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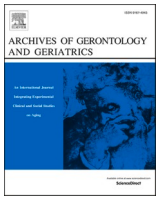

Grip strength buffers the harmful association between multimorbidity and depression among middle-aged and older adults

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HIGHLIGHTS

- For the first time the moderating effect of grip strength in the association between multimorbidity and depression was explored.
- Grip strength buffers the harmful association between multimorbidity and depression.
- Muscle-strengthening activities may be used to reduce the impact of multimorbidity on depression.

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ABSTRACT

Background: Grip strength (GS) is associated to both multimorbidity and depression, however its possible moderating effect is unknown. This study aimed to investigate GS moderating effect on the association between multimorbidity and depression.
Methods: Data from SHARE wave 8 was used. Participant were 41457 middle-aged and older adults (17954 men) from 18 European countries. A regression analysis was conducted for the moderating effect of sex- and age-specific GS quartiles (W) on the association between number of chronic diseases (X_1) or multimorbidity (X_2) and depression symptoms (Y).
Results: More chronic diseases were associated with greater depressive symptomatology (men: $B = 0.39$, 95 % CI: 0.35, 0.42; women: $B = 0.42$, 95 % CI: 0.39, 0.45). On the other hand, being in a higher GS quartile was associated with fewer depression symptoms, and this association was stronger the higher the quartile was. Having a higher GS represented a decrease in depression symptoms associated with multimorbidity for men (quartile 1: $B = 0.85$, 95 % CI = 0.74, 0.95 vs. quartile 4: $B = 0.49$, 95 % CI = 0.38, 0.61) and women (quartile 1: $B = 1.08$, 95 %CI = 0.97, 1.19 vs. quartile 4: $B = 0.59$, 95 %CI: 0.47, 0.70).
Conclusions: Strategies aiming to reduce the impact of multimorbidity on mental health should promote muscle-strengthening physical activity among middle-aged and older adults.

1. Background

Mental health conditions are increasing worldwide. Among them, depression is a common mental disorder characterised by persistent sadness and a lack of interest or pleasure (APA, 2013). The worldwide prevalence of major depressive disorder is approximately 6%, however, the lifetime risk of depression is three times higher (15–18 %) (Malhi & Mann, 2018). Depression can profoundly affect all aspects of life, such as

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quality of life, relationships with others, education, work opportunities, and productivity (WHO, 2017). Furthermore, depression is often associated with physical comorbidity (Lotfaliany et al., 2018) and other mental disorders (Plana-Ripoll et al., 2019). In addition to being a burden for individuals, depression imposes an immense economic burden on society and healthcare systems due to the costs of pharmacotherapy and psychotherapy in the long term for many people (Chisholm et al., 2016).

Depression is a common comorbidity among patients with chronic diseases, being two to three times more likely in people with multimorbidity (Read et al., 2017). However, multimorbidity and depression have a bidirectional association, as baseline depression can also contribute to an increased risk of multimorbidity (Triolo et al., 2020). Largely due to the aging population trend, the prevalence of multimorbidity is increasingly common and complicates the assessment and management of depression (Read et al., 2017).

Physical activity is a well-known protective factor associated with depression (Marques et al., 2021) and multimorbidity (Marques et al., 2018). Engaging in physical activity improves health by different mechanisms. One of them is by increasing physical fitness, including muscular fitness. Thus, grip strength, a maximum hand static force measure commonly used to capture overall muscular strength, is also related to depression and multimorbidity. Having greater grip strength decreases the odds of depression, especially for older adults (Marques et al., 2020), and multimorbidity (Bohannon, 2019).

Prevention of depression should be a priority of the public health system for adults and older adults with multimorbidity, for whom depression is highly prevalent (Hu et al., 2022). Given its inverse association with depression and multimorbidity, grip strength may have an important role in managing depression for people with multimorbidity. However, to the best of our knowledge, the moderator role of grip strength in the relationship between multimorbidity and depression in middle-aged and older adults remains unexplored. As grip strength can be improved through physical activity, this knowledge could be useful to adapt guidelines and improve outcomes to limit the adverse effects of multimorbidity on depression. Therefore, this study aimed to investigate the moderating role of grip strength in the relationship between multimorbidity and depression.

