Title: Handgrip strength in older adults with chronic diseases from 27 European countries and Israel

Running title: Handgrip and chronic disease

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Abstract

Background/Objectives: Understanding the association of deconditioned strength with the most prevalent chronic diseases in older adults and inferring possible interventional strategies is of utmost importance. We aimed to investigate the association between handgrip strength and chronic diseases in a large representative European population of adults over the age of 50 years.

Subjects/Methods: Individuals aged 50 or older residing in 27 European countries and Israel participated in this cross-sectional study. Data on prior or current chronic disease and handgrip strength were retrieved from the 7th wave of Survey of Health, Ageing and Retirement in Europe (SHARE). We tested associations using binary logistic regression adjusted for potential confounders.

Results: Based on data from 73,463 participants, the examined diseases showed a negative association with handgrip strength in the fully adjusted model. Participants from the highest tertile of handgrip strength had particularly lower odds for Parkinson ((Adjusted odds ratio (AOR) = 0.42 [95% Confidence Interval =0.32-0.56])), stroke (AOR = 0.51 [95% Confidence Interval = 0.44-0.59], and emotional disorders ((Adjusted odds ratio (AOR) = 0.51 [95% Confidence Interval =0.45-0.58])) compared with participants with the lowest level of handgrip strength in the fully adjusted model.

Conclusions: There is a negative association between handgrip strength and a wide range of chronic diseases. Evaluating handgrip strength in this population may provide a valuable clinical measure and a simple preventive strategy in relation to these diseases. The present findings support the use of resistance training for the prevention of specific chronic conditions, particularly Parkinson, stroke and emotional disorders.

Key words: epidemiology; muscle; risk factors; aging; health

Introduction

As life-expectancy increases and the population ages, the prevalence of chronic diseases rises, especially in adults older than 50 years (1,2). Chronic diseases burden society at an individual patient level as well as through high healthcare costs (2). Many chronic diseases also lead to loss of physical functioning and consequently a high level of dependence (3). Therefore, tackling chronic diseases has become a topic of increasing interest worldwide, with a particular focus on those representing the highest burden, including cardiovascular diseases, neuropsychiatric conditions, cancer, digestive diseases, respiratory diseases and musculoskeletal diseases (4). Factors like age, lower income, and low socioeconomic status are associated with higher prevalence of chronic diseases (2,4–7). However, to tackle the high-burden chronic diseases, there is a need for identifying modifiable objective physical measures of chronic diseases that can be targeted through proper interventional strategies, such as muscle strength training.

Higher muscle strength can have beneficial effects on chronic diseases as well as in adults experiencing poor health (6,8,9). Likewise, chronic cardiometabolic diseases may have a negative effect on muscle strength as well muscle quality (10,11). Handgrip strength is a reliable indicator for overall muscle strength (12,13) and is a simple and low-cost measurement, feasible in clinical practice. Previous cross-sectional research has shown that handgrip strength is associated with different chronic diseases; for instance, a study analyzing 1145 participants from Hong Kong, showed that lower handgrip strength was related to increased odds of having 18 chronic diseases in men and women (5). Similarly, a more recent cross sectional study among 34,129 participants from 6 low- and middle-income countries, including China, Ghana, India, Mexico, Russia and South-Africa also indicated that lower handgrip strength is related to a range of chronic diseases, concluding that handgrip strength could be valuable for clinical use (7).

While the before-mentioned studies showed an association between lower handgrip strength and several relevant chronic diseases, several limitations were present. First, they did not focus on chronic diseases ranked as those with the highest burden in Europe. Second, they did not include large representative samples of participants. Hence, understanding the association of handgrip strength with the most prevalent chronic diseases in Europe using a large representative sample and inferring possible interventional strategies is of utmost importance.

Therefore, the main objective of this study was to investigate the association between handgrip strength and chronic diseases in a large representative European population of adults over the age of 50 years.

Materials/Subjects and Methods

Subjects

We conducted a cross-sectional study analysing data from Survey of Health, Ageing and Retirement in Europe (SHARE) wave 7, a survey recruiting individuals aged 50 or over residing in 27 European countries and Israel (14).

