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Association of regional muscle strength with mortality and hospitalisation in older people

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Abstract

Background: the association between muscular strength, mortality and hospitalisation with ageing can change depending on sex and the body region analysed (e.g. upper and lower limb muscles).

Objective: to determine the effect of measuring lower and upper extremities muscular strength on the relationship between strength, mortality and hospitalisation risk in elder men and women.

Design: a population-based cohort study using data from the Toledo Study for Healthy Aging (TSHA).

Methods: a Spanish population sample of 1,755 elders aged ≥65 years participated in this study. Upper (handgrip and shoulder) and lower limbs (knee and hip) maximal voluntary isometric strength was obtained using standardised techniques and equipment. Cox proportional hazards model was used to examine mortality and hospitalisation over 5.5 and 3 years of follow-up, respectively.

Results: after adjustment for potential confounding factors, including co-morbidities and BMI, hazard ratio of death and hospitalisation was significantly lower in the stronger women and men, but showing regional- and sex-specific differences. That is shoulder, knee and hip muscle regions in women and handgrip and shoulder in men (all $P < 0.05$). There was a cumulative effect of measuring several muscle strengths over the risk of health events ($P < 0.05$), so that mortality hazard ratio increased by 45% in women and 25% in men per muscular strength (shoulder, grip, knee and hip) in the weaker strength quartile increase ($P < 0.01$).

Conclusions: regional muscle strength is a predictor of medium-term mortality and hospitalisation in elder men and women. Multiple strength measures including lower and upper body limb muscles are better predictors than a single strength measurement.

Keywords: *ageing, regional muscle strength, sex, hospitalisation, death, older people*

Introduction

Decline in muscle strength and function is a well-known consequence of the ageing process. In fact, it has been reported that by the seventh and eighth decade of life, maximal voluntary contractile strength is decreased, on average, up to 30% for both men and women in proximal and distal muscles [1]. There is growing evidence that objective measures of physical performance, especially muscle strength, act as markers and predictors of current and future health outcomes, including cardiovascular disease, fractures, cognitive outcomes, institutionalisation and hospitalisation, in elderly people [2]. Grip strength is typically favoured over other types of muscle strength tests in epidemiological studies due to its ease of measurement, higher reliability and relative low cost. Therefore, most studies about strength and health outcomes or mortality in elderly people use this type of strength [3–5]. Several studies have shown that poor grip strength predicts increased all-cause mortality and hospitalisation in older people [3–8]. Cooper *et al.* carried out a meta-analysis with a total of 44,636 participants and found that higher grip strength was associated with lower subsequent mortality. In most of studies included, people in the weakest sex-specific quartile of grip strength had significantly higher rates of mortality than did those in the strongest quarter [9]. Furthermore, the association persisted after adjustment for body size and was not explained by nutritional status, the presence of chronic disease or degree of physical activity. Cooper and colleagues recognised sex as a potential source of heterogeneity on the effects of physical capability on mortality, as well as another previous study from our research group evaluating the associations between physical activity and strength during the ageing process [9–11]. These evidences suggest that sex should be taken into consideration when exploring the relationship between muscle strength and health events in elders.

There are important limitations in the use of grip strength as a marker of muscle function. Those include the choice of equipment and measurement protocol that can vary widely between studies, as reviewed by Roberts *et al.* [12]. Moreover, although lower extremity strength is deemed to be of great importance in daily functioning in real life, less is known about its association with the risk of mortality in elders [13–16]. To our knowledge, there is a lack of studies that tested whether the association between upper and lower extremities strength and longevity varies throughout the ageing process; therefore, we hypothesise that the effect of muscle strength over all-cause mortality and hospitalisation events varies if it is measured in the lower or upper body extremities, being this association modulated by sex.

Therefore, the aims of this study were to confirm, in an elderly Spanish population, the well-known affirmation that grip strength is associated with higher risk of health events (death and hospitalisation) and to clarify whether muscle strength in other muscular groups (shoulder, hip and knee) has a similar association, after adjustment for body size and other confounders. We also aimed to test whether these associations show the same pattern between sexes.

