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Associations between muscular strength and mental health in cognitively normal older adults: a cross-sectional study from the AGUEDA trial

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A R T I C L E I N F O

Keywords:
Muscular fitness
Aging
Psychological ill-being
Psychological well-being
Self-esteem

A B S T R A C T

Objective: To examine the associations between muscular strength and mental health.
Design: We used baseline data of 91 cognitively healthy older adults (71.69 ± 3.91 years old, 57 % women) participating in the AGUEDA randomized controlled trial.
Methods: Muscular strength was assessed using both objective (i.e., handgrip strength, biceps curl, squats, and isokinetic test) and perceived (i.e., International Fitness Scale) indicators. Psychological ill-being indicators: anxiety, depression, stress, and loneliness; and psychological well-being indicators: satisfaction with life, self-esteem, and emotional well-being) were assessed using a set of valid and reliable self-reported questionnaires. Linear regression analyses were performed adjusting for sex, age, years of education, body mass index , alcohol, diet, and smoking (model 1), and additionally by cardiorespiratory fitness (model 2).
Results: Elbow extension was positively associated with stress in model 1 (β = 0.252, 95 % Confidence Interval [95 % CI] = 0.007 to 0.497, p = 0.044), and even after further adjustment for cardiorespiratory fitness (β = 0.282, 95 % CI = 0.032 to 0.532, p = 0.028). Perceived strength was negatively associated with depressive symptoms in model 1 (β = -0.271, 95 % CI = -0.491 to -0.049, p = 0.017) and model 2 reported associations tending towards significant (β = -0.220, 95 % CI = -0.445 to 0.005, p = 0.055). Handgrip strength was positively associated with self-esteem in model 1 (β = 0.558, 95 % CI = 0.168 to 0.949, p = 0.006) and model 2 (β = 0.546, 95 % CI = 0.135 to 0.956, p = 0.010). No further associations were found among other muscular strength and mental health variables.

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Conclusion: Handgrip had a moderate association with self-esteem and there was a small association between perceived strength with depressive symptoms and elbow extension with stress. No other associations were observed between muscular strength and mental health outcomes in cognitively normal older adults.

Introduction

The World Health Organization (WHO) estimates that, by 2050, the world's population over 60 years of age will reach 2.1 billion (*Ageing and Health*, n.d.). Worldwide, mental disorders affect 21 % of the elderly, which contribute to other physical health problems, neurodegenerative diseases, or high morbidity (Botto et al., 2022; Diniz et al., 2013). In Spain, mental disorders affect 32 % of older adults, with the highest prevalence for anxiety (18 %) and major depression (10 %) (Andreas et al., 2017). These are alarming figures, especially given the sizeable public healthcare costs that derive from them GBD 2019 Mental Disorders Collaborators, 2022 . Most studies in this population have focused on treating mental disorders, however, preventing the onset of the disease is essential by reducing risk factors, halting its progression, and attenuating its consequences. The first signs of mental disorders are shown as symptoms, and for this reason, it is relevant to identify modifiable risk factors (Marques et al., 2020).

Muscular strength, defined as the maximal capacity of a muscle, or group of muscles, to exert a force under a given set of conditions, is a modifiable risk factor for mortality and disease incidence (García-Hermoso et al., 2018; Izquierdo et al., 2021). Aging results in diminished muscular strength attributed to physiological changes such as decreased voluntary activation, increased antagonist muscular co-activation, a reduced muscle mass due to sarcopenia, and the overall decline in muscular performance (Arnold & Bautmans, 2014; Byrne et al., 2016; Kennis et al., 2013). Several meta-analyses showed that lower handgrip strength is associated with an increased risk of depressive symptoms in adults and older adults (Huang et al., 2021; Marques et al., 2020; Zasadzka, Pieczyńska, Trzmiel, Kleka, & Pawlaczyk, 2021). In addition, higher levels of handgrip strength are associated with a lower incidence of depression and anxiety in adults and older people (Cabanas-Sánchez et al., 2022). There is a range of psychosocial, behavioral, and neurobiological mechanisms that may explain the link between muscular strength and mental health (Nguyen Nguyen Ho et al., 2023). For example, participating in physical activity (i.e., resistance training) that enhances muscular strength may provide older adults with self-confidence that leads to improved well-being. In addition, resistance training is an activity that requires focus and attention safely in executive movements. The cognitive demand of resistance training may facilitate improvements in cognition (Robinson et al., 2023). Regarding neurobiological mechanisms, there is a link between muscular strength and mental health posits that increased muscular strength may elevate hormone levels, including cytokines and myokines, which play a protective role against depression through pathways such as synaptic plasticity or monoamine metabolis (Haroon et al., 2012).