Representativeness of SHARE waves is guaranteed through a multi-stage stratified sampling design; countries are divided into different strata regarding geographical areas, and municipalities or zip codes within those strata are utilized as Primary Sampling Units (PSUs) with probability of being sampled proportional to their size (15). The survey was carried out from February to November 2017 using computer-assisted personal interviews in the home of the participants. Data from SHARE were collected using ex-ante harmonized interviews and include calibrated weights to address the potential selection bias usually associated with non-respondent errors. Furthermore, new respondents were also added to compensate for such attrition. Respondents of the regular extended panel along with SHARELIFE survey, which uses a condensed regular panel, were initially eligible for the study. Individuals aged 50 years with valid values in the outcome variables were included in the final sample (99%). Subject characteristics are described at the results section and in Supplementary Table S1. The study adhered to the principles of the World Medical Declaration of Helsinki and got the approval of the Ethics Committee of Research in Humans of the University of Valencia (register code 1510464). The present study adheres to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (16).

Procedures

Handgrip strength (Independent variable). Interviewers carried out the measurements after having participated in training sessions to learn the SHARE protocol for measuring handgrip strength. This consisted in measuring twice each hand using a handheld dynamometer (Smedley, S Dynamometer, TTM, Tokyo, 100 kg). Participants were instructed to set their elbow in a 90° angle flexion while either standing or sitting, neutral wrist position, and upper arm set in a vertical position against the trunk. Interviewers verbally encouraged participants with standardized instructions to grip with the maximum possible effort. The maximum measurement performed in one hand was considered the estimation of handgrip strength.

Chronic condition (outcome). Previously experienced or current chronic condition was self-reported by the participants through the following question: “Has a doctor ever told you that you had/currently have any of the conditions on this card? With this we mean that a doctor has told you that you have this condition, and that you are either currently being treated for or bothered by this condition”. The referred

card included the following options: “A heart attack including myocardial infarction or coronary thrombosis or any other heart problem including congestive heart failure”, “High blood pressure or hypertension”, “High blood cholesterol”, “A stroke or cerebral vascular disease”, “Diabetes or high blood sugar”, “Chronic lung disease such as chronic bronchitis or emphysema”, “Stomach or duodenal ulcer, peptic ulcer”, “Cancer or malignant tumour, including leukaemia or lymphoma, but excluding minor skin cancers”, “Parkinson disease”, “Cataracts”, “Hip fracture”, “Other fractures”, “Alzheimer's disease, dementia, organic brain syndrome, senility or any other serious memory impairment”, “Other affective or emotional disorders, including anxiety, nervous or psychiatric problems”, “Rheumatoid Arthritis”, “Osteoarthritis, or other rheumatism”, “Chronic kidney disease”, “None”, and “Others conditions, not yet mentioned”. Those participants selecting any of the options commented above were considered to have had or have the selected condition. Besides, participants selecting two or more of the aforementioned options, excluding “None”, were considered as having multimorbidity.

Control variables. Self-reported age and sex, education, body mass index, current smoke habit, physical inactivity, alcohol consumption, fruits and vegetables consumption and country of residence were identified as potential confounders according to relevant literature on the topic. Education was self-reported by participants and thereafter coded using the 1997 version of the International Standard Classification of Education. Body mass index was calculated from self-reported height and weight and subsequently grouped into 4 categories according to standards proposed by World Health Organization (WHO). Physical inactivity was determined through two questions: “How often do you engage in vigorous physical activity such as sports, heavy housework, or a job that involves physical labour”, and “How often do you engage in activities that require a moderate level of energy such as gardening, cleaning the car, or doing a walk?”. Participants selecting the option of “Hardly ever, or never” in the two questions were considered to be physically inactive. Alcohol consumption was assessed using the question: “Did you consume at least one alcoholic beverage the last 7 days?”, and potential answers comprised “Yes”, “No”, “Refusal” or “Don’t´ Know”. Current Fruits and vegetables consumption was assessed with the following question: “In a regular week, how often do you consume a serving of fruits or vegetables?”, and potential answers comprised the following options: “Refusal”, “Don’t´ Know”, “Everyday”, “3-6 times a week”, “Twice a week”, “Once a week”, and “Less than once a week”. Finally, current smoking habit was assessed asking the following: “Do you smoke at the present time?” and the potential answers were “Yes”, “No”, “Refusal” or “Don’t´ Know”.