Methods

Study design and participants

Data were taken from the Toledo Study for Healthy Aging (TSHA), whose complete methodology has been reported elsewhere [17–19]. Briefly, the TSHA is a population prospective cohort study aimed at studying the determinants and consequences of frailty in institutionalised and community-dwelling individuals older than 65 years living in the province of Toledo, Spain. Data were collected in three stages. In the first one, six psychologists conducted computer-assisted interviews, performed face to face. In the second stage, three nurses did a physical examination and performed some clinical and performance tests at the subject's home. In the third stage, the participants went to their health centre to provide a blood sample while fasting. For this study, we used data from the participants in the TSHA who had undergone the psychological interview and nursing assessment. Only the subjects included in the second stage (nursing physical examination) (1,972 subjects) and that completed the four strength measurements (grip, shoulder abduction, hip flexion and knee extension) were considered. Therefore, the final sample was compounded by 1,755 participants: 985 women (56.1%) and 770 men (43.9%). Baseline data were collected from June 2006 until September 2009. The study obtained the approval from the Local Ethics Committee and the participants provided written informed consent.

Measurements

Anthropometrics and confounding variables

Height was measured to the nearest centimetre using a portable stadiometer (Medizintechnik seit 1890, KaWe, Germany), and weight was measured with a SECA precision scale (SECA 884 floor scale, Germany). Individuals removed their shoes, socks and heavy clothes prior to weighing. BMI was calculated as weight (kg) divided by height^2 (m^2).

For quantification of co-morbidities, a questionnaire version of the Charlson Comorbidity Index was used [20]. We also assessed depressive symptoms by a 15-item Yesavage Geriatric depression scale (GDS) [21].

Muscle strength tests

Upper limb (grip and shoulder abduction) and lower limb (knee extensors and hip flexors) maximal voluntary isometric strength was measured in kilograms in all subjects using a hydraulic hand dynamometer (Jamar Preston, Jackson, MI, USA) and a manual muscle test system (Lafayette, IN, USA). All measurements were gathered using international standard procedures [22, 23]. For each participant, the dominant upper and lower limbs were selected for measurements. The maximal voluntary contraction (MVC) was measured in the sitting position during shoulder abduction: leg raises and leg extension. During 6 s, subjects were encouraged to exert the highest strength against a fixed manual dynamometer in the lowest time. The best of three attempts, with at least 1-min resting periods in between, was recorded. MVC (kg) was determined as the highest value of the force produced. Upper limbs' strength is reported as the mean value of grip and shoulder abduction forces measured. Lower limbs' strength is reported as the mean value of knee extensors and hip flexors forces assessed.

Mortality and hospitalisation

Data on all-cause mortality were obtained using information from the Spanish National Mortality Database and through follow-up interviews by telephone. Individuals who died and the date of death were identified. Hospitals database and telephone follow-up were used to detect hospitalisations. Subjects were followed up during a median period time of 5.5 years (range: 0.3–6.79) for all-cause mortality and 3 years (0.04–4.8) for hospitalisation.

Statistical analysis

Descriptive data are presented as median values (inter-quartile range). Baseline characteristics between survivors and decedents, hospitalised and non-hospitalised were compared using a Mann–Whitney test. The associations of vital status and hospitalisation with upper and lower body strengths were assessed using a Cox proportional hazards model including age, BMI, educational level, Geriatric depression scale (GDS) and Charlson index as potential confounders. In a first model, we included the interaction term between muscle strength and sex. All of them were strongly significant ($P < 0.001$). Then, we repeated the analysis for each sex separately. Muscle strength was classified by quartiles in our study population, being quartile 1 (Q1) the lowest and quartile 4 (Q4) the highest strength values. To assess the effect of poor muscle strength on mortality and hospitalisation risks, a score was created identifying the sum of strengths in the weakest (Q1) quartile for the four measurement sites (grip, shoulder, hip and knee) (score = 0–4, Model 1, Table 3).

Analyses were made with the Statistical Package R for windows (Vienna, Austria) (http://www.r-project.org), version 2.15.2. *P* value was set at level <0.05.

Results

Study sample

Table 1 shows data for age, anthropometrics, co-morbidities, educational level and muscle strength determinations of survivors and decedents among men and women, respectively. Median follow-up was 5.5 years; during this time, 163 men and 124 women died. In general, decedents were older, had lower baseline strength (grip, hip flexion, knee extension and shoulder abduction), and worst health conditions than survivors (Table 1). Descriptive data for hospitalisation showed a similar pattern (Supplementary data, available in *Age and Ageing* online).

Regional muscle strength, all-cause mortality and hospitalisation in elder men and women

Table 2 shows the risk of death from all causes (hazard ratios (HRs) (95% CI) associated with muscle strength levels. The weakest muscle strength quartile (Q1), for all the different muscle sites measured (grip, shoulder, knee and hip), was taken as reference group for comparison. HR of death was significantly lower in the stronger women (best two strength quartiles, Q3 and Q4) for shoulder and knee muscle regions and in very strong women (Q4) for hip muscle site (all $P < 0.05$, Table 2).