Although the associations between muscular strength and mental health symptoms appear mechanistically plausible, there are still several gaps in our understanding of these relationships during the aging. First, most studies have focused on examining associations between muscular strength and symptoms of depression (Huang et al., 2021; Marques et al., 2020; Zasadzka et al., 2021) and anxiety (Jiang, Westwater et al., 2022). Therefore, more research is needed to understand the role of muscular strength in older adults and focus on other psychological ill-being outcomes, such as loneliness. These outcomes are particularly relevant for the mental health of older people, which are major risk factors for physical and mental illness in older adults (Ong et al., 2016; Thoits, 2010). Second, few studies have examined associations between muscular strength and psychological well-being outcomes in older adults (i.e., "the combination of feeling good and functioning effectively") such as satisfaction with life (Chang et al., 2001; Jiang, Westwater et al., 2022). Older adults with higher psychological well-being are more likely to be healthier, live longer and enjoy a better quality of life (Tam et al., 2021; Tamosiunas et al., 2019). As such, there is a need to examine associations between muscular strength and psychological ill-being as well as psychological well-being in older adults. Third, most studies have only focused on field-based muscular strength such as the handgrip test when relating it to mental health in the elderly (Zasadzka, Pieczyńska et al., 2021). Although handgrip strength is a well-known indicator of overall muscular strength (Bohannon, 2019), it is important to contrast findings with complementary muscular strength indicators (i.e., laboratory tests and self- assessments). Some measurements may be more sensitive than others or some measurements are related to different mechanisms of action. Finally, there is a need to examine associations between individuals' perceived strength, which is understood as the self-assessment of their muscular strength, and their mental health. It is possible that self-perceptions act as a mediator of the relationship between muscular strength and mental health. It could reveal additional insights to complement the information provided by objective measures of muscular strength.

Overall, examining the associations of different muscular strength indicators using objective (i.e., field and laboratory tests) and perceived indicators (i.e., self-reports), with positive and negative indicators of mental health, will provide novel information needed for further identification of risk factors. Therefore, our study aimed to examine the associations between muscular strength (i.e., handgrip strength, biceps curl, squats, elbow-knees extension, and perceived strength) and mental health including psychological ill-being (i.e., anxiety, depression, stress, and loneliness) and well-being (i.e., satisfaction with life, self-esteem, and emotional well-being) in cognitively normal older adults.

Methods

Design and ethics

Our study was carried out under the framework of the AGUEDA trial ("Active Gains in brain Using Exercise During Aging"). AGUEDA is a single-site, two-arm, single-blind randomized controlled trial (RCT). Participants were recruited by community-dwelling older adults in Granada (Spain) city and surrounding areas from March 2021 to May 2022. In particular, the present cross-sectional analyses were completed using data from the baseline assessment before randomization, from a total sample of 91 cognitively normal older adults (65–80 years).

We have previously provided a detailed description of the study's inclusion and exclusion criteria (Fernandez-Gamez et al., 2023; Solis-Urra et al., 2023). In brief, before the enrollment of participants in the assessments, a telephone screening and an on-site screening were performed to determine whether participants met inclusion/exclusion criteria. The main inclusion criteria were to be a cognitively normal older adult between 65 to 80 years, without depressive symptoms (assessed by the Geriatric Depression Scale (Fernández-San Martín et al., 2002), and physically inactive.

Our study was conducted according to the Declaration of Helsinki and has been approved by the Research Ethics Board of the Andalusian Health Service (CEIM/CEI Provincial de Granada; #2317-N-19) on May 25th, 2020. The trial was registered on Clinicaltrials.gov (ClinicalTrials.gov Identifier: (NCT05186090); Submission date: December 22, 2021), and all participants gave written informed consent after all study details were explained to them.

Muscular strength

Muscular strength was assessed using both objective and perceived measures. Objective indicators for upper and lower-body muscular strength were assessed using: a handgrip test (Rijk et al., 2016; Roberts et al., 2011), biceps curl and squats following the Senior Fitness Test (SFT) (Langhammer & Stanghelle., 2015), and an isokinetic test (Abdalla et al., 2020; E G Arter et al., 2012) including elbow and knees extension. Perceived strength was assessed using the International Fitness Scale (IFIS) (Merellano-Navarro et al., 2017).