Statistical analyses

Analyses were performed with Stata v16.1. We used binary logistic regression to examine the association between handgrip strength and a set of chronic diseases. The models were adjusted for age and sex (Model 1), and, additionally, for body mass index, education, smoking habit, physical inactivity, fruits and vegetables consumption and country (Model 2). Overall missing values (36%) on handgrip strength, education, smoking habit, physical inactivity, alcohol consumption, and smoking habit, and fruits and vegetables consumption variables were imputed using multiple imputation (5 imputed datasets in a chained model using all the study variables). To examine trends in the association between handgrip strength and chronic diseases, we categorized the independent variable using tertiles. We checked interactions between handgrip strength and sex using a chunk test and found no significant interaction. Finally, to check the robustness of the association between handgrip and each specific chronic condition, we also performed sensitivity analyses accounting for the complex survey-design, and calibrated weights with a considerably reduced sample of participants with models using complete-case analyses (n=42,915) (Supplementary Table S1). Furthermore, we also examined consistency of the estimations by mutually adjusting each chronic condition for the rest of chronic conditions in the full model (Model 2). The level of statistical significance was set at $P < 0.05$.

Results

A total of 73,463 participants on average aged 63.6 (SD = 9.8) years were finally included in the analyses. Of those, 57.0% were women, and 51.8% experienced multimorbidity. Table 1 displays the basic characteristics of the study sample, including the percentage of participants having each of the examined diseases, and categorized levels of handgrip strength. The most prevalent diseases were hypertension (44.6%), and high blood cholesterol (25.0%).

Table 2 shows adjusted models for the association between handgrip strength and prior or current diseases. Handgrip strength showed a significant negative association with the examined conditions in the fully adjusted model (Model 2) when comparing participants from the third and the first tertile (reference). This association also showed a dose-response fashion in most of the cases. Handgrip strength showed highest significant negative association for emotional disorders among participants included in the second tertile (Adjusted odds ratio (AOR) = 0.66 [95%CI =0.61-0.71]) and for Parkinson in the case of the third tertile (AOR = 0.42 [95% Confidence Interval (CI)=0.32-0.56]) in a decreasing trend when compared with participants from the first tertile in the fully adjusted model (Model 2). Similarly, handgrip strength showed

the second lowest odds for Parkinson among participants included in the second tertile (AOR = 0.67 [95%CI =0.52-0.86]) and for Stroke in the third tertile (AOR = 0.51 [95%CI =0.44-0.59]) when compared with participants from the first tertile in the fully adjusted model (Model 2). The opposite, higher odds for having no diseases, was observed for participants from the second (AOR = 1.42 [95%CI =1.34-1.50]) and the third tertile (AOR = 1.68 [95%CI =1.56-1.81]) of handgrip strength in relation to those from the first tertile in Model 2.

Sensitivity analyses confirmed the robustness of the examined association for all the examined variables with exception of hypertension, high cholesterol, chronic lung disease, cancer, and stomach, duodenal or peptic ulcer (Supplementary Table S1).

Discussion

In this large-scale study from 28 countries, we observed a negative association between handgrip strength and a range of chronic diseases. This result endorses those from other cross-sectional studies, in which weaker handgrip strength was associated with higher odds for chronic diseases (5,7). A smaller study with 1145 participants from Hong Kong also found associations between lower levels of muscle strength and 18 chronic diseases (5), based on the 12 categories of the World Health Organization's International Classification of Diseases (17) (anaemia, anxiety, cataract, cerebral vascular accident, chronic kidney disease stage 3 or above, chronic obstructive airways disease, depression, diabetes, history of fall in the past 12 months, hepatitis B, hyperlipidaemia, hypertension, hyperthyroidism, ischemic heart diseases, kyphosis, malignancy within 5 years, knee osteoarthritis, and peptic ulcer). However, in both of the abovementioned studies, Alzheimer and Parkinson, two of the chronic diseases observed among the most highly associated with lower handgrip in the present study, were not included in the list of investigated chronic diseases. Remarkably, we found significant associations for these two chronic diseases. The relation of handgrip strength and Alzheimer's disease is in line with the results of a recent longitudinal study, where it was found that handgrip strength is associated with poorer cognitive functioning (18). Similarly, a prospective Japanese study also showed that a decline in handgrip strength was associated with dementia later in life (19). A possible mechanism explaining this association could be the relation of dementia with sarcopenia; this was observed in a recent systematic review, which found that patients with dementia may have increased prevalence of sarcopenia (20). Similarly, low levels of muscle strength have also been shown in patients with Parkinson's disease (21), which could be an explanation for the negative association with handgrip strength that we found in this study.