In men, the HR of death was significantly lower in the mild to very strong individuals (Q2–Q4) for handgrip and in the stronger and very stronger (Q3, Q4) for the shoulder site (all $P < 0.05$, Table 2). HRs of hospitalisation (Table 2) followed a similar pattern to that observed in mortality in women, whereas in men, additional lower hospitalisation HRs were observed in the strongest hip (Q4) and knee (Q3) muscle sites (Table 2).

Table 1. Descriptive characteristics of the participants stratified by gender and survival status

	Women					Men				
	Alive (*n* = 861)		Dead (*n* = 124)		*P*	Alive (607)		Dead (*n* = 163)		*P*
	Median	IQR	Median	IQR		Median	IQR	Median	IQR	
Age (years)	74.0	70–77	81	77–85.5	<0.001	74	70–77	79	75–83	<0.001
BMI (kg/m^2)	29.6	26.6–32.9	29.6	32.9–30.3	0.89	28.2	25.8–30.8	27.4	24.5–30.8	<0.001
Muscle strength										
Grip (kg)	18.0	14.0–20.3	12.0	8.0–16.0	<0.001	30.0	25.0–36.0	23.0	18.0–29.0	<0.001
Shoulder (kg)	10.6	7.5–14.4	6.6	4.7–8.6	<0.001	18.0	13.1–24.7	13.0	9.1–17.8	<0.001
Hip (kg)	15.0	10.3–21.0	9.1	6.9–14.1	<0.001	21.5	15.5–26.0	16.0	12.0–22.8	0.001
Knee (kg)	10.7	7.3–16.3	6.9	4.5–9.3	<0.001	15.2	10.1–21.6	11.1	6.8–15.3	<0.001
Upper limbs (kg)	14.3	11.0–17.7	9.6	7.7–12.2	<0.001	24.5	19.8–30.0	18.0	13.8–23.3	<0.001
Lower limbs (kg)	13.2	9.1–18.7	8.0	6.0–11.3	<0.001	18.3	13.3–24.6	13.8	9.9–19.1	<0.001
	%		%		*P*	%		%		*P*
Education level					<0.05					<0.001
None	65.8		74.6				62.6		66.9	
Less than primary school	19.3		19.7				16.1		17.8	
Greater than or equal to primary school	14.9		5.7				21.4		15.3	
Charlson Index					<0.001					<0.001
0	46.5		36.6			49.7		36.8		
1	24.9		23.6			27.3		27.0		
2	14.7		18.7			12.1		21.5		
3	7.1		8.1			5.3		3.7		
>3	6.8		13.0			5.6		11.0		
GDS					<0.001					<0.001
>4	29.0		51.4			14.4		21.3		

Values are median and inter-quartile range.
BMI, body mass index; GDS, Geriatric depression scale.

Table 2. Cox proportional hazard model (HR, 95% CI) for death and hospitalisation in elderly women and men regarding muscle strength quartiles

	Grip HR (95% CI)	Shoulder HR (95% CI)	Knee HR (95% CI)	Hip HR (95% CI)
Mortality				
Women				
Muscle strength weakest quartile (Q1)	ref	ref	ref	ref
Q2	0.76 (0.47–1.23)	0.66 (0.41–1.06)	0.78 (0.50–1.23)	1.00 (0.64–1.56)
Q3	1.01 (0.57–1.77)	0.43 (0.22–0.85)**	0.48 (0.25–0.94)**	0.61 (0.34–1.08)
Q4	0.38 (0.15–1.01)***	0.29 (0.12–0.69)*	0.16 (0.05–0.52)*	0.18 (0.06–0.60)*
Men				
Muscle strength weakest quartile (Q1)	ref	ref	ref	ref
Q2	0.51 (0.34–0.77)*	0.76 (0.50–1.16)	0.75 (0.48–1.18)	0.79 (0.52–1.21)
Q3	0.47 (0.28–0.77)*	0.49 (0.30–0.81)*	0.85 (0.54–1.35)	0.60 (0.35–1.03)***
Q4	0.29 (0.14–0.58)*	0.51 (0.28–0.92)**	0.64 (0.37–1.12)	0.67 (0.40–1.11)
Hospitalisation				
Women				
Muscle strength weakest quartile (Q1)	ref	ref	ref	ref
Q2	0.82 (0.55–1.23)	0.87 (0.60–1.26)	0.95 (0.66–1.36)	0.70 (0.48–1.03)***
Q3	0.73 (0.47–1.14)	0.56 (0.35–0.90)**	0.62 (0.40–0.95)**	0.45 (0.28–0.71)*
Q4	0.78 (0.49–1.27)	0.36 (0.21–0.63)*	0.28 (0.15–0.51)*	0.44 (0.26–0.72)*
Men				
Muscle strength weakest quartile (Q1)	ref	ref	ref	ref
Q2	0.70 (0.47–1.04)***	0.68 (0.45–1.02)	1.08 (0.72–1.62)	0.69 (0.46–1.03)
Q3	0.65 (0.42–1.00)***	0.54 (0.35–0.83)*	0.99 (0.65–1.53)	0.52 (0.32–0.84)**
Q4	0.62 (0.37–1.01)***	0.62 (0.38–0.98)**	0.61 (0.36–1.01)***	0.87 (0.57–1.33)