Handgrip strength

Each participant was encouraged to perform the maximal isometric force twice with each hand using a hand dynamometer (TKK 5101 Grip D, Takey, Tokyo Japan). The subject holds the dynamometer in the hand to be tested, with the arm at right angles and the elbow by the side of the body. When ready the subject squeezes the dynamometer with maximum isometric effort, which is maintained for about 5 seconds. No other body movement is allowed. The maximum value of each hand was taken and averaged in kilograms (kg) as an indicator of upper-body muscular strength.

Biceps curl

Participants performed bicep curl maximal repetitions in 30 seconds with the dominant arm using a dumbbell of 2.26 kg/5 lbs for women and 3.62 kg/8 lbs for men. The participant took the test twice and was considered the highest score. The test was carried out sitting on a chair and the number of repetitions was used as an indicator of upper-body muscular strength.

Squats

Participants performed as many squats as possible in 30 seconds. The participant started by sitting on a chair and was instructed to stand up and sit back down on the chair. Participants had their hands folded across their chests to avoid helping themselves get up and they performed the squats test twice. The participant took the test twice and was considered the highest score. The maximum number of repetitions was used as an indicator of lower-body muscular strength.

Isokinetic test

Elbow extension. This test was performed using the isokinetic machine (Gymnex Iso-2 dynamometer, EASYTECH S.r.l., Italy). Initially, the participant's position was as follows: back fully against the back of the seat. The non-performing handheld grip at the end. The elbow angle was approximately 130° to the horizontal. Elbow height was at the participant's chest height. In addition, before the exercise was performed, the participant received specific instructions and started with a warm-up, which consisted of performing 10 repetitions at a slow and controlled speed. Then, the exercise consisted of extending the participant's elbow by 180° a total of five times while exerting the maximum possible force. The exercise was performed sequentially with each arm. The result was obtained from the average of the five repetitions of elbow extension in both arms, using the maximum peak force, also known as torque and it was expressed in Newton meters (Nm).

Knee extension. This test was performed using the same isokinetic device that was used for elbow extension. Initially, the participant's position was as follows: knee formed an angle of approximately 90° to the horizontal. The back was fully against the back of the seat and the hands held the grips at both ends. In addition, before the exercise was performed, the participant received specific instructions and started with a warm-up. Then, the exercise consisted of extending the participant's knee by 180 degrees a total of five times while exerting the maximum possible force. The exercise was performed sequentially with each leg. The result was obtained from the average of the five repetitions of knee extension in both legs, using the maximum peak force (Nm).

Perceived strength

Perceived strength was assessed using a single item from the International Fitness Scale (IFIS). Participants were asked to "rate their level of muscular strength as compared to people of the same age", with answers based on a 5-point Likert scale (very poor, poor, average, good, and very good). A higher score indicates greater perceived strength.

Mental health

Psychological ill-being outcomes

Anxiety and depressive symptoms. The Hospital Anxiety and Depression Scale (HADS) is a valid and reliable self-report questionnaire to assess anxiety and depressive symptoms in the Spanish population (Herrero et al., 2003). It consisted of 14 items with a categorized range from 0 to 3. The sum of the scores on odd-numbered questions generates a final score for anxiety and the sum on even-numbered questions generates a final score for depression. Each direct score obtained ranges between 0 to 21 with a higher score corresponding to a higher level of anxiety or depression.

Stress. The Perceived Stress Scale (PSS) is a valid and reliable self-report tool to assess stress in adults. It consists of 14 items with a five-point scale response format. The direct score obtained ranges from 0 to 56 with a greater score indicating a higher level of perceived stress (Baik et al., 2019; Cohen et al., 1983).

Loneliness. The University of California, Los Angeles Loneliness (UCLA-L) scale is a valid and reliable self-report to assess loneliness in older adults. This consists of 10 questions, with a four-point scale response format, giving a minimum of 10 and a maximum of 40 points so that an increased score corresponds to a higher level of loneliness (Russell., 1996).

Psychological well-being

Satisfaction with life. The Satisfaction with life questionnaire (SWLQ) is a valid and reliable self-report to assess satisfaction with life in older adults. It consisted of five questions with a five-point scale response format, with a minimum total score of 5 (low satisfaction) and a maximum of 25 (high satisfaction) (Vázquez et al., 2013).

Self-esteem. The Rosenberg Self-Esteem scale (RSE) is a valid and reliable self-report to assess self-esteem in adults. It consisted of 10 items with a four-point scale response format. The total score ranged from 0 to 30, which indicates that a higher score corresponds to a higher level of self-esteem (Mayordomo et al., 2020; Morejón et al., 2004).

Emotional well-being. SF-36 questionnaire is a valid and reliable self-report to assess emotional well-being in older adults. It consists of 5 items with a five-point scale response format, giving a minimum of 0 and a maximum of 100 points. The direct score obtained indicates that a higher score corresponds to a higher level of emotional well-being (Alonso et al., 1995; Vilagut et al., 2005).