Moreover, we also found negative associations for all included diseases related to cardiovascular diseases with handgrip strength, including heart attack, hypertension, cholesterol, diabetes and stroke. This association was partially incongruent with the results of the previously mentioned study from Vancampfort et al (7), where diabetes and hypertension were not significantly associated with weak handgrip strength. The large sample size in our study may explain the statistically significant associations. However, as the authors mentioned, mixed results on this have been previously found, thus the current evidence remains inconsistent (22–24). Whilst yet no consensus is present on whether there is a significant association of cardiovascular diseases and handgrip strength, we provide results with the largest sample size of the other previously mentioned studies that there is a significant association. A possible explanation supporting our result is that it has been well established that the incidence of cardiovascular diseases is higher in people that are less physically active (25,26), which might lead to lower muscle strength.

In agreement with prior research we also observed a negative association of handgrip strength and musculoskeletal diseases, including hip or other fractures, osteoarthritis and rheumatoid arthritis (5,7), supporting the general perception that handgrip strength is mainly related to the muscular system (27).

Interestingly, we observed a non consistent association of handgrip strength with cancer, which has also been shown in the male population of the study by Cheung et al (5). Evidence supporting our result is the fact that tumour cells are known to promote loss of muscle mass and function (28), which may be an underlying mechanism of the negative association with handgrip strength. It has been shown that higher muscle strength is related to prolonged survival in patients with cancer (29), thus highlighting that using handgrip strength as a predictive indicative measure could be of great importance.

In agreement with our result concerning emotional disorder and handgrip strength, a large cross-sectional study from the U.S. performed from 2011-2014, showed a significant association of depression with reduced handgrip strength (30). Possible underlying mechanisms may include biological factors, such as mitochondrial dysfunction, or low grade chronic immune mechanisms linked with oxidative stress (31). However, the causal relation between depression and reduced handgrip strength should be further investigated.

Finally, the fact that a positive association was observed between none condition and handgrip strength strengthens the notion that the observed negative association between different examined diseases and handgrip strength are robust.

Even though the strength of this study includes a large representative sample of the examined population, from 27 European countries and Israel, and an objective measurement of the exposure, we acknowledge several limitations. First, the design is a cross-sectional study, for which we need to take into consideration that causality has not been determined and that the reverse association (i.e. individuals with chronic diseases have lower handgrip strength as a consequence of the condition) is still plausible. Therefore, a longitudinal study would contribute to further investigate this point. Second, another limitation entails that some residual confounding might still be affecting the results, although given the robustness of the findings, it is quite unlikely that such margin importantly changes the observed estimates. Moreover, additional analyses with weighted complete-case analyses accounting for survey design did show consistence for most of the estimates observed in the main analyses. Third, the possibility of a low to moderate degree of heterogeneity between countries affecting the examined associations exist, but the fact that our main model was adjusted for country and that additional analyses were weighted according to each country population as well as accounted for the complex survey design provides consistency to our estimates. Also, the fact that a number of participants might have experienced several concurrent morbidities (e.g., diabetes and hypertension) that could have influenced the results exists, although the sensitivity analyses conducted shows that our estimates are highly reliable.

In conclusion, handgrip strength is negatively associated with a wide range of chronic diseases in older adults. Evaluating handgrip strength in this population may provide a valuable clinical measure and a simple preventive strategy in relation to these diseases. The present findings support the use of resistance training for the prevention of specific chronic conditions, particularly Parkinson, stroke and emotional disorders, which may benefit from such type of training when achieving handgrip strength levels corresponding with the highest tertile of the population of European older adults.