Women muscle strength quartiles: Handgrip: Q1 < 12 kg, Q2 = 15–17 kg, Q3 = 18–20 kg, Q4 > 20 kg; Shoulder: Q1 < 7 kg, Q2 = 7–10 kg, Q3 = 11–13.9 kg, Q4 > 13.9 kg; Knee: Q1 < 6.8 kg, Q2 = 6.8–10 kg, Q3 = 11–15.6 kg, Q4 > 15.6 kg; Hip: Q1 < 9.5 kg, Q2 = 9.5–14.1 kg, Q3 = 14.2–20.3 kg, Q4 > 20.3 kg. Men muscle strength quartiles: Handgrip: Q1 < 23 kg, Q2 = 23–29 kg, Q3 = 30–35 kg, Q4 > 35 kg; Shoulder: Q1 < 12.1 kg, Q2 = 12.1–16.8 kg, Q3 = 16.9–23.8 kg, Q4 > 23.8 kg; Knee: Q1 < 9.4 kg, Q2 = 9.4–14.1 kg, Q3 = 14.1–20.5 kg, Q4 > 20.5 kg; Hip: Q1 < 14.2 kg, Q2 = 14.2–20.1 kg, Q3 = 20.2–25.9 kg, Q4 > 25.9 kg. Model adjusted by age, BMI, educational level, Geriatric depression Scale and Charlson Index.

*$P < 0.01$.

**$P < 0.05$.

***$P < 0.1$.

Table 3. Cox proportional hazard model (HR, 95% CI) for death and hospitalisation in elderly women and men regarding worst muscle strength quartile classification

	Women						Men					
	Death		*P*	Hospitalisation		*P*	Death		*P*	Hospitalisation		*P*
	HR	95% CI		HR	95% CI		HR	95% CI		HR	95% CI	
Model 1: weakest strength quartile increase (grip, shoulder, knee or hip, score = 0–4)												
Score = 0	ref			ref			ref			ref		
Score = 1	1.45	1.17–1.79	0.001	1.30	1.13–1.49	0.001	1.25	1.11–1.42	0.001	1.16	1.04–1.31	0.011
Score = 2	2.09	1.37–3.21	0.001	1.68	1.28–2.21	0.001	1.57	1.23–2.01	0.001	1.36	1.07–1.71	0.011
Score = 3	3.03	1.60–5.75	0.001	2.18	1.45–3.29	0.001	1.96	1.36–2.84	0.001	1.58	1.11–2.24	0.011
Score = 4	4.39	1.87–10.29	0.001	2.83	1.64–4.90	0.001	2.46	1.50–4.02	0.001	1.84	1.15–2.94	0.011

The model shows the relative effect of harbouring any of the worst muscle strength quartiles of the four measured sites (grip, shoulder, knee and hip) on mortality and hospitalisation risks. Score = 0: no strengths in the weakest quartile, reference; Score = 1: one strength in the weakest strength quartile; Score = 2: two strengths in the weakest quartile; Score = 3: three strengths in the weakest quartile and Score = 4: four strengths in the weakest quartile. Women worst muscle strength quartiles: handgrip <12 kg; shoulder <7 kg; knee <6.8 kg and hip <9.5 kg. Men worst muscle strength quartiles: handgrip <23 kg; shoulder <12.1 kg; knee <9.4 kg and hip <14.2 kg. Model adjusted by age, BMI, educational level, Geriatric depression scale and Charlson Index.

Poor muscle strength, all-cause mortality and hospitalisation in elder men and women

Table 3 displays the relative effect of harbouring one, two, three or four of the worst muscle strength quartiles of the four measured sites (grip, shoulder, knee and hip) on mortality and hospitalisation risks taking zero as reference and adjusting by age, BMI, GDS, Charlson index and educative level. This statistical model shows that every worst strength quartile increase at any of the measured sites results in a significantly 25 and 45% higher risk of death, as well as 16 and 30% higher risk of hospitalisation in men and women, respectively ($P < 0.01$, Table 3).