Covariates

Based on the available literature focused on mental health in older adults, we included the following covariates in our models: sex, age and years of education (Gove & Tudor, 1973; Jokela et al., 2013; Lam et al., 2020); diet, alcohol consumption and smoking (Grajek et al., 2022; Quittschalle et al., 2021), body mass index (BMI) and cardiorespiratory fitness (CRF) (Kandola et al., 2019; Ul-Haq et al., 2014; Vancampfort et al., 2017). Years of education were obtained by asking them "*How many years of education did you complete?*". Diet quality was assessed with the adherence to the Mediterranean diet (MEDAS 14) questionnaire, using a total score ranging from 0 to 14 (Ferreira-Pêgo et al., 2016). We asked participants how often they consumed more than 5 alcoholic drinks for men and more than 4 for women in the last 12 months. Alcohol consumption was categorized into heavy (>5 drinks per week), moderate (<1 drink per month or 1–2 drinks per week), and never (never or not in the last 12 months). Participants were also asked: "Do you smoke?", and responses were categorized into current smokers, former smokers, or have never smoked. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Finally, cardiorespiratory fitness was assessed with the 2-km walking test (sec) (Kandola et al., 2019; Vancampfort et al., 2017), in which participants were asked to complete 2 km walking as fast as possible around a rectangular circuit.

Statistical analysis

The descriptive characteristics of the study sample were presented as means and standard deviation (SD) or number (percentages). Normal distribution was inspected with histograms and Shapiro Wilk test. Interactions between sex and muscular strength variables were tested for psychological ill-being and psychological well-being, but no significant interactions were found. We explored Pearsońs correlation between muscular strength (exposures) measures and mental health (outcomes). The associations between muscular strength and mental health outcomes were examined using linear regression models, adjusted for sex, age, years of education, diet, alcohol, smoking, and BMI (model 1). Finally, model 2 was additionally adjusted by cardiorespiratory fitness to examine whether cardiorespiratory fitness attenuated the association of muscular strength with mental health outcomes. We used the standardized β values and 95 % CI to show the associations together with their P-value (the significance level was set at $p<0.05$). We interpreted it as an association size indicator, in which a value of 0.2 is considered a small association size, 0.5 is considered a medium association size and 0.8 is considered a large association size. False discovery rate (FDR) (Benjamini–Hochberg method) was used to adjust for multiple comparisons (Benjamini & Hochberg.,1995). Correction for multiple comparisons was based on all models one and all models two, for a total of 84 tests. The analyses were conducted in R Studio (version 4.1.1) with the *stats* and *lm.beta* packages. The database and analysis script are reposited at GitHub: (https://github.com/aguedaprojectugr/Muscular_strength_Mental_health.git).

Results

Descriptive characteristics are presented in Table A. Ninety-one cognitively healthy older adults 71.69± 3.91 years old, participated in the study, of which 57 % were women.

Associations of muscular strength with psychological ill-being and psychological well-being outcomes are shown in Figs. A.1 and A.2, respectively. For psychological ill-being, elbow extension was positively associated with stress in model 1 ($\beta = 0.252$, 95 % Confidence Interval [95 % CI] = 0.007 to 0.497, $p = 0.044$), and even after further adjustment for cardiorespiratory fitness ($\beta = 0.282$, 95 % CI = 0.032 to 0.532, $p = 0.028$). Perceived strength was inversely associated with depressive symptoms in model 1 (β = -0.271, 95 % CI = -0.491 to -0.049, p = 0.017), and model 2 reported associations tending towards significant (β = -0.220, 95 % CI = -0.445 to 0.005, p = 0.055). For psychological well-being, handgrip strength was positively associated with self-esteem in model 1 ($\beta = 0.558$, 95 % CI = 0.168 to 0.949, $p = 0.006$) and model 2 (β = 0.546, 95 % CI = 0.135 to 0.956, p = 0.010). No further associations were found between other muscular strength variables and psychological ill-being (**Table B.1**) or psychological well-being (**Table B.2**). Overall, the present study found a relationship between muscular strength and mental health highlighting a positive moderate significant association between handgrip strength and self-esteem. However, these results should be taken cautiously as all associations became non-significant when analyses were adjusted for multiple comparisons (all $p_{FDR} > 0.252$). All the correlations between muscular strength and mental health outcomes are represented in **Figure B**, in supplementary material.

Discussion

This study examined the associations between different measures of muscular strength and mental health including psychological ill-being and well-being in a sample of cognitively normal older adults. Overall, perceived muscular strength was associated with depressive symptoms, in contrast, we did not observe any association between any objectively measured muscular strength indicators and depressive symptoms. We found a moderate association between handgrip strength and self-esteem. Contrary to our expectations, higher elbow extension muscular strength was positively associated with stress levels. Most of these associations were independent of cardiorespiratory fitness status but became non-significant when analyses were adjusted for multiple comparisons. No other associations were observed between muscular strength and mental health outcomes in cognitively normal older adults.

Higher levels of perceived muscular strength were associated with lower depressive symptoms in older adults . A possible explanation could be that experiencing a sense of strength may enhance the confidence of older individuals in maintaining their daily routines and fulfilling certain psychological needs, such as social connection and autonomy, which in turn, could protect them against the onset of depressive symptoms. In contrast, we did not observe any association between any objectively measured muscular strength indicators and depressive symptoms. It may suggest that for older people feeling stronger could be more relevant than being stronger itself (Rejeski et al., 2005). , This explanation is not in line with previous studies that observed an association between objectively measured muscular strength and depression in older people (Cabanas-Sánchez et al., 2022; Jiang, Westwater et al., 2022; López-Bueno et al., 2023). However, we only included participants without any severe mental disorder, which might partially explain the differences observed. f. Therefore, future studies in clinical and non-clinical samples are warranted in older people with different mental health conditions. Lastly, no previous studies have explored the role of both objective and perceived muscular strength in the mental health of cognitively normal older adults, which hampers the comparison of our results with current literature. In other populations, such as in people with fibromyalgia (Munguía-Izquierdo et al., 2021), both objective and perceived overall physical fitness was independently associated with lower psychological ill-being (i.e., negative emotions). In children and adolescents, perceived muscular strength was suggested as a mechanism that could explain the effect of physical exercise on psychological ill-being outcomes (Lubans et al., 2016). Overall, understanding the role of both objective and perceived strength in the mental health of older people might help to design more effective interventions for protecting mental health at these ages. Thus, more studies with larger sample sizes and including both muscular strength components are still needed in older people.

This study shows that handgrip strength was positively associated with self-esteem in our study sample. Previous evidence shows that muscular strength was related to other well-being variables (Chang et al., 2001; Jiang, Westwater et al., 2022). Even though we cannot compare these results in older adults, there are studies in children that show that greater muscular strength is related to self-esteem (Rodriguez-Ayllon et al., 2018). One explanation for the relationship between muscular strength and self-esteem could be that the elderly with greater strength may have a better feeling of being fit, greater self-confidence, and positive energy associated with good health. Additionally, elderly with greater muscular strength could have a better perception of their body image, so that they feel that they are stronger or even that their strength is aligned with aesthetic or personal ideals. Hence, self-esteem could be a mechanism through which muscular strength might improve other components of mental health. In our study, we have observed that self-esteem correlates with other components such as depression and anxiety. Therefore, future studies should test whether self-esteem is a mechanism through which strength is associated with other mental health outcomes. In the literature, self-esteem has been shown one of the most important mechanisms which mediate the associations between physical activity and psychiatric symptoms in youth (Rodriguez-Ayllon et al., 2023). Consequently, it is essential to investigate whether this outcome holds for muscular strength as well.

Contrary to our expectations (i.e., higher muscular strength would be associated with lower levels of stress (Kwak & Kim, 2022), we found that higher elbow extension muscular strength was positively associated with stress levels in older adults. This result must be interpreted carefully for several reasons. First, the overall stress levels in our population were low (i.e. "occasionally stressed" for males and "rarely or never stressed" for females) with only a limited proportion of individuals with high-stress levels, which makes our result less reliable. Second, this test based on the isokinetic device, has not been validated in older adults, so more research would be needed to confirm that this instrument measures accurately muscular strength in this population. Lastly, in this study, we assessed the relationship between muscular strength and chronic stress levels (how stressed you have felt in the last month). However, resistance training could have a greater acute effect on stress as seen with other blood markers or other myokines, which do not remain in the blood for a long time (Kraemer & Ratamess, 2005; Rodriguez-Ayllon et al., 2023). As our study is limited to being cross-sectional, we need intervention studies to analyze the acute and chronic effects of muscular strength on stress.

The correlation between muscular strength and other mental health variables, such as loneliness, has not been established, despite initial expectations of a potential relationship with physical activity (Lindsay Smith et al., 2017; Noh & Park, 2020). It is plausible that psychosocial mechanisms inherent to physical activity, such as socialization, are the factors that demonstrate an association with these mental health variables, as opposed to the mere aspect of physical fitness itself. It could be that physical activity and not muscular strength are related to them. Together, the small-moderate magnitude of the associations identified in this study and their loss of statistical significance after adjusting for multiple comparisons might suggest a limitation in statistical power for detecting these effects. Therefore, further investigations with larger sample sizes are warranted to deepen our understanding of the relationship between muscular strength and mental health in older adults.

Our study has several limitations. Firstly, it had a cross-sectional design, therefore, we are unable to infer causation. Secondly, the small sample size could explain the few associations found in the analyses. Thirdly, although we have controlled for potential confounding factors, there may be other variables that could interfere with these associations. The study has also several strengths, such as a defined cognitive status on the sample, the standardization, and objective muscular strength measurements including both field and laboratory tests for the lower and upper body, the assessment of perceived strength, and the inclusion of a broad set of mental health indicators.

Conclusion

Our most robust finding suggests that handgrip muscular strength is positively associated with self-esteem in cognitively normal older adults, which in turn was correlated with most of the explored psychological well-being and ill-being outcomes. Moreover, there was a positive small association between elbow extension and stress and a negative association between perceived strength and depressive symptoms. Many of these associations remained unaffected by cardiorespiratory fitness status; nevertheless, they lost statistical significance upon adjusting for multiple comparisons in the analyses. No other associations were observed between muscular strength and mental health outcomes in older adults. Future longitudinal studies, incorporating larger sample sizes and including both perceived and objective muscular strength indicators, remain necessary in elderly. The findings of this research collectively provide valuable insights into considering muscular strength as a potential element in exercise interventions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijchp.2024.100450.

Appendix

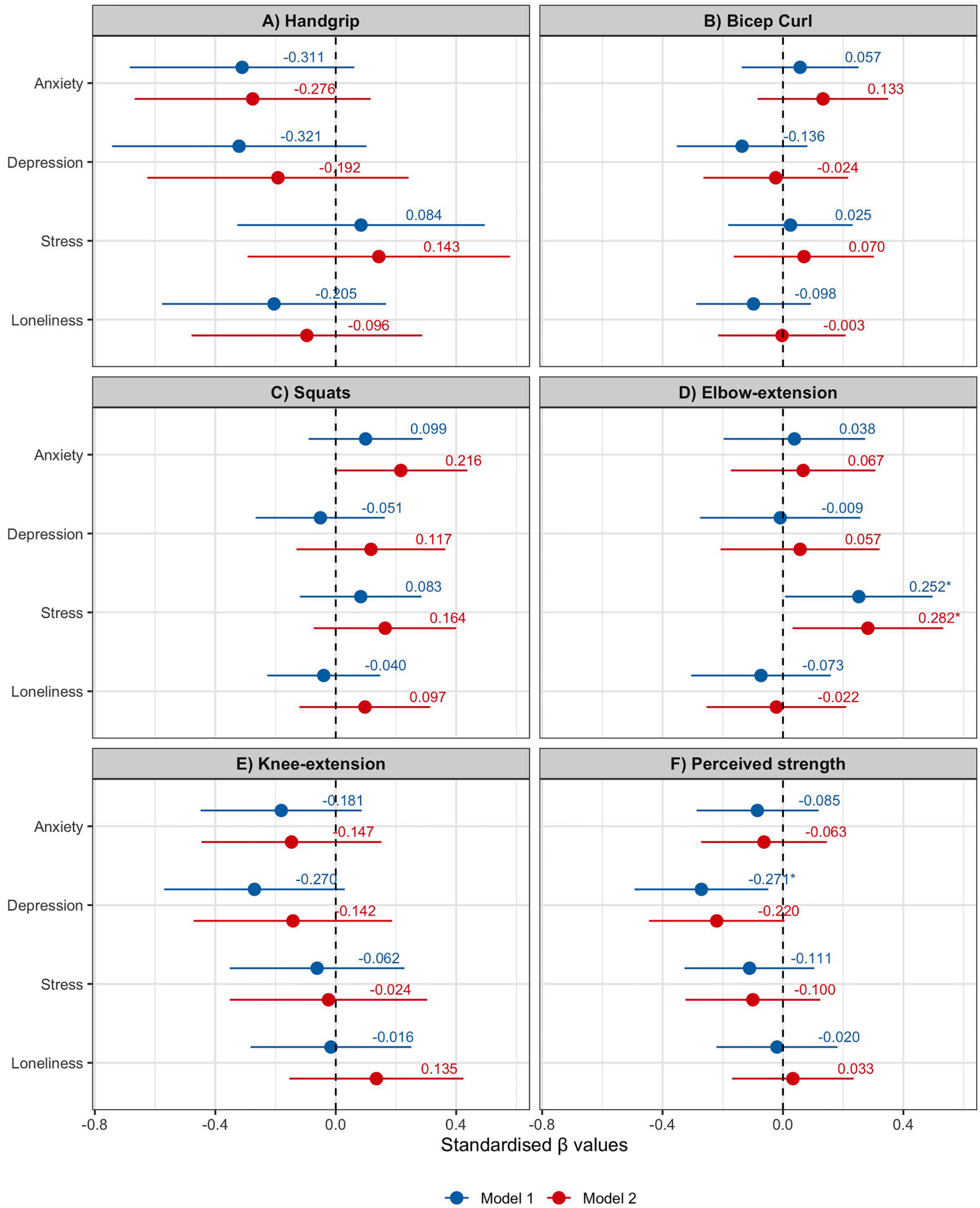

Fig. A.1. Associations of muscular strength with psychological ill-being in cognitively normal older adults. Model 1 was adjusted for sex, age, years of education, body mass index (BMI), diet, smoking, and alcohol, and model 2 was additionally adjusted for cardiorespiratory fitness. Values are standardized regression coefficients (β). * Denotes statistically significant.

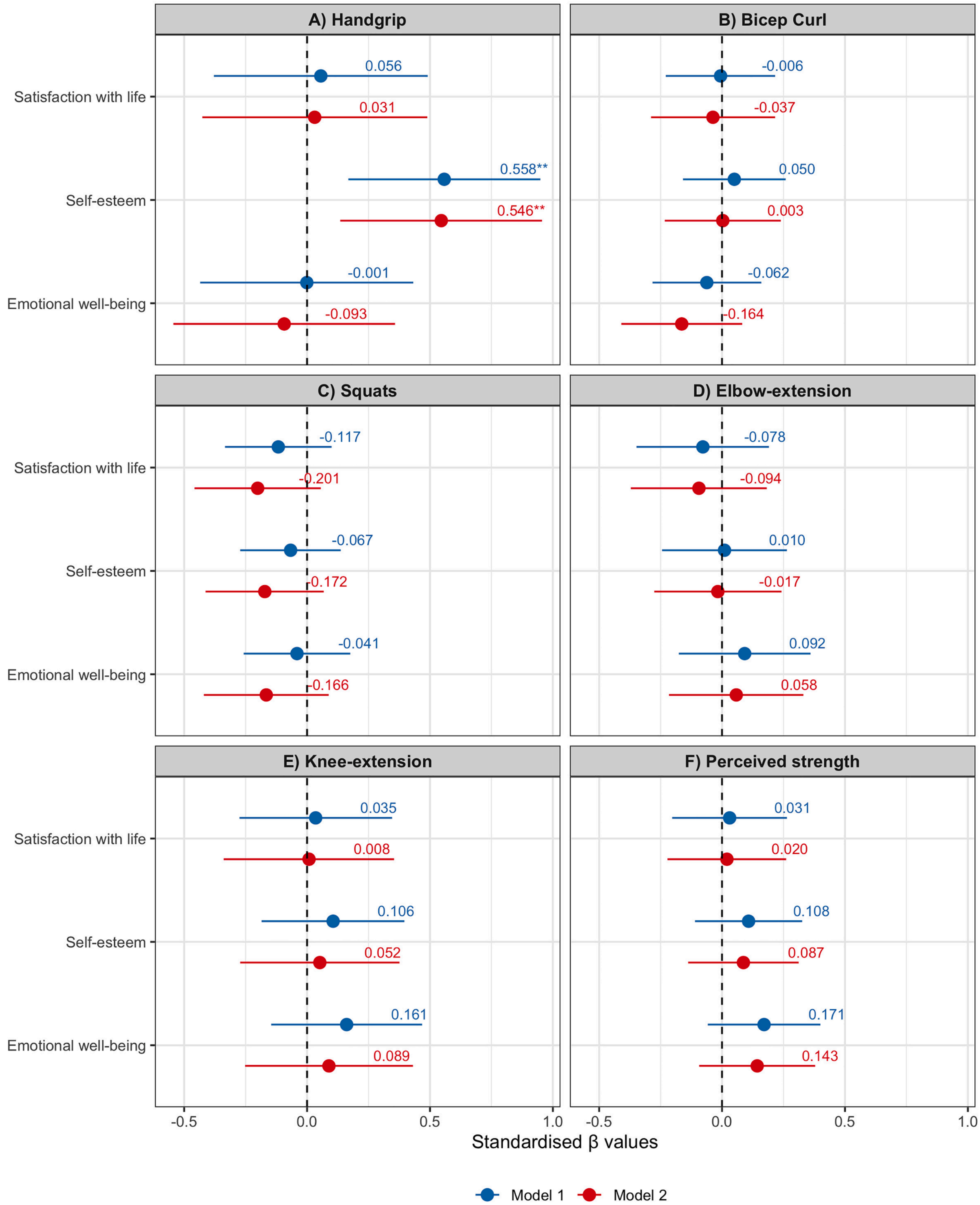

Fig. A.2. Associations of muscular strength with psychological well-being indicators in cognitively normal older adults. Model 1 was adjusted for sex, age, years of education, body mass index (BMI), diet, smoking, and alcohol, and model 2 was additionally adjusted for cardiorespiratory fitness. Values are standardized regression coefficients (*β*).
*Denotes statistically significant ($p < 0.05$). ** Denotes statistically significant ($p < 0.01$).

Table A
Descriptive characteristics of the study sample.

	Total sample		Males		Females	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Age (years)	91	71.69 (3.91)	39	71.46 (3.64)	52	71.87 (4.13)
Weight (kg)	91	73.94 (13.45)	39	82.55 (11.12)	52	67.48 (11.31)
Height (cm)	91	160.64 (9.13)	39	168.96 (7.12)	52	154.41 (4.10)
Body Mass Index (kg/m^2)	91	28.58 (4.27)	39	28.87 (3.06)	52	28.36 (5.00)
Years of education (years)	91	11.62 (4.92)	39	14.10 (4.90)	52	9.75 (4.08)
Alcohol intake (n, %)	91		39		52	
Never		15 (16.5)		2 (5.1)		13 (25.0)
Moderate		43 (47.3)		20 (51.3)		23 (44.2)
Heavy		33 (36.3)		17 (43.6)		16 (30.8)
Smoking status (n, %)	91		39		52	
Never		8 (8.8)		5 (12.8)		3 (5.8)
Former or Nonsmoker		83 (91.2)		34 (87.2)		49 (94.2)
Diet (MEDAS score 0–14)	91	8.20 (1.82)	39	7.23 (1.39)	52	8.92 (1.78)
2 km walking test (s)	91	1395.87 (224.04)	39	1303.82 (180.96)	52	1464.90 (229.86)
MoCA (0–30)	91	25.58 (2.13)	39	26.31 (1.91)	52	25.04 (2.14)
MMSE (0–30)	91	28.92 (1.06)	39	28.85 (0.96)	52	28.98 (1.13)
STICS-m (0–41)	91	33.96 (2.74)	39	34.51 (2.49)	52	33.54 (2.86)
Muscular strength						
Handgrip Strength (kg)	91	28.21 (9.77)	39	37.71 (6.95)	52	21.09 (3.42)
Biceps Curl (reps)	91	16.05 (3.78)	39	17.18 (3.56)	52	15.21 (3.76)
Squats (reps)	91	13.98 (2.96)	39	14.64 (2.97)	52	13.48 (2.87)
Knee Extension (Nm)	91	96.78 (33.92)	39	123.01 (30.92)	52	77.11 (19.94)
Elbow Extension (Nm)	91	90.19 (34.26)	39	113.09 (34.50)	52	73.02 (21.96)
Perceived Strength (0–5)	90	3.20 (0.72)	39	3.41 (0.72)	51	3.04 (0.69)
Mental Health						
Psychological ill-being						
Anxiety (0–21)	90	9.58 (3.87)	39	7.38 (2.70)	51	11.23 (3.82)
Depression (0–21)	90	9.19 (3.99)	39	8.13 (4.11)	51	9.98 (3.74)
Stress (0–56)	90	15.29 (7.38)	39	12.18 (7.49)	51	17.67 (6.40)
Loneliness (10–40)	90	18.06 (5.31)	39	14.82 (3.65)	51	20.53 (5.07)
Psychological well-being						
Satisfaction with Life (5–25)	90	20.43 (3.75)	39	21.28 (3.52)	51	19.78 (3.82)
Self-esteem (0–30)	90	18.20 (3.14)	39	19.18 (3.34)	51	17.45 (2.79)
Emotional well-being (0–100)	90	55.16 (7.67)	39	57.64 (6.47)	51	53.31 (8.03)

Values are mean (standard deviation) or percentages. MEDAS, Mediterranean Diet Adherence Score; MoCa: The Montreal Cognitive Assessment, MMSE: Mini-Mental State Examination, STICS-m: Telephone Interview for cognitive status-modified, Nm, newton-meter.

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