**RESEARCH ARTICLE**

# Association among muscle strength from upper and lower limb with risk of falls in elderly

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**Abstract:**

**Background:** Falls represent a serious public health problem, especially for the elderly, and are associated with high rates of morbidity and mortality, decreased functional capacity, and early institutionalization. Falls have a multifactorial etiology, with muscle weakness being a significant risk factor. **Objectives:** To analyze the association between upper and lower limb muscle strength and the risk of falls in the elderly. **Methods:** This is a cross-sectional observational study with 81 individuals aged ≥ 60 years. Participants were subjected to the following assessment instruments International Physical Activity Questionnaire - IPAQ (short version), the Timed Up and Go Test (TUG), the handgrip strength test (HST), and the 30-second chair stand test. **Results:** Associations were observed between physical activity and HST ($p = 0.004$) and TUG ($p = 0.010$). Age was significantly associated with performance in the chair stand and rise test ($p = 0.042$) and TUG ($p < 0.001$). Multiple linear regression demonstrated that HST and age are predictors of the risk of falls. **Conclusion:** Low HST is a predictor of falls in the elderly (determined by TUG). Physically active elderly individuals had higher HST and a lower risk of falls compared to insufficiently active elderly individuals.

**Keywords:** Handgrip strength; muscle strength; falls; elderly.

## BACKGROUND

Falls represent a serious public health issue, particularly for the elderly[1, 2], and are associated with high rates of morbidity and mortality, decreased functional capacity, and early institutionalization[1]. Falls are the second leading cause of unintentional injury-related deaths worldwide, accounting for 40% of all injury-related deaths among the elderly. It is estimated that 37.3 million falls per year are severe enough to require medical attention[1]. The risk of falling increases with age for various reasons, including weakness and frailty, balance problems, cognitive issues, vision problems, medications, illnesses, and environmental hazards.

Falls have a multifactorial etiology, and muscle weakness is a significant risk factor[2-5]. The World Health Organization (WHO) estimated that individuals with muscle weakness are five times more likely to experience falls compared to those with normal muscle strength[1]. In this context, handgrip strength (HGS) is a convenient, reliable, and globally used neuromuscular assessment in clinical practice. Assessing HGS helps identify individuals with low strength, which can contribute to the development of specific preventive healthcare services aimed at reducing the risk of morbidity, mortality, and dependence in activities of daily living[6].

Low HGS is independently associated with a significantly higher risk of falls[3]. Moreover, low HGS is linked to reduced mobility and dependence in the daily activities of the elderly. Studies also indicate that falls are more frequent among elderly individuals with low HGS and reduced walking speed[7, 8].

Additionally, lower limb muscle weakness is a predictor of falls. A meta-analysis of prospective studies showed that lower limb muscle weakness was associated with a 1.5-fold increased risk of falls in the elderly, while upper limb muscle weakness was associated with a 1.7-fold increased risk[9].

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A practical and applicable test to measure lower limb strength is the chair stand test[10]. Therefore, the main objective of this study was to analyze the association between upper and lower limb muscle strength and the risk of falls in the elderly.

## METHODS

### Study Design

This study was part of a project called "Conviver," conducted from 2022 to 2023. It is an observational cross-sectional study involving individuals aged 60 years or older residing in Goianésia (GO), Brazil. The research was approved by the Research Ethics Committee of the Evangelical University of Goiás (protocol nº. 60995722.2.0000.5076) and was conducted following ethical standards established in the Helsinki Declaration. All participants were fully informed about the risks associated with participating in the study and provided written informed consent.

### Population and Sample

A convenience sample was recruited from the "Centro de Convivência dos Idosos Gibrail Kinjo Esber Brahin". Volunteers were invited to participate in the research after a presentation and clarification session. A total of 280 elderly individuals volunteered and were included in the study. To assess the statistical power of the sample, GPOWER software version 3.1.9.7 was used, employing the family F test under the reference of multiple linear regression with an effect size of 0.3280212, calculated using the correlation coefficient (R2) of 0.247 obtained in the analysis of handgrip strength (HGS) and age as predictors of the risk of falls. For this purpose, $\alpha = 0.05$, predictors = 2, and participants = 81 were adopted.