Discussion

The main findings of this study are as follows: (i) Strength is a modifiable factor related to both medium-term death and hospitalisation probabilities in the elderly adults. In this 5.5-year follow-up study of elderly men and women, lower levels of shoulder, knee and hip strength in women, and handgrip and shoulder strength in men, were associated with increased mortality from all causes after adjustment for relevant confounders. Higher hospitalisation risk was also observed after a 3-year follow-up period in association to lower levels of muscle strength. (ii) Poor strength at upper extremities in elder men is associated with higher risk of mortality and hospitalisation, whereas lower extremities strength is associated with higher hospitalisation risk in women after adjustment for important confounders such as BMI, education and co-morbidity. (iii) The lowest level of strength at any regional measured site increases the HR of death and hospitalisation ∼45 and 30% for women and 25 and 16% for men, respectively.

Our findings regarding poor regional strength and mortality are in accordance with other studies. That is Xue *et al.* found in a sample of community-dwelling women aged 70–79 in which higher knee and hip strength were significantly associated with lower risk of mortality after adjusting for age, race, education and BMI. Specifically, the risk of mortality was 1.4 and 3.8 times higher for every 0.5 SD decrease in knee (i.e. 2.3 kg) and hip (i.e. 2.7 kg) strength, respectively [13]. Xue's results together with ours highlight the need to measure strength at different sites, especially at the lower and upper extremities, because strength may decline at different rates depending on the muscle groups over time [24], and strength loses in muscles that greatly determine whole body functionality (i.e. legs for the ability to walk) may prevail over upper extremities muscle strength in its relationship with mortality. In addition, it is somehow risky to take a single strength measurement as a whole body representative, because it could be masking the real strength status of the person due to punctual and local muscular diseases, disuse and fatigue among others. Similar results regarding knee extension and grip strength were found by other authors in men and women aged 70–79 years, independently of muscle mass and other confounders like inflammatory status [16]. On the contrary, Singh *et al.* [14] found in a cohort of older people with peripheral arterial disease that leg strength predicted mortality in men but not in women. However, the fact that not all our subjects were suffering from peripheral arterial disease and age differences makes difficult the comparison between studies.

Moreover, our results suggest that there is a differential pattern in the relationship between muscle strength and mortality by sex. Specifically, in terms of health events (hospitalisation and death) rate reduction, lower extremities muscle strength seems to be more important in women compared with men. Although the underlying mechanisms are not known yet, we think that one possible explanation could be that, due to women have lower values of absolute muscle strength than men, they may be closer to a disability threshold. On the other hand, quartile muscle strength comparison in our study showed the great importance that loosing upper extremities strength has in older men, although for both men and women, being classified in the weakest strength quartile at any of the muscular strengths measured, increased mortality and hospitalisation risks ∼45 and 30% in the case of women, and 25 and 16% in men, respectively.

Consequently, to guarantee low probability of mortality and hospitalisation, the importance of maintaining a high level of strength during the ageing process increases as age increases. Our results also highlight the crucial importance of taking into consideration regional strength measurements, to be able to target the major muscular groups and extremities that should be trained (i.e. upper extremities in older men and both upper and lower extremities in old women). In addition, this work questions the usefulness of handgrip strength as a predictor of health events in women. Grip strength is usually chosen due to its ease of measurement, higher reliability and relative low cost, despite there is no international consensus on the equipment and protocols to use [12]. Our results did not show handgrip strength to be associated with either hospitalisation or death HRs in women. In consequence, the associations between low muscle strength and health events would have been masked if we had chosen only handgrip strength as a whole body strength representative in women taking part in our study. In agreement, other researchers have also failed to show any relationship between handgrip strength and mortality or hospitalisation in elder women [12, 25].

The strong points of this investigation are that upper and lower body strength were measured in a large cohort using the same methodology and the adjustment of the outcomes with Cox proportional hazard model by use of relevant confounders, such as co-morbidity and depression trait in the statistical analysis, which are decisive to investigate the current research question. On the other hand, more studies with longer mortality and hospitalisation follow-up are needed to confirm our results.

In conclusion, according to our results, lower levels of upper- and lower body strength are related to higher risk of all-cause mortality in elders. Keeping in mind that physical activity and specific training programs are able to improve muscle strength in this specific population, and in light of our results, interventions with exercise in elders should take into consideration age, sex, upper and lower body extremities strength to diminish the risk of mortality during the ageing process.

Key points

- Regional muscle strength role in mortality risk.
- Gender differences in the relationship between muscle strength and health events.
- Regional muscle strength and health events in elders.

Conflicts of interest

None declared.

Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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