2. Methods

2.1. Procedures and participants

Secondary data from the Survey of Health, Aging, and Retirement in Europe (SHARE) was used. Data was collected from October 2019 to March 2020, before the COVID-19 pandemic, being part of the SHARE wave 8, (Börsch-Supan, 2022). SHARE collects information on individuals aged 50 and over in some European countries and Israel biannually since 2000, providing a multidisciplinary view to future challenges of population ageing. Data was collected through face-to-face interviews of approximately 90 min at the participant's residence. In each country data collection was the responsibility of a national organization (e.g. universities), however it was organized similarly by following the SHARE methodology (Bergmann & Börsch-Supan, 2021). Household visits conducted by trained interviewers were performed using Computer Assisted Personal Interview. SHARE protocol was approved by the Ethics Council of the Max-Plank Society for the Advancement of Science, verifying the procedures to guarantee confidentiality and data privacy.

Participants from SHARE wave 8 that presented data on grip strength, depression symptoms, multimorbidity, physical activity participation, country, sex and age were included in the study. The sample comprised 41 457 participants, 17 954 men and 23 503 women (mean age ± standard deviation= 69.82 ± 9.00 years) from 18 countries (Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Israel, Italy, Luxembourg, Poland, Portugal, Slovenia, Spain, Sweden, and Switzerland).

2.2. Measures

Outcome: depression symptoms. The EURO-D 12-item scale was administered to measure depression symptoms. Prince et al. (1999) described the scale and the validating process elsewhere. Score range between 0 and 12, with higher scores indicative of higher depressive symptomatology.

Moderator: grip strength. Grip strength was assessed twice on each hand using a handheld dynamometer (Smedley, S Dynamometer, TTM, Tokyo) with respondents standing or sitting, keeping the upper arm tight against the trunk, their elbow fixed at a 90° angle, and a neutral wrist position. Participants were asked to squeeze the dynamometer with each hand as hard as possible and maintain it for 5 s. Before the assessment, participants could practice. The force of grip strength was recorded in kilograms (valid measurements comprised values of two measures in one hand that differed by less than 20 kg). Grip strength measurements of 0 kg or over 100 kg were excluded. Moreover, as grip strength significantly differs between men and women and declines with age (Leong et al., 2016), sex- and age-specific quartiles were calculated. Therefore, the sample was simultaneously stratified by sex and categorical age using five years age groups (50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85–89 and over 90). For each sex and age group the grip strength quartile was calculated. A higher quartile indicates stronger grip strength for a particular sex and age group.

Independent variable and covariates. The main independent variable was multimorbidity, defined as two or more chronic conditions (van den Akker et al., 2001). To assess multimorbidity, participants were asked to report the presence or absence of diseases diagnosed by a medical doctor. The number of chronic diseases was summed to produce a score and classify participants as having or not multimorbidity. Covariates considered in this study were age, sex, country, and physical activity behaviour. All covariates were self-reported. To assess physical activity behaviour, participants reported the number of days per week they engage in moderate physical activity (e.g., brisk walking, gardening, or household activities) and in vigorous physical activity (e.g., hiking, sports, carrying heavy loads). Responses included "more than once a week", "once a week", "up to 3 times a month", and "hardly ever or never". The last two response options were grouped into "less than once a week".

2.3. Statistical analysis

Data analysis was performed using SPSS Statistics, version 29 (IBM Corp., Armonk, NY). Statistical significance was set at $p < 0.05$. Descriptive statistics (including the percentage or mean and 95 % confidence interval [CI]) were calculated for all variables for the total sample and each sex separately. Then, a moderator regression analysis was conducted for two models (see Fig. 1) with the PROCESS macro for SPSS version 4.2 (Hayes, 2022). In both models, the moderator was grip strength quartiles (W), and the dependent variable was depression symptoms (Y). In model 1 the independent variable was the number of chronic diseases (X_1), whereas in model 2 it was multimorbidity (X_2). Both models were adjusted for age, country and physical activity behaviour, and the analysis was stratified by sex.

3. Results

Table 1 shows the characteristics of the participants. Participation in moderate physical activity was similar for men and women. However, more men than women reported participating in vigorous physical activity more than once a week (36.5 %, 95 % CI: 35.8, 37.2 vs 29.3 %, 95 % CI: 28.8, 29.9). More than half (52.0 %, 95 % CI: 51.6, 52.6) of the participant had multimorbidity, and it was slightly more prevalent in women (50.2 %, 95 % CI: 49.5, 50.9 vs. 53.4 %, 95 % CI: 52.8, 54.1).