Inclusion criteria required participants to be aged ≥ 60 years, enrolled in the "Projeto Conviver," free from severe visual and auditory deficits that would hinder test administration, and capable of understanding and responding to the applied instruments. Elderly individuals with a history of cardiovascular diseases or events (e.g., acute myocardial infarction, stroke, coronary artery disease, arrhythmias, peripheral vascular disease), musculoskeletal limitations preventing physical testing, those who refused to sign the Informed Consent Form (ICF), or those scoring below 13 points on the Mini-Mental State Examination (MMSE) were excluded.

### Instruments and Data Collection

After inclusion in the study and signing the ICF, elderly individuals underwent an initial assessment through an interview (semi-structured questionnaire for sample characterization). Subsequently, the level of physical activity was measured using the International Physical Activity Questionnaire - IPAQ (short version)[11], the Mini-Mental State Examination (MMSE) for cognitive screening, and anthropometric data (body weight and height). The time taken to complete each questionnaire was approximately 5 minutes.

Following the questionnaire administration, physical-functional data were collected, including (a) the Timed Up and Go Test (TUG), (b) Bilateral handgrip strength test, and (c) 30-second chair stand test. The time required to perform each test was approximately 5 minutes. Between each physical test, participants had a 5-minute rest before initiating the next test. A familiarization session was conducted to reduce the learning effect. After 48 hours, the retest was performed in the same order (TUG test, handgrip strength test, and 30-second chair stand test).

### TUG Test

With a chair placed on the ground, a cone was positioned 3 meters away. The participant started the test seated in the chair with feet on the floor and back against the chair. Upon the "go" signal, the individual would stand up, move to the right or left, go around the cone, return to the chair, and sit down again. This test was performed in triplicate, and the shortest time was recorded. Participants were instructed to walk at a comfortable (non-running) and safe pace, using their usual shoes and without any physical assistance[12].

**Handgrip Strength Test**

Handgrip strength was measured using a hydraulic hand dynamometer (model 5030 J1, Sammons Preston Rolyan, Bolingbrook, IL, USA). Three attempts at maximum voluntary handgrip strength were made, with a 30-second interval between attempts, for both the right and left hands, alternating sides during the attempts. Elderly individuals were instructed to remain seated in a chair (without forearm support), with an upright posture, knees flexed at 90°, shoulders close to the body in a neutral rotation, elbows flexed at 90°, and forearm and wrist in a neutral position (intermediate between pronation and supination)[13]. Participants were given the command to "squeeze the device as tightly as you can" and were instructed to grip as hard as possible and hold for 3 seconds. The procedure was performed in triplicate, with the average of three attempts considered[14].

**30-Second Chair Stand Test**

Volunteers were instructed to cross their arms against their chest. Upon receiving the verbal command, the participant would stand up completely and then return to a fully seated position. Participants were encouraged to sit and stand as many times as possible in 30 seconds. The result was determined by counting the number of times the participant correctly performed the chair stand and rise movements[10].

**Statistical Analysis**

Data normality was tested using the Shapiro-Wilk test, as well as skewness, kurtosis, graphical analysis, and histograms. Descriptive analyses, measures of central tendency (mean and median), dispersion analyses (standard deviation [SD] and interquartile range [IQR]), and frequency distribution (absolute and relative) were used. To compare handgrip strength, chair stand and rise test, and TUG test based on activity level and sedentary behavior, independent samples t-tests were used for handgrip strength, and the Mann-Whitney U test was used for the chair stand and rise test and the TUG test.

To assess associations of HGS, chair stand and rise test, and TUG test according to age group (60-69 years, 70-79 years, and ≥80), the chi-squared test was used. HGS, chair stand and rise test, and TUG test were transformed into dichotomous variables (high and low performance) by dividing participants by the median values of the variables. Multiple linear regression was used to determine whether handgrip strength and age were predictors of the risk of falls. Linear regression models were constructed to determine the correlation between performance in the HGS, chair stand and rise test, and TUG test with sociodemographic variables, level of education, MMSE score, presence of hypertension, cancer, fibromyalgia. The beta (β) value and their respective 95% confidence intervals (CI) were calculated. Modeling was done by the backward stepwise method, where all variables listed for adjustments were entered into the model and then removed one by one, considering the highest "p-values."

The association between physical activity level and performance in the HGS, chair stand and rise test, and TUG test was assessed using Poisson regression with robust estimator, calculating Prevalence Ratios (PR) and their respective 95% CIs. Modeling was done by the backward stepwise method, where all variables listed for adjustments, and control for possible confounders (MMSE and age), were entered into the model and then removed one by one, considering the highest "p-values." All procedures were carried out using the Statistical Package for the Social Sciences (SPSS) version 26.0, and a significance level of 5% was adopted.

## RESULTS

In the study, 81 individuals participated, with a mean age of 69 ± 6.3 years, and 93.8% were female (n=76). The mean body mass was 62.2 ± 13.7 kg, mean height was 157 ± 6.1 cm, and mean BMI was 26.3 ± 5.0 kg/m². Other descriptive variables are presented in Table 1.

**Table 1.** Sociodemographic characteristics of the elderly involved in the study

| Characteristics | n | % |
|---|---|---|
| **Age** | | |
| 60-69 years old | 47 | 58 |
| 70-79 years old | 30 | 37 |
| >80 years old | 4 | 5 |
| **Falls** | | |
| Yes | 63 | 77,8% |
| Not | 18 | 22,2% |
| **Race** | | |
| White | 26 | 32,1 |
| Brown | 45 | 55,5 |
| Black | 10 | 12,3 |
| **Marital status** | | |
| Marriage | 32 | 39,5 |
| Divorced | 12 | 14,8 |
| Single | 6 | 7,4 |
| Widower | 31 | 38,3 |
| **Education** | | |
| Illiterate | 16 | 19,5 |
| Completed primary school | 10 | 12,3 |
| Incompleted primary school | 42 | 51,9 |
| Completed secondary school | 8 | 9,9 |
| Incompleted secondary school | 2 | 2,5 |
| Post-graduation | 3 | 3,7 |
| **Monthly income** | | |
| 0 | 4 | 4,9 |
| 1 | 42 | 51,9 |
| 2 | 22 | 27,2 |
| 3 | 5 | 6,2 |
| 4 | 3 | 9,8 |
| **Level of physical activity** | | |
| Sufficiently active | 73 | 90,1 |
| Insufficiently active | 8 | 9,9 |
| **Sedentary behavior** | | |
| Low SC | 61 | 75,3 |
| High SC | 20 | 24,7 |

The comparison of HGS, muscle strength, and the risk of falls in the elderly based on age is shown in Table 2. A significant difference was observed for the chair stand and rise test (SRT) (p=0.042) and TUG (p <0.001).

**Table 2.** Comparison of palmar grip strength, muscle strength, and risk of falls according to the age of the elderly.

| Variable | Age (years) | | | *p* |
|---|---|---|---|---|
| | 60 to 69<br>n = 47 | 70 to 79<br>n = 30 | >80<br>n = 4 | |
| Hand grip strength (kg) | 22,6 ± 5,1 | 21,1 ± 5,7 | 21,4 ± 4,2 | 0,446 |
| Sit and stand test (rep) | 13 [4] | 11 [5] * | 9,5 [6] | 0,042 |
| Timed Up and Go Test (s) | 8,5 [2] | 10,1 [2,9] * | 11 [5,4] * | <0,001 |

Note: Data expressed as mean and standard deviation for palmar grip. Median and interquartile range (IQR) for stand and rise test (SRT) and TUG. kg: kilograms. rep: repetitions. s: seconds. *Significant difference for individuals aged 60 to 69 years.

Physically active elderly individuals showed better performance in the HGS (p = 0.004) and TUG (p = 0.010) tests compared to insufficiently active elderly individuals. Additionally, elderly individuals with low sedentary behavior time demonstrated better performance in the SRT (p = 0.030) and TUG (p = 0.049) tests (Table 3).