Data Availability Statement

The data is available upon request from www.share-project.org.

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Author Contributions

JCAL, RM and RLB conceived and designed study; RLB completed all data analyses; All authors discussed the results; RM and JCAL wrote the manuscript. All authors revised the manuscript, provided feedback and have final approval of the version to be submitted.

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Ethical Approval

The study adhered to the principles of the World Medical Declaration of Helsinki and got the approval of the Ethics Committee of Research in Humans of the University of Valencia (register code 1510464).

Competing Interests

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Tables.

Table 1. Study sample characteristics (N=73,463)			
Characteristic	**Category**	**n (%)**	**Mean (SD)**
Age			63.6 (9.8)
Sex			
	Men	31,573 (43.0)	
	Women	41,890 (57.0)	
Body mass index (kg/m^2)			27.2 (4.7)
Education			
	None	3,079 (4.2)	
	Primary	11,572 (15.8)	
	Lower secondary	12,136 (16.5)	
	Upper secondary	27,058 (36.8)	
	Post-secondary non-tertiary	3,761 (5.1)	
	First stage of tertiary	15,322 (20.9)	
	Second stage of tertiary	535 (0.7)	
Current smoking habit			
	No	26,108 (35.5)	
	Yes	47,355 (64.5)	
Alcohol consumption (one alcoholic beverage the last 7 days)			
	No	37,293 (50.8)	
	Yes	36,170 (49.2)	
Physical inactivity			
	No	64,306 (87.5)	
	Yes	9,157 (12.5)	
Fruits or vegetables consumption			
	Every day	51,658 (70.3)	
	3-6 times a week	16,284 (22.2)	
	Twice a week	3,426 (4.7)	
	Once a week	1,129 (1.5)	
	Less than once a week	956 (1.3)	
Country			
	Austria	3,106 (4.2)	
	Germany	3,631 (4.9)	
	Sweden	3,054 (4.2)	
	Spain	4,496 (6.1)	
	Italy	4,318 (5.9)	
	France	3,105 (4.2)	
	Denmark	2,986 (4.1)	
	Greece	2,487 (3.4)	
	Switzerland	2,235 (3.0)	
	Belgium	4,634 (6.3)	
	Israel	2,094 (2.9)	
	Czech Republic	3,996 (5.5)	
	Poland	4,353 (6.0)	
	Luxembourg	1,225 (1.7)	
	Hungary	1,512 (2.1)	
	Portugal	1,252 (1.7)	
	Slovenia	3,646 (5.0)	
	Estonia	5,009 (6.8)	
	Croatia	2,361 (3.2)	
	Lithuania	1,973 (2.7)	
	Bulgaria	1,929 (2.6)	

	Cyprus	1,188 (1.6)	
	Finland	1,967 (2.7)	
	Latvia	1,680 (2.3)	
	Malta	1,237 (1.7)	
	Romania	2,022 (2.8)	
	Slovakia	1,967 (2.7)	
Heart attack			
	No	64,222 (87.4)	
	Yes	9,241 (12.6)	
Hypertension			
	No	40,730 (55.4)	
	Yes	32,733 (44.6)	
Cholesterol			
	No	55,133 (75.0)	
	Yes	18,330 (25.0)	
Stroke			
	No	70,246 (95.6)	
	Yes	3,217 (4.4)	
Diabetes			
	No	63,194 (86.0)	
	Yes	10,269 (14.0)	
Chronic lung disease			
	No	69,511 (94.6)	
	Yes	3,952 (5.4)	
Cancer			
	No	69,806 (95.0)	
	Yes	3,657 (5.0)	
Stomach, duodenal, or peptic ulcer			
	No	70,324 (95.7)	
	Yes	3,139 (4.3)	
Parkinson			
	No	72,785 (99.1)	
	Yes	678 (0.9)	
Cataracts			
	No	67,144 (91.4)	
	Yes	6,319 (8.6)	
Hip fracture			
	No	72,098 (98.1)	
	Yes	1,365 (1.9)	
Other fractures			
	No	69,361 (94.4)	
	Yes	4,102 (5.6)	
Alzheimer			
	No	71,606 (97.5)	
	Yes	1,857 (2.5)	
Emotional disorder			
	No	68,434 (93.2)	
	Yes	5,029 (6.8)	
Rheumatoid arthritis			
	No	65,843 (89.6)	
	Yes	7,620 (10.4)	
Osteoarthritis			
	No	59,261 (80.7)	
	Yes	14,202 (19.3)	
Kidney disease			
	No	71,721 (97.6)	
	Yes	1,742 (2.4)	
None			

	No	58,405 (79.5)	
	Yes	15,058 (20.5)	
Other			
	No	60,710 (82.6)	
	Yes	12,753 (17.4)	
Multimorbidity			
	No	35,377 (48.2)	
	Yes	38,086 (51.8)	
Handgrip (kg)			32.6 (11.6)
	Tertile 1	26,030 (35.4)	20.9 (4.4)
	Tertile 2	23,801 (32.4)	31.5 (3.1)
	Tertile 3	23,632 (32.2)	46.8 (6.9)

Table 2. Associations between handgrip and chronic condition diagnosed.				
N=73,463	**Model 1**		**Model 2**	
	OR	95%CI	OR	95%CI
Heart attack				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.80	0.76-0.85	0.82	0.79-0.87
Tertile 3	0.77	0.71-0.83	0.78	0.72-0.85
Hypertension				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.92	0.89-0.96	0.91	0.87-0.95
Tertile 3	0.97	0.93-1.03	0.91	0.87-0.97
Cholesterol				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.88	0.84-0.92	0.87	0.83-0.92
Tertile 3	0.91	0.86-0.97	0.89	0.83-0.95
Stroke				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.66	0.59-0.74	0.68	0.61-0.76
Tertile 3	0.49	0.43-0.55	0.51	0.44-0.59
Diabetes				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.76	0.71-0.81	0.77	0.72-0.81
Tertile 3	0.66	0.60-0.72	0.64	0.59-0.70
Chronic lung disease				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.82	0.75-0.90	0.83	0.76-0.91
Tertile 3	0.67	0.60-0.75	0.67	0.60-0.74
Cancer				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.96	0.87-1.05	0.94	0.86-1.04
Tertile 3	0.87	0.75-1.00	0.84	0.73-0.97
Stomach, duodenal, or peptic ulcer				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.76	0.68-0.83	0.79	0.71-0.88
Tertile 3	0.68	0.60-0.77	0.73	0.63-0.84
Parkinson				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.63	0.49-0.80	0.67	0.52-0.86
Tertile 3	0.39	0.30-0.51	0.42	0.32-0.56
Cataracts				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.88	0.82-0.95	0.86	0.80-0.92
Tertile 3	0.82	0.75-0.90	0.78	0.71-0.86
Hip fracture				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.70	0.61-0.81	0.75	0.65-0.87
Tertile 3	0.66	0.54-0.82	0.73	0.59-0.91
Other fractures				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.78	0.72-0.85	0.80	0.73-0.87
Tertile 3	0.84	0.75-0.94	0.86	0.77-0.97
Alzheimer				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.63	0.54-0.73	0.71	0.60-0.84
Tertile 3	0.54	0.46-0.65	0.65	0.54-0.78

Emotional disorder				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.63	0.59-0.68	0.66	0.61-0.71
Tertile 3	0.49	0.43-0.55	0.51	0.45-0.58
Rheumatoid arthritis				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.67	0.62-0.72	0.70	0.64-0.75
Tertile 3	0.56	0.51-0.61	0.58	0.53-0.64
Osteoarthritis				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.86	0.82-0.90	0.83	0.79-0.87
Tertile 3	0.88	0.82-0.94	0.82	0.76-0.88
Kidney disease				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.74	0.66-0.84	0.77	0.67-0.88
Tertile 3	0.54	0.45-0.66	0.56	0.46-0.69
None				
Tertile 1	ref	ref	ref	ref
Tertile 2	1.40	1.33-1.48	1.42	1.34-1.50
Tertile 3	1.57	1.47-1.68	1.68	1.56-1.81
Other				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.91	0.87-0.96	0.91	0.87-0.96
Tertile 3	0.80	0.74-0.84	0.78	0.73-0.84
Multimorbidity				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.73	0.71-0.76	0.73	0.70-0.76
Tertile 3	0.65	0.62-0.69	0.62	0.59-0.66