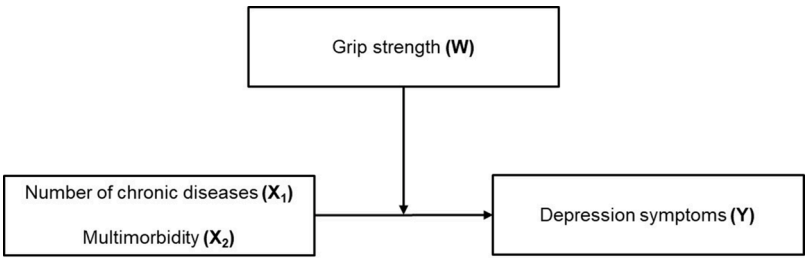

Fig. 1. Moderator regression analysis models: association between number of chronic diseases (X_1) or multimorbidity (X_2) and depression symptoms (Y) moderated by grip strength (W).

Table 1
Participants characteristics for the total sample and by sex.

	Mean or % (95 %CI)		
	Total (n =41 457)	Men (n =17 954)	Women (n =23 503)
Age (years)	69.82 (69.73, 69.91)	70.22 (70.09, 70.34)	69.52 (69.40,69.64)
Moderate physical activity			
Less than once a week	18.5 (18.1, 18.9)	17.6 (17.1, 18.2)	19.2 (18.7, 19.7)
Once a week	14.9 (14.6, 15.2)	15.0 (14.5, 15.6)	14.9 (14.5, 15.4)
More than once a week	66.6 (66.1, 67.0)	67.4 (66.7, 68.1)	65.9 (65.3, 66.5)
Vigorous physical activity			
Less than once a week	52.4 (51.9, 52.9)	48.5 (47.8, 49.2)	55.4 (54.7, 56.0)
Once a week	15.2 (14.8, 15,5)	15.0 (14.5, 15.5)	15.3 (14.8, 15.8)
More than once a week	32.4 (32.0, 32.9)	36.5 (35.8, 37.2)	29.3 (28.8, 29.9)
Grip strength (kg)	32.03 (31.92, 32.13)	40.67 (40.53, 40.82)	25.42 (25.34, 25.51)
Grip strength groups			
Quartile 1	27.9 (27.4, 28.2)	27.5 (26.9, 28.2)	28.1 (27.5, 28.6)
Quartile 2	25.6 (25.2, 26.0)	25.7 (25.1, 26.4)	25.5 (24.9, 26.0)
Quartile 3	23.4 (22.9, 23.8)	23.7 (23.1, 24.3)	23.1 (22.5, 23.6)
Quartile 4	23.1 (22.7, 23.5)	23.1 (22.5, 23.7)	23.2 (22.5, 23.6)
Chronic diseases (number)	1.86 (1.84, 1.87)	1.79 (1.77, 1.81)	1.91 (1.89, 1.93)
Multimorbidity			
No	48.0 (47.5, 48.5)	49.8 (49.1, 50.6)	46.6 (45.9, 47.2)
Yes	52.0 (51.6, 52.6)	50.2 (49.5, 50.9)	53.4 (52.8, 54.1)
EURO-D scale (score)	2.32 (2.29, 2.34)	1.90 (1.87, 1.93)	2.63 (2.60, 2.66)

Furthermore, women presented more depression symptoms than men (1.90, 95 % CI: 1.87, 1.93 vs. 2.63, 95 % CI: 2.60, 2.66).

Participants characteristics by grip strength quartile are presented in table S2. Men and women in the highest quartile reported participating more in moderate and vigorous physical activity. Furthermore, they had a lower prevalence of multimorbidity and depression scores than those in the lowest quartile.

The moderation analysis for model 1 (X_1= number of chronic diseases) is presented in Table 2. More chronic diseases were associated with greater depressive symptomatology (men: B = 0.39, 95 % CI: 0.35, 0.42; women: B = 0.42, 95 % CI: 0.39, 0.45). On the other hand, being in a higher grip strength quartile was associated with fewer depression symptoms, and this association was stronger the higher the quartile was. The interaction effect of chronic diseases with grip strength was negative, meaning that being in a higher grip strength quartile hampered the positive association between the number of chronic diseases and depression. For men, compared with quartile 1, being in any grip strength quartile provided significant protection (quartile 2: B = -0.11, 95 % CI: -0.15, -0.06; quartile 3: B = -0.11, 95 % CI: -0.16, -0.07; quartile 4: B = -0.15, 95 % CI: -0.20, -0.10), whereas for women this moderation effect was only significant for quartiles 3 and 4 (quartile 3: B = -0.06, 95 % CI: -0.11, -0.02; quartile 4: B = -0.11, 95 % CI: -0.16, -0.06). This interaction is corroborated by the decreasing B coefficient of the association between chronic diseases and depression symptoms observed with increasing grip strength quartile. To further investigate the possible interaction with age a sub-group analysis for each age group examining the moderating effect of grip strength was performed (table S2). The pattern of association was different for different age groups and for men and women. Men presented a varying pattern with younger age groups (50–59 years) presenting a moderating effect for middle quartiles (2 and 3) and older age groups (85+ years) and others (60–64 and 70–47 years) showing a greater moderating effect for the highst grip strength quartile. Women main moderation effect was found only for the strongest quartile and between 60 and 79 years old.

Table 2
Moderation analysis for the association between the number of chronic diseases and depression symptoms by sex- and age-specific grip strength quartile.

	B (95 %CI) for EURO-D scale (score)	
	Men (n = 17 954)	Women (n = 23 503)
Chronic diseases (number)	0.39 (0.35, 0.42)	0.42 (0.39, 0.45)
Grip strength groups		
Quartile 1	0.00 (ref.)	0.00 (ref.)
Quartile 2	-0.06 (-0.18, 0.05)	-0.21 (-0.33, -0.10)
Quartile 3	-0.07 (-0.19; 0.05)	-0.27 (-0.39, -0.15)
Quartile 4	-0.14 (-0.26, -0.24)	-0.34 (-0.46, -0,22)
Chronic diseases x grip strength (interaction)		
Quartile 1	0.00 (ref.)	0.00 (ref.)
Quartile 2	-0.11 (-0.15, -0.06)	-0.04 (-0.09, 0.00)
Quartile 3	-0.11 (-0.16, -0.07)	-0.06 (-0.11, -0.02)
Quartile 4	-0.15 (-0.20, -0.10)	-0.11 (-0.16, -0.06)
Chronic diseases by grip strength		
Quartile 1	0.39 (0.35, 0.42)	0.42 (0.39, 0.45)
Quartile 2	0.28 (0.25, 0.31)	0.38 (0.35, 0.41)
Quartile 3	0.27 (0.23, 0.31)	0.36 (0.32, 0.39)
Quartile 4	0.23 (0.19, 0.27)	0.31 (0.27, 0.35)

Analysis was adjusted for age, country, moderate and vigorous physical activity.

The association between multimorbidity and depression symptoms moderated by grip strength for men and women (model 2, X_2= multimorbidity) is illustrated in Fig. 2. Grip strength significantly moderated this association, having a protective effect. For both sexes being in a

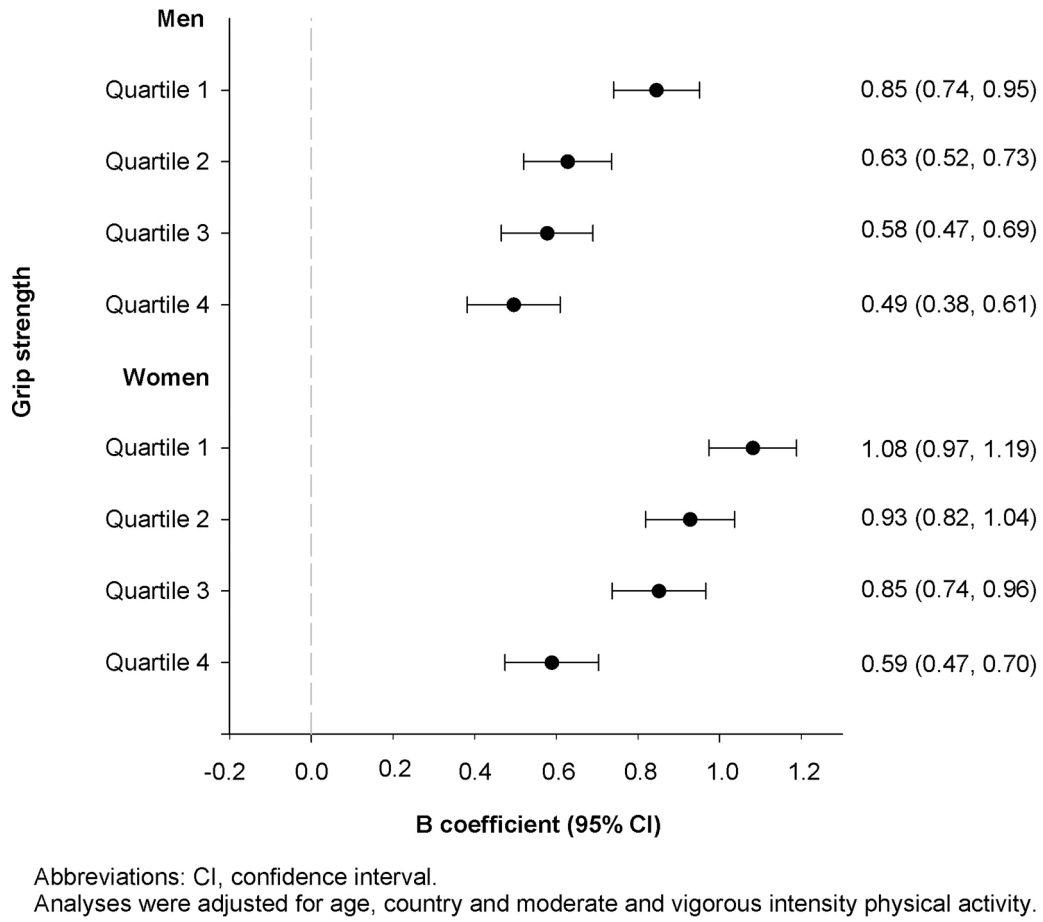

Fig. 2. Association between multimorbidity and depression symptoms moderated by grip strength for men and women.

higher grip strength quartile represented a decrease in depression symptoms associated with multimorbidity. For women in quartile 1, having multimorbidity contributed to having one more depression symptom (B = 1.08, 95 %CI: 0.97, 1.19), while being in quartile 4 only contributed to "half" a symptom (B = 0.59, 95 %CI: 0.47, 0.70). A similar reduction was observed for men, as the B coefficient decreased from 0.85 (95 % CI: 0.74, 0.95) in quartile 1 to 0.49 (95 % CI: 0.38, 0.61) in quartile 4.

4. Discussion

For the first time, this study explored the moderating effect of grip strength in the association between multimorbidity and depression symptoms among middle-aged and older adults from 14 European countries. Findings showed that individuals with greater grip strength have a weaker association between multimorbidity and depression, suggesting that grip strength has a protective effect. Thus, public health strategies aiming to reduce the impact of multimorbidity on mental health should promote muscle-strengthening physical activity among middle-aged and older adults.

A recent scoping review showed the prevalence of multimorbidity (defined as having more than one chronic condition) considerably varies, from 15.3 to 93.1 %, between investigations (Chua et al., 2021). In this study, the prevalence of multimorbidity was 52.0 %, in the middle of the literature prevalence range. Furthermore, the prevalence was slightly higher for women (53.4 %) than for men (50.2 %). Sex is a well-recognised determinant of multimorbidity. Men tend to have more cardiovascular and metabolic disorders, and women have more psychogeriatric diseases (Abad-Diez et al., 2014). In fact, in this study, women presented more depression symptoms than men, being consistent with previous research (Salk et al., 2017).

Having more chronic diseases was associated with greater depressive symptomatology. In contrast, greater grip strength was related to fewer symptoms. These findings are corroborated by previous research (Marques et al., 2020; Read et al., 2017). Furthermore, a negative interaction effect of chronic diseases and grip strength on depression was found. Therefore, being in a higher grip strength quartile hampered the positive association between both the number of chronic diseases and multimorbidity with depression. Although it was expected that grip strength could buffer this relationship as it is known to protect against depression (Marques et al., 2020) and multimorbidity (Bohannon, 2019), to the best of our knowledge, this is the first study to examine its moderation effect. The association between multimorbidity and depression was weaker the higher the quartile was for both sexes. Following our findings, future research should investigate how possible differences between men and women may affect the protective effect of grip strength on the association between multimorbidity and depression.

Several mechanisms may explain why grip strength, an indicator of overall muscular strength, affects the association between multimorbidity and depression. This is especially relevant for middle-aged and older adults with an age-related decline in muscle mass and strength. As a potential physical mechanism, skeletal muscle contraction releases several cytokines into circulation. These cytokines could protect against the risk of several diseases, including depression (Kohler et al., 2017). Therefore, having greater muscle strength is related to a better anti-inflammatory profile among middle-aged and older age, decreasing the risk for several physical diseases (Bano et al., 2017) and depression (Steptoe et al., 2012). Furthermore, resistance training lowers oxidative stress (Gacitua et al., 2018), which is associated with increased multimorbidity and depression (Kandola et al., 2019).

Multimorbidity may lead to increase functional difficulties in addition to ageing that jeopardises the performance of daily life tasks. On a psychological aspect, poor physical functioning can affect feelings of achievement (Laredo-Aguilera et al., 2018) and self-efficacy, representing protective factors for depression symptoms (Kandola et al., 2019). Moreover, resistance training reduces painful comorbidities such as arthritis and low back pain (Magni et al., 2017) and improves neuromuscular coordination and balance, reducing the risk of falls and injuries from falls (Granacher et al., 2013). Eventually, having greater strength allows for more independence in daily life activities (Laredo-Aguilera et al., 2018). Thus, older adults with greater mobility and less disability can engage in social activities and receive social support, leading to a lower risk for depression (Kandola et al., 2019).

From a public health perspective, these findings emphasise the importance of promoting physical activity and improving muscular fitness to counteract the nefarious association between multimorbidity and depression, supported by the age-related decline in muscle mass and strength (Kim & Choi, 2013). Therefore, it reinforces the current physical activity recommendations, which suggest that older people engage in muscle-strengthening activities involving major muscle groups at least twice a week. Therefore, mental health professionals and public health policy should include resistance training as a preventive measure and treatment strategy to buffer the impact of multimorbidity and depression.

Several limitations of this study warrant mention. First, the cross-sectional design precludes making causal inferences, thus, a potential reverse relationship cannot be excluded. Secondly, the grip strength assessment did not consider information about cultural variations of the use of grip strength in daily social routines and participants' hand size, which could affect grip strength. Moreover, grip strength was only reported from participants who agreed to perform this test, leading to potential selection bias. It is possible that participants included were the ones with better grip strength in the SHARE sample. Thirdly, the number of chronic diseases, depression symptoms and physical activity behaviour were self-reported, which can lead to bias. Finally, information about each participant's family history of depression that may affect depression symptoms was unavailable. Despite these limitations, this study also presents some strengths. A large representative sample from several countries with heterogeneous participants in terms of culture and sociodemographic characteristics was used. Therefore, our findings may be generalisable. Grip strength was collected using a standardised protocol in all countries and by trained individuals. Furthermore, using sex- and age-specific quartiles allowed for a better classification of middle-aged and older adults in their relative strength profile.

5. Conclusion

Regardless of gender and age, grip strength has a protective moderator effect on the relationship between multimorbidity and depression symptoms among middle-aged and older adults. Greater grip strength was related to a decreased association between multimorbidity and depression symptoms, buffering this harmful association. Our findings suggest that policies for promoting mental health should include physical activity to increase muscle strength to improve mental health.

Declaration of generative AI in scientific writing

No AI tolls were used during the preparation of this work.

CRediT authorship contribution statement

Clément Blanchet: Writing – original draft, Investigation, Formal analysis, Conceptualization. **Miguel Peralta:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Marcelo de Maio Nascimento:** Writing – review & editing, Investigation. **Élvio R. Gouveia:** Writing – review & editing, Supervision, Investigation. **Gerson Ferrari:** Writing – review & editing, Investigation. **Tiago D. Ribeiro:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Adilson Marques:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

None to declare.

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Supplementary materials

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References

Abad-Diez, J. M., Calderon-Larranaga, A., Poncel-Falco, A., Poblador-Plou, B., Calderon-Meza, J. M., Sicras-Mainar, A., Clerencia-Sierra, M., & Prados-Torres, A. (2014). Age and gender differences in the prevalence and patterns of multimorbidity in the older population. *BMC Geriatrics, 14*, 75.

APA. (2013). *Diagnostic and Statistical Manual of Mental Disorders: DSM-5* (5th ed.). Arlington, VA: American Psychiatric Association.

Bano, G., Trevisan, C., Carraro, S., Solmi, M., Luchini, C., Stubbs, B., Manzato, E., Sergi, G., & Veronese, N. (2017). Inflammation and sarcopenia: A systematic review and meta-analysis. *Maturitas, 96*, 10–15.

Bergmann, M., Börsch-Supan, A., 2021. SHARE wave 8 methodology: Collecting cross-national survey data in times of COVID-19, Munich.

Bohannon, R. W. (2019). Grip strength: An indispensable biomarker for older adults. *Clinical Interventions in Aging, 14*, 1681–1691.

Börsch-Supan, A., 2022. Survey of health, ageing and retirement in Europe (SHARE) Wave 8, 8.0.0 ed.

Chisholm, D., Sweeny, K., Sheehan, P., Rasmussen, B., Smit, F., Cuijpers, P., & Saxena, S. (2016). Scaling-up treatment of depression and anxiety: a global return on investment analysis. *The Lancet Psychiatry, 3*, 415–424.

Chua, Y. P., Xie, Y., Lee, P. S. S., & Lee, E. S. (2021). Definitions and prevalence of multimorbidity in large database studies: A scoping review. *International Journal of Environmental Research and Public Health, 18*.

Gacitua, T., Karachon, L., Romero, E., Parra, P., Poblete, C., Russell, J., & Rodrigo, R. (2018). Effects of resistance training on oxidative stress-related biomarkers in metabolic diseases : A review. *Sport Sciences for Health, 14*, 1–7.

Granacher, U., Gollhofer, A., Hortobagyi, T., Kressig, R. W., & Muehlbauer, T. (2013). The importance of trunk muscle strength for balance, functional performance, and fall prevention in seniors: a systematic review. *Sports medicine (Auckland, N.Z.), 43*, 627–641.

Hayes, A. (2022). *Introduction To Mediation, Moderation, And Conditional Process Analysis : A Regression-Based Approach* (3rd ed.). New York: The Guilford Press.

Hu, T., Zhao, X., Wu, M., Li, Z., Luo, L., Yang, C., & Yang, F. (2022). Prevalence of depression in older adults: A systematic review and meta-analysis. *Psychiatry Research, 311*, Article 114511.

Kandola, A., Ashdown-Franks, G., Hendrikse, J., Sabiston, C. M., & Stubbs, B. (2019). Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neuroscience and Biobehavioral Reviews, 107*, 525–539.

Kim, T. N., & Choi, K. M. (2013). Sarcopenia: definition, epidemiology, and pathophysiology. *Journal of Bone Metabolism, 20*, 1–10.

Kohler, C. A., Freitas, T. H., Maes, M., de Andrade, N. Q., Liu, C. S., Fernandes, B. S., Stubbs, B., Solmi, M., Veronese, N., Herrmann, N., Raison, C. L., Miller, B. J., Lanctot, K. L., & Carvalho, A. F. (2017). Peripheral cytokine and chemokine alterations in depression: a meta-analysis of 82 studies. *Acta Psychiatrica Scandinavica, 135*, 373–387.

Laredo-Aguilera, J. A., Carmona-Torres, J. M., Garcia-Pinillos, F., & Latorre-Roman, P. A. (2018). Effects of a 10-week functional training programme on pain, mood state, depression, and sleep in healthy older adults. *Psychogeriatrics : The Official Journal of the Japanese Psychogeriatric Society, 18*, 292–298.

Leong, D. P., Teo, K. K., Rangarajan, S., Kutty, V. R., Lanas, F., Hui, C., Quanyong, X., Zhenzhen, Q., Jinhua, T., Noorhassim, I., AlHabib, K. F., Moss, S. J., Rosengren, A., Akalin, A. A., Rahman, O., Chifamba, J., Orlandini, A., Kumar, R., Yeates, K., Gupta, R., Yusufali, A., Dans, A., Avezum, A., Lopez-Jaramillo, P., Poirier, P., Heidari, H., Zatonska, K., Iqbal, R., Khatib, R., & Yusuf, S. (2016). Reference ranges of handgrip strength from 125,462 healthy adults in 21 countries: a prospective urban rural epidemiologic (PURE) study. *Journal of Cachexia, Sarcopenia and Muscle, 7*, 535–546.

Lotfaliany, M., Bowe, S. J., Kowal, P., Orellana, L., Berk, M., & Mohebbi, M. (2018). Depression and chronic diseases: Co-occurrence and communality of risk factors. *Journal of Affective Disorders, 241*, 461–468.

Magni, N. E., McNair, P. J., & Rice, D. A. (2017). The effects of resistance training on muscle strength, joint pain, and hand function in individuals with hand osteoarthritis: a systematic review and meta-analysis. *Arthritis research & therapy, 19*, 131.

Malhi, G. S., & Mann, J. J. (2018). Depression. *Lancet (London, England), 392*, 2299–2312.

Marques, A., Gaspar de Matos, M., Bordado, J., Gouveia, E. R., Peralta, M., & Gomez-Baya, D. (2021). Different levels of physical activity and depression symptoms among older adults from 18 countries: A population-based study from the Survey of Health, Ageing and Retirement in Europe (SHARE). *European Journal of Sport Science, 21*, 887–894.

Marques, A., Gaspar de Matos, M., Henriques-Neto, D., Peralta, M., Gouveia, E. R., Tesler, R., Martins, J., & Gomez-Baya, D. (2020). Grip strength and depression symptoms among middle-age and older adults. *Mayo Clinic Proceedings, 95*, 2134–2143.

Marques, A., Peralta, M., Gouveia, E. R., Chavez, F. G., & Valeiro, M. G. (2018). Physical activity buffers the negative relationship between multimorbidity, self-rated health and life satisfaction. *Journal of Public Health -Uk, 40*, E328–E335.

Plana-Ripoll, O., Pedersen, C. B., Holtz, Y., Benros, M. E., Dalsgaard, S., de Jonge, P., Fan, C. C., Degenhardt, L., Ganna, A., Greve, A. N., Gunn, J., Iburg, K. M., Kessing, L. V., Lee, B. K., Lim, C. C. W., Mors, O., Nordentoft, M., Prior, A., Roest, A. M., Saha, S., Schork, A., Scott, J. G., Scott, K. M., Stedman, T., Sorensen, H. J., Werge, T., Whiteford, H. A., Laursen, T. M., Agerbo, E., Kessler, R. C., Mortensen, P. B., & McGrath, J. J. (2019). Exploring comorbidity within mental disorders among a danish national population. *JAMA Psychiatry, 76*, 259–270.

Prince, M. J., Reischies, F., Beekman, A. T., Fuhrer, R., Jonker, C., Kivela, S. L., Lawlor, B. A., Lobo, A., Magnusson, H., Fichter, M., van Oyen, H., Roelands, M., Skoog, I., Turrina, C., & Copeland, J. R. (1999). Development of the EURO-D scale–a European, Union initiative to compare symptoms of depression in 14 European centres. *The British Journal of Psychiatry : The jouRnal of Mental Science, 174*, 330–338.

Read, J. R., Sharpe, L., Modini, M., & Dear, B. F. (2017). Multimorbidity and depression: A systematic review and meta-analysis. *Journal of Affective Disorders, 221*, 36–46.

Salk, R. H., Hyde, J. S., & Abramson, L. Y. (2017). Gender differences in depression in representative national samples: Meta-analyses of diagnoses and symptoms. *Psychological Bulletin, 143*, 783–822.

Steptoe, A., Demakakos, P., de Oliveira, C., & Wardle, J. (2012). Distinctive biological correlates of positive psychological well-being in older men and women. *Psychosomatic Medicine, 74*, 501–508.

Triolo, F., Harber-Aschan, L., Murri, M. B., Calderon-Larranaga, A., Vetrano, D. L., Sjoberg, L., Marengoni, A., & Dekhtyar, S. (2020). The complex interplay between depression and multimorbidity in late life: risks and pathways. *Mechanisms of Ageing and Development, 192*.

van den Akker, M., Buntinx, F., Roos, S., & Knottnerus, J. A. (2001). Problems in determining occurrence rates of multimorbidity. *Journal of Clinical Epidemiology, 54*, 675–679.

WHO, 2017. Depression and other common mental disorders : Global health estimates, Geneva.