**Table 3.** Comparison between the hand grip strength, Stand and Rise test, and Timed Up and Go tests and their relationship with physical activity level and sedentary behavior in the elderly.

| Tests | Level of Physical Activity | | | Sedentary Behavior | | |
|---|---|---|---|---|---|---|
| | Physically Active | Insufficiently Active | *p* | Low SC | High SC | *p* |
| HGS (kg) | 22,56 ± 5,09 | 17,06 ± 4,32 | 0,004 | 22,41 ± 5,03 | 20,82 ± 5,86 | 0,240 |
| RST (rep) | 12,00 [4,00] | 9,00 [9,00] | 0,090 | 12,00 [4,00] | 10,5 [6,00] | 0,030 |
| *TUG* (s) | 9,1 [2,40] | 12,6 [5,00] | 0,010 | 9,1 [2,35] | 9,8 [2,85] | 0,049 |

Note: Data expressed as mean and standard deviation for palmar grip strength. Median and interquartile range (IQR) for RST (stand and rise test) and Timed Up and Go test (TUG). kg: kilograms. rep: repetitions. s: seconds.

Table 4 demonstrates the association between the level of physical activity and performance in the HGS, RST, and TUG tests adjusted for upper limbs and age. Table 5 shows the association of age with performance in the HGS, RST, and TUG tests in the elderly.

**Table 4.** Univariate and multivariate analysis of the association between physical activity level and the HGS, RST, and TUG tests

| Variables | Level of Physical Activity | | | |
|---|---|---|---|---|
| | Univariate Analysis<br>RP [CI 95%] | p* | Multivariate Analysis<br>RP [CI 95%] | p* |
| HGS | 0,83 [0,75 – 0,92] | <0,001 | 0,84 [0,76 – 0,91] | **<0,001** |
| RST | 0,82 [0,65 – 1,02] | 0,071 | 0,99 [0,89 – 1,11] | 0,940 |
| TUG | 1,19 [1,06 – 1,34] | 0,001 | 1,23 [1,08 – 1,42] | **0,003** |

Note: *Wald test. PR: prevalence ratio. HGS: hand grip strength. RST: sit-to-stand test. TUG: time up and go.

**Tabela 5.** Association between age and performance in the hand grip strength, Timed Stair Climb, and Timed Up and Go tests in the elderly involved in this study

| Variables | Age (years) | | | p |
|---|---|---|---|---|
| | 60 to 69<br>n (%) | 70 to 79<br>n (%) | >80<br>n (%) | |
| HGS | | | | 0,206 |
| High | 27 (57,4) | 11 (37,7) | 2 (50) | |
| Low | 20 (42,6) | 19 (63,3) | 2 (50) | |
| RST | | | | 0,168 |
| High | 25 (53,2) | 10 (33,3) | 1 (25) | |
| Low | 22 (46,8) | 20 (66,7) | 3 (75) | |
| TUG | | | | <0,001 |
| High | 33 (70,2) | 7 (23,3) | 1 (25) | |
| Low | 14 (29,8) | 23 (76,7) | 3 (75) | |

Note: HGS: hand grip strength. RST: sit-to-stand test. TUG: time up and go.

Multiple linear regression resulted in a statistically significant model [F(2,77) = 12.634, p < 0.001; R2 = 0.247], demonstrating that handgrip strength (β = -0.252; t = -2.537; p = 0.013) and age (β = 0.400; t = 4.023; p < 0.001) are predictors of the risk of falls. The risk of falls, determined by performance in the TUG test in seconds, corresponds to 0.085 - 0.140 x (handgrip strength) + 0.185 x (age). The model that tested the correlation of HGS proved to be statistically significant [F(3,77) = 6.576, p = 0.001; R2 = 0.204]. HGS remained correlated with hypertension (β = 3.028; 95% CI: 0.72–5.34; t = 2.611; p = 0.011), cancer (β = 7.729; 95% CI: 3.07–12.39; t = 3.305; p = 0.001), and MMSE (β = 0.285; 95% CI: 0.03–0.54; t = 2.248; p = 0.027).

The model that tested the correlation of RST proved to be statistically significant [F(1,79) = 7.975, p = 0.006; R2 = 0.092]. Only MMSE remained correlated with TSL (β = 0.340; 95% CI: 0.10–0.58; t = 2.824; p = 0.006). Similar results were found in the model that tested the correlation of TUG, which was statistically significant [F(1,79) = 11.874, p = 0.001; R2 = 0.131], and MMSE remained correlated (β = -0.249; 95% CI: -0.39 – -0.11; t = -3.446; p = 0.001).

**DISCUSSION**

The present study showed that physically active elderly individuals have HGS and a lower risk of falls compared to insufficiently active elderly individuals; that age and HGS are predictors of falls in the elderly, as determined by the TUG test; and that elderly individuals over 80 years old performed worse in the RST test and TUG test compared to those aged 60-69 years. All the physical-functional tests used in this study are validated and recognized worldwide(15). These tests are reproducible, applicable, simulate activities of daily living for elderly patients, and are related to morbidity(14) and mortality(16).

Insufficiently active elderly individuals showed poorer performance in TUG and HGS. These results highlight the importance of active aging and its impact on physical-functional aspects such as muscle strength, walking speed, and dynamic balance. Our results align with a study(17) involving a representative sample (n = 81,473) that showed an association between physical disability, cardiovascular diseases, and TUG.

Traditionally, the TUG test has been used as an indicator of a higher risk of falls. However, TUG can have new implications in geriatrics and gerontology. For instance, a study tracked elderly individuals (> 85 years) for five years[18] and found that routine laboratory tests (Polymerase Chain Reaction - PCR, homocysteine, hemoglobin, High density lipoprotein - HDL, ALT, albumin, and creatinine) were as accurate in predicting mortality as physical-functional capacity, specifically the gait speed test.

In our study, elderly individuals aged over 80 performed worse in the TUG and RST tests compared to those aged 60-69. There is a relationship between age, TUG performance, and lower limb muscle strength[19]. TUG is a commonly used clinical performance measure to assess lower limb function, mobility, and fall risk. It encompasses movements used in daily life, such as balance, walking speed, and functional abilities like sitting and standing. On the other hand, RST is a biomechanically demanding movement due to the transition from a stable sitting position to standing, requiring complex muscle coordination to maintain balance and stability as one rises[10].

Another interesting result in our study is that the risk of falls in the elderly, as determined by the TUG, may be related to HGS. In this regard, HGS can be a predictor of falls in the elderly, and it is a quick, technically safe, and validated test. Measuring HGS is recommended regardless of the level of physical activity[20].

The risk of falls has been associated with various factors, including individual components of sarcopenia[3], such as loss of muscle mass, frailty syndrome[21], and age-related physical function1. A study involving octogenarian and nonagenarian women showed a significant correlation between age and TUG and RST times, emphasizing the importance of these tests in the elderly population and their risk for falls.

According to the frailty phenotype proposed by Fried[21], frailty criteria include weakness or low HGS, slow walking speed, and low physical activity levels. Frailty is a predictor of adverse outcomes such as falls, hospitalizations, disabilities, and death. It is associated with various chronic diseases, including cardiovascular and pulmonary diseases, as well as mortality.

Low HGS can also be a predictor of sarcopenia and frailty syndrome. According to the European Consensus on Sarcopenia[22], women and men with low HGS have a higher risk of sarcopenia, with cutoff values of 16 kg and 27 kg, respectively. If a patient presents low HGS, low muscle mass, and physical-functional decline confirmed by TUG, they may be diagnosed with severe sarcopenia.

Despite the clinically significant results, our study has some limitations, as follow: the number of male elderly participants and the relatively small number of elderly participants over 80 years old. Therefore, we suggest the need for further studies with larger samples to analyze the association between upper and lower limb muscle strength and the risk of falls in the elderly.

## CONCLUSIONS

The results of our study indicate that low handgrip strength is a predictor of falls in the elderly, as determined by the TUG. Additionally, physically active elderly individuals have higher handgrip strength and a lower risk of falls compared to insufficiently active elderly individuals.

**Author Contributions:** EVC contributed to the design of the project, and development of the study and data collection. RPV contributed to the critical review, data analysis, correction, and approval of the final version.

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**Conflict of interest:** No author has a conflict of interest to declare.

## REFERENCES


1 WHO. Falls. 2021.https://www.who.int/news-room/fact-sheets/detail/falls#:~:text=Falls are the second leading,-and middle-income countries. [accessed 2020 Aug 29]

2 Cuevas-Trisan R. Balance Problems and Fall Risks in the Elderly. Clin Geriatr Med 2019; 35: 173–183.

3 Neri S, Lima R, Ribeiro H, Vainshelboim B. Poor handgrip strength determined clinically is associated with falls in older women. J Frailty, Sarcopenia Falls 2021; 06: 43–49.

4 Cuevas-Trisan R. Balance Problems and Fall Risks in the Elderly. Phys Med Rehabil Clin N Am 2017; 28: 727–737.

5 Sim M, Prince R, Scott D, Daly R, Duque G, Inderjeeth C et al. Utility of four sarcopenia criteria for the prediction of falls-related hospitalization in older Australian women. 2018. Osteoporos Int 2019; 30: 167-176.

6 Bohannon R. Grip strength: An indispensable biomarker for older adults. Clin Interv Aging 2019; 14: 1681–1691.

7 Bonadias A, Gonçalves S, Neri R, Toledo O, Cristina J, Bottaro M et al. Muscle quality is associated with dynamic balance , fear of falling , and falls in older women. Exp Gerontol 2018; 104: 1–6.

8 McGrath R, Blackwell T, Ensrud K, Vincent B, Cawthon P. The Associations of Handgrip Strength and Leg Extension Power Asymmetry on Incident Recurrent Falls and Fractures in Older Men. J Gerontol A Biol Sci Med Sci 2021; 76: e221–e227.

9 Moreland J, Richardson J, Goldsmith C, Clase C. Muscle weakness and falls in older adults: a systematic review and meta-analysis. J Am Geriatr Soc 2004; 52: 1121–1129.

10 Jones C, Rikli R, Beam W. A 30-s Chair-Stand Test as a Measure of Lower Body Strength in Community-Residing Older Adults. Res Q Exerc Sport 1999; 70: 113–119.

11 Matsudo S, Araújo T, Matsudo V, Andrade D, Andrade E, Oliveira L et al. Questionário Internacional De Atividade Física (Ipaq): Estupo De Validade E Reprodutibilidade No Brasil. Rev Bras Atividade Física Saúde 2012; 6: 5–18.

12 Rikli R, Jones C. Development and validation of a functional fitness test for community-residing older adults. J Aging Phys Act 1999; 7: 129–161.

13 Marin R, Pedrosa M, Moreira-Pfrimer L, Matsudo S, Lazaretti-Castro M. Association Between Lean Mass and Handgrip Strength With Bone Mineral Density in Physically Active Postmenopausal Women. J. Clin. Densitom. 2010; 13: 96–101.

14 Bohannon R. Muscle strength: Clinical and prognostic value of hand-grip dynamometry. Curr Opin Clin Nutr Metab Care 2015; 18: 465–470.

15 Rikli R, Jones C. Development and validation of a functional fitness test for community-residing older adults. J Aging Phys Act 1999; 7: 129–161.

16 Balogun S, Winzenberg T, Wills K, Scott D, Jones G, Aitken D et al. Prospective associations of low muscle mass and function with 10-year falls risk, incident fracture and mortality in community-dwelling older adults. J Nutr Heal Aging 2017; 21: 843–848.

17 Son K, Shin D, Lee J, Kim S, Yun J, Cho B. Association between timed up and go test and future incidence of disability: A nationwide representative longitudinal study in Korea. PLoS One 2022; 17: 1–12.

18 van Houwelingen A, den Elzen W, Mooijaart S, Heijmans M, Blom J, de Craen A et al. Predictive Value of a Profile of Routine Blood Measurements on Mortality in Older Persons in the General Population: The Leiden 85-Plus Study. PLoS One 2013; 8: 1–8.

19 Zarzeczny R, Nawrat-Szołtysik A, Polak A, Maliszewski J, Kiełtyka A, Matyja B et al. Aging effect on the instrumented Timed-Up-and-Go test variables in nursing home women aged 80-93 years. Biogerontology 2017; 18: 651–663.

20 Villamizar-Pita P, Angarita-Fonseca A, de Souza H, Martínez-Rueda R, Villamizar García M, Sánchez-Delgado J. Handgrip strength is associated with risk of falls in physically active older women. Health Care Women Int 2022; 43: 1301–1314.

21 Fried L, Tangen C, Walston J, Newman A, Hirsch C, Gottdiener J et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001; 56: M146-56.

22 Cruz-Jentoft A, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019; 48: 16–31.