and MSD. Another strength is that multidisciplinary teamwork was involved, from physicians, dentists, nurses, dietitians, and psychologists, which contributed to reliable data collection and accounted for a variety of important factors.

There were several limitations to our study. First, the participants were limited to those who could visit a local survey venue, potentially introducing selection bias and including individuals with relatively well-maintained activities of daily living. Second, subtypes of physical frailty were assessed based solely on walking speed and grip strength. Further assessments of physical frailty should consider comprehensive measures, including, for example, weight loss, fatigue, and exercise habits. However, the objective indicators used in our study, namely walking speed and grip strength, are considered reliable indicators of physical function and capture the physical function of older individuals adequately.

In conclusion, older age was a risk factor for subtypes of physical frailty assessed by walking speed and grip strength, but other risk factors differed according to the presence of MSD and age. Among 70-year-old individuals without MSD, a dissatisfied financial status was a risk factor. Among 70-year-olds with MSD, a higher BMI increased the risk of subtypes of physical frailty. MSD was a risk factor for 80-year-old individuals. Offering support through information on social security systems and resources for 70-year-olds without MSD and maintaining an appropriate weight for those with MSD could prevent frailty. Preventive care for physical frailty in older adults should consider age and the presence of MSD.

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## Disclosure statement

The authors declare that they have no competing interests.

## Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

**Table S1.** Risk factors associated with subtypes of physical frailty incidence in those aged 80 years old.

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