Model 1. Adjusted for age and sex
Model 2. Adjusted for age, sex, body mass index, education, smoking habit, physical inactivity, alcohol consumption, smoking habit, fruits and vegetables consumption, and country
OR Odds Ratio
CI Confidence Interval

***Supplementary Table S1*. Survey adjusted and calibrated weighted associations between handgrip and current or prior condition diagnosed (complete-case analyses).**				
N=42,915	**Model 1**		**Model 2**	
	OR	95%CI	OR	95%CI
Heart attack				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.78	0.68-0.89	0.77	0.67-0.89
Tertile 3	0.72	0.59-0.88	0.68	0.56-0.84
Hypertension				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.85	0.77-0.95	0.83	0.75-0.93
Tertile 3	0.97	0.84-1.13	0.86	0.74-1.00
Cholesterol				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.84	0.74-0.94	0.83	0.73-0.93
Tertile 3	0.94	0.79-1.11	0.88	0.74-1.04
Stroke				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.48	0.35-0.65	0.48	0.35-0.66
Tertile 3	0.26	0.18-0.37	0.26	0.18-0.37
Diabetes				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.67	0.58-0.77	0.66	0.57-0.76
Tertile 3	0.56	0.45-0.69	0.49	0.39-0.61
Chronic lung disease				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.83	0.66-1.04	0.83	0.66-1.04
Tertile 3	0.78	0.58-1.05	0.76	0.56-1.02
Cancer				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.88	0.70-1.11	0.88	0.70-1.12
Tertile 3	0.93	0.68-1.28	0.93	0.68-1.27
Stomach, duodenal or peptic ulcer				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.72	0.57-0.93	0.73	0.57-0.93
Tertile 3	0.76	0.52.1.11	0.76	0.52-1.12
Parkinson				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.44	0.29-0.69	0.44	0.29-0.68
Tertile 3	0.21	0.11-0.41	0.21	0.11-0.40
Cataracts				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.77	0.63-0.94	0.77	0.63-0.94
Tertile 3	0.71	0.53-0.96	0.70	0.52-0.95
Hip fracture				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.48	0.30-0.77	0.49	0.30-0.77
Tertile 3	0.37	0.19-0.74	0.38	0.19-0.75
Other fractures				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.58	0.45-0.74	0.58	0.45-0.75
Tertile 3	0.56	0.38-0.84	0.56	0.38-0.84
Alzheimer				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.27	0.18-0.38	0.26	0.18-0.38

Tertile 3	0.18	0.10-0.31	0.18	0.10-0.30
Emotional disorder				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.56	0.46-0.69	0.56	0.46-0.69
Tertile 3	0.39	0.28-0.55	0.38	0.27-0.54
Rheumatoid arthritis				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.60	0.50-0.72	0.59	0.49-0.72
Tertile 3	0.37	0.28-0.49	0.35	0.27-0.46
Osteoarthritis				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.80	0.70-0.91	0.79	0.70-0.90
Tertile 3	0.83	0.67-1.03	0.80	0.64-0.99
Kidney disease				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.60	0.46-0.78	0.61	0.47-0.79
Tertile 3	0.37	0.24-0.57	0.35	0.23-0.54
None				
Tertile 1	ref	ref	ref	ref
Tertile 2	1.58	1.37-1.82	1.62	1.40-1.88
Tertile 3	1.37	1.10-1.69	1.54	1.24-1.93
Other				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.85	0.73-0.98	0.85	0.73-0.98
Tertile 3	0.79	0.63-0.98	0.77	0.62-0.96
Comorbidity				
Tertile 1	ref	ref	ref	ref
Tertile 2	0.69	0.62-0.77	0.67	0.60-0.75
Tertile 3	0.64	0.54-0.76	0.56	0.48-0.67

Model 1. Adjusted for age and sex
Model 2. Adjusted for age, sex, body mass index, and country.
OR Odds Ratio
CI Confidence Interval