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Does motor functioning mediate the relationship between executive functions and psychological well-being of atypically developing older adults?

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Abstract

The contribution of motor efficiency to the maintenance of psychological well-being in cognitively impaired older individuals is still insufficiently examined. This investigation primarily intended to evaluate whether muscular strength mediates the relationship between different facets of psychological well-being (i.e., personal satisfaction, emotional competence, coping), negative mood, and central executive efficiency through the Clock-Drawing, Trail-Making (Part A), and verbal fluency tests. Furthermore, the impact of cognitive decline on self-reported psychological well-being and depression was explored, using the handgrip strength (HGS) measure as a covariate. One hundred and nineteen older participants, 44 males and 75 females, aged 63 years and older (M_{age} = 77.7 years, SD = 5.6 years), completed a battery of tests assessing executive functions, HGS, depression, and psychological well-being. Significant low to moderate associations were found between distinct executive functions, HGS, psychological well-being, and depression. In addition, personal satisfaction did not correlate with any measure of executive functions, the clock-drawing score was associated only with coping index, and self-reported depression correlated only with the Trail-Making Test score. Moreover, a series of mediation analyses documented that executive functions (primarily assessing verbal fluency and motor speed) and HGS explained approximately 20–46% of the variance in perceived psychological well-being and depression. Finally, more cognitively impaired participants reported worse total psychological well-being, emotional competence, and coping. In conclusion, motor proficiency mediates the relationship between selective measures of executive functions and perceived psychological well-being and depression in cognitively impaired individuals.

Keywords Aging · Cognitive impairment · Executive functions · Atypical development · Handgrip strength (HGS) · Psychological well-being

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Introduction

The rise of the aging society represents a crucial challenge for the promotion of quality of life in late adulthood, especially for those who exhibit evident signs of cognitive impairment. Quality of life is a complex construct. Indeed, it refers to "the extent to which a person obtains satisfaction from life" (VandenBos & APA, 2015, p. 871) through physical well-being, life satisfaction, social participation, skill-development opportunities, and emotional well-being. Though lacking a univocal definition, successful aging encompasses the maintenance of social participation and well-being, including the assessment of physical functioning and different facets of mental health, such as psychological well-being (for a review, see Gu et al., 2017).

Despite the paucity of studies examining the nature of the relationships between motor functioning, cognitive efficiency, and perceived mental health in late adulthood, a short review of the existing literature on these issues will be presented below. Mental health refers to a dynamic state of psychological well-being in which the individual recognizes, expresses and modulates his/her emotional status (e.g., life satisfaction, negative mood), and cognitive and social skills, and deals with stressful life events (Galderisi et al., 2015). Therefore, psychological well-being is a fundamental dimension of mental health, that refers to a state of happiness and contentment (VandenBos & APA, 2015). Psychological well-being is also the ability to fulfill meaningful goals, maintain positive relationships, manage the surrounding environment, develop one's potential, and accept one's positive and negative characteristics (Ryff, 1989).

From an applied viewpoint, it is relevant to highlight the interplay among the afore-mentioned constructs in the later decades of life — especially in cognitively impaired individuals — for at least two related reasons. First, the decline of functional and cognitive skills needed for everyday activities implies the possible loss of independence in late adulthood and leads to a decrease in psychological well-being (Wilson et al., 2013). Second, the analysis of functional and cognitive losses may be helpful in detecting those clinical signs that are essential for implementing early interventions on physical and mental health of older individuals with varying degrees of cognitive impairment.

The Association Between Motor and Cognitive Efficiency in Late Adulthood

Research has documented that the ability to effectively perform basic motor tasks is associated with cognitive performance. In this regard, cognitive performance is linked with functional mobility, which includes walking, rising from and sitting down in a chair, turning, etc. For instance, the results of a recent meta-analysis (de Oliveira Silva et al., 2019) suggest that the Timed-Up-and-Go test — the most widespread clinical test to assess functional mobility in older adults — might be effectively employed as a marker to support the diagnosis and identification of the stages of dementia, including the prodromal phase. Additionally, muscular strength, which plays a relevant role in ensuring suitable levels of mobility and independence in daily living (Blankevoort et al., 2010; Mihalko & McAuley, 1996), is also strongly associated with cognitive status. In clinical contexts, handgrip strength (HGS) is widely employed as a biomarker of the physical health status of older adults, as this task is easy to administer and well representative of the overall body strength (Bohannon, 2015, 2019). Moreover, HGS has been found to be moderately to highly correlated with several scales designed to assess upper limb functions and it can discriminate older adults based on their level of mobility. Thus, HGS can be considered a reliable measure that provides a broad idea of independence in most activities of daily living. Recent studies also reported that low levels of HGS are associated with less efficient higher-order control processes (e.g., executive functions), and overall cognition in non-demented older individuals, whereas deficits of HGS at baseline are strongly associated with the risk of developing mild cognitive impairment (MCI) (e.g., Boyle et al., 2010). Overall, the regular assessment of HGS may represent an efficient way to monitor cognitive changes (Fritz et al., 2017), even from middle age (Adamo, 2020). Thus, it may serve as a predictor of cognitive loss with advancing age.

The detrimental effects of age-related factors have been documented with regard to cognitive efficiency as well. There is evidence that even in healthy aging, senescence implies crucial modifications in cognitive processes, including a decrease in fluid control resources such as Executive Functions (EFs) (Salthouse, 2019). Moreover, several brain regions involved in EFs (e.g., prefrontal cortex, hippocampus) also modulate motor tasks, such as walking, knee extension, and postural balance (Makizako et al., 2011; Tabara et al., 2015). Thus, it is not surprising that a significant decrease in the efficiency of EF processes (set-shifting, inhibition, verbal fluency, and processing speed) is associated with a significant deterioration of mobility and HGS (Camargo et al., 2016; Kose et al., 2016). In particular, recent studies reported that EF impairments often coexist with slower gait speed and postural instability (Amboni et al., 2013; Montero-Odasso et al., 2012). There is also evidence that gait speed evaluated at baseline in cognitively healthy individuals predicts cognitive decline and EF efficiency at a 15-months follow-up (Savica et al., 2017). Such a strong link between gait and EFs has also been documented in older individuals with mild-moderate or severe cognitive impairment. McGough et al. (2013) reported that in individuals with early signs of MCI, global cognitive efficiency and EFs are associated with faster habitual gait speed, whereas HGS correlated only with processing speed. A similar pattern was observed in older individuals with either MCI or dementia, confirming that processing speed and global cognitive efficiency are significant predictors of HGS (Hesseberg et al., 2020).

Based on the findings, it can be reasonably expected that engaging in regular physical activity may be beneficial for cognitive efficiency. Indeed, it has been documented that compared to their sedentary peers, older individuals who are physically active are also characterized by better EFs (e.g., response inhibition, motor control) and undergo lower age-related brain volume loss in the frontal and temporal areas involved in EFs and memory tasks (Tseng et al., 2013). In particular, aerobic and resistance exercises are considered crucial for preserving cognitive function in late adulthood (Lustig et al., 2009). Furthermore, a recent longitudinal study on community-dwellers over 65 years old with and without cognitive decline (i.e., MCI and dementia) found that physical activity and physical therapy interventions concurred to improve EF efficiency (Cezar et al., 2021). This is consistent with a review conducted by Barnes and Yaffe (2011), according to which 10% reduction in the prevalence of sedentary life in late adulthood is potentially able to reduce the occurrence of Alzheimer's disease cases by 380.000 worldwide. All these findings suggest that the objective assessment of motor functioning by means of instruments that do not require interpretation, judgement or personal impressions (VandenBos & APA, 2015) should be encouraged in late adult lifespan, since higher levels of physical activity are associated with a lower future risk of MCI or dementia (Covell et al., 2015).

The Association Between Motor Efficiency and Psychological Well-Being in Late Adulthood

Research has also documented that a significant reduction in the hand muscular strength negatively impacts distinct facets of the quality of life of older adults, such as psychological well-being (e.g., Metz, 2000). As pointed out by Taekema et al. (2010), motor deficits related to handgrip significantly impact older individuals' ability to manage daily living activities (e.g., self-care, shopping). The direct consequence of motoric losses in older people is a reduction in their social participation and autonomy, which may also affect their mental health. Thus, lower HGS and reduced mobility have been demonstrated to correlate with greater negative mood in older participants with and without signs of cognitive decline (Ashdown-Franks et al., 2019; Taekema et al., 2010). Veronese et al. (2017) showed that mobility deficits and reduced walking speed at baseline in individuals aged 65–96 predict self-reported depressive symptoms four years later. This was recently confirmed by a longitudinal study conducted in an area of exceptional longevity (i.e., the Sardinian Blue Zone) by Fastame et al. (2020); at baseline and a 24-month follow-up, gait abilities were negatively associated with perceived depressive symptoms. Moreover, further research found that older individuals who were more physically active (i.e., regularly engaged in gardening activities) and cognitively healthy (i.e., Mini-Mental State Examination score > 24) self-reported fewer depressive symptoms than the more sedentary participants (Fastame et al., 2018). Consistently, perceived functional health was also found to predict life satisfaction and negative mood in late adulthood, that is, cognitively healthy older individuals who self-assessed higher physical health also reported greater life satisfaction and fewer depressive symptoms (Fastame, 2021).

Finally, in a recent review and meta-analysis, Sun et al. (2021) concluded that aerobic trainings or combined physical-cognitive interventions were not effective in improving the self-rated mood and quality of life of older individuals reporting subjective cognitive complaints (i.e., a condition not supported by objective cognitive decline but is considered the earliest prodromal stage of Alzheimer's disease). However, to our knowledge, few studies have investigated the impact of motor functioning on the perceived mental well-being of older individuals diagnosed with MCI or dementia. Therefore, further research investigating this issue is needed.

EF as a Predictor of Psychological Well-Being in Late Adulthood

Relatively little is known about the predictive role of EFs on psychological well-being in late adulthood. A study conducted by Toh et al. (2020) in a large sample of cognitively intact American participants found that the efficiency of several EFs (i.e., verbal fluency, working memory, inhibition, and processing speed) predicted life satisfaction through the mediation of the sense of control. According to Toh et al. (2020), this means that the ability to control obstacles (performed through EF skills) facilitates goal pursuit, which boosts life satisfaction and positive affect in later life. Furthermore, it has also been shown by Nieto et al. (2020) that cognitively intact older individuals (i.e., 60–81-year-olds) who displayed better EFs (i.e., inhibition and working memory) also reported fewer avoidant coping strategies. Overall, this suggests that EF skills in late adulthood are a protective factor because they serve to manage age-related stressful events (e.g., affective losses, facing health-related problems). Older individuals use their EFs and coping strategies to control stress and avoid emotional consequences (e.g., greater depressive symptoms, lower life satisfaction) through self-regulation of their behavior.

However, existing systematic studies exploring the impact of EF functions on the perceived psychological well-being and depressive symptoms of cognitively impaired older individuals are lacking. To our knowledge, only one study documented that worse verbal fluency and reduced speed of processing were associated with greater self-reported depressive signs in older individuals displaying MCI, whereas depression, memory complaints, and global cognitive efficiency contributed to predicting an eudaimonic well-being index (Gates et al., 2014). In conclusion, further studies conducted with cognitively impaired older individuals are needed to clarify the role played by other EFs in accounting for different facets of psychological well-being.

The Association Between Psychological Well-Being, and Cognitive and Motor Efficiency in Late Adulthood

Recent research suggested that subjective well-being (i.e., assessed by calculating a composite index based on self-reported depression, hedonic well-being, satisfaction with physical health, and satisfaction with family ties and non-family ties) in late adulthood is influenced by self-reported functional and cognitive limitations and the availability of protective resources, such as social support and an active lifestyle (Carmel et al., 2017). Even though older people display significant inter-individual variability in cognitive decline (i.e., MCI versus dementia), recent evidence highlighted that lower cognitive efficiency was associated with lower mobility, greater depressive signs, and limited coping strategies in late adulthood (Siltanen et al., 2019).

However, thus far, the concurrent association between objectively assessed motor proficiency, EFs, and psychological well-being has not been sufficiently investigated in cognitively impaired older individuals. To our knowledge, only one study examined the interplay between negative mood, physical health, and EFs in patients with MCI. It documented that objectively assessed functional independence of individuals exhibiting amnestic multidomain MCI was predicted by age, a composite index of attention (which also included some measures of inhibition), and self-reported depressive signs (Bombin et al., 2012). Despite this relevant evidence, further research is needed to clarify the nature of the associations between the different dimensions of psychological well-being, EFs, and HGS of cognitively impaired older individuals.

The Study

The novelty of this investigation resides in examining the interaction between objectively assessed motor efficiency, a set of EFs, and perceived psychological well-being and negative mood in a sample of atypically developing older individuals. Specifically, this investigation intended to explore: 1) the relationship between EFs, HGS, self-reported psychological well-being, and depression in participants with MCI or dementia; 2) the contribution of muscular strength in mediating the relationship between EFs and perceived psychological well-being and depression scores of cognitively impaired older individuals; 3) the impact of cognitive decline on self-assessed psychological well-being and depression, using HGS as a covariate.

Based on previous literature: 1) significant negative associations between HGS and depressive symptoms were expected (Ashdown-Franks et al., 2019; Taekema et al., 2010), as well as a positive association between the former and psychological well-being was hypothesized (Metz, 2000); 2) significant relationships between EFs and HGS were also hypothesized (Camargo et al., 2016; McGough et al., 2013; Tseng et al., 2013); 3) better EFs were expected to be associated with better coping strategy (Nieto et al., 2020); 4) EFs were expected to be a significant predictor of HGS (Hesseberg et al., 2020; Mose, 2016) and life satisfaction (Toh et al., 2020), respectively; 5) motor deficits were expected to predict depressive symptoms (Veronese et al., 2017); 6) more cognitively impaired participants were expected to exhibit less motor efficiency and fewer coping strategies than older participants with MCI (Bombin et al., 2012; Siltanen et al., 2019); and 7) individuals with MCI were expected to show better perceived psychological well-being than demented peers (Carmel et al., 2017). Due to the lack of relevant evidence, a priori further hypotheses were not stated.

Method

Participants

One hundred and nineteen cognitively impaired older individuals (74 with MCI and 45 with dementia), 44 males and 75 females ($M_{age} = 77.7$ years, $SD = 5.6$ years, age range = 63–92 years) were recruited at the Center for Cognitive Disorders and Dementia (Geriatric Unit, SS. Trinità Hospital) in Cagliari (Italy). To participate in the study, the following inclusion criteria had to be satisfied: 1) be aged > 60 years; 2) be resident in the metropolitan area of Cagliari; 3) be community-dwellers (i.e., not institutionalized), that is, the participant had to reside in his/her own home with or without a caregiver; 4) have received a diagnosis of cognitive decline (i.e., MCI or dementia); 5) be free of neurological (e.g., Parkinson's disease, multiple sclerosis, and stroke) and orthopedic conditions interfering with motor functioning. All participants ($n = 119$), 74 with MCI and 45 with dementia, agreed to be enrolled in the study. None of the participants with dementia was under the age of 65. The participation was voluntary; therefore, the respondents did not receive any economic compensation or other rewards. Written informed consent was provided by all the participants or their caregivers before participation in the study.

Materials

Each participant completed the following tasks:

The Psychological Well-Being and Ageing Questionnaire (PWAQ, De Beni et al. 2017) is a tool that evaluates different facets of psychological well-being and that has been validated for the Italian geriatric population. It encompasses 37 items and provides 4 indexes of well-being assessing total well-being (i.e., PWAQ-tot, which refers to the global perceived psychological well-being reported by a person), personal satisfaction (i.e., PS-PWAQ, which encompasses the degree of satisfaction with what was achieved in past, level of self-appreciation in the present, and expectations of being satisfied in future), coping (i.e., SC-PWAQ, which assesses the ability to deal with everyday problems and the ability to overcome issues), and emotional competence (i.e., EC-PWAQ, that refers to the ability to identify and understand emotional states of others, establishing long-lasting social relationships). Each respondent had to self-rate the frequency of a set of daily situations on a Likert scale ranging from 1 (never) to 4 (often). The maximum total score is 148. A score ≤ 103 reflects a low level of total psychological well-being. Cronbach's alpha was 0.91 in the current sample.

The short form of the Geriatric Depressive Scale (GDS, Yesavage & Sheikh, 1986) was designed to evaluate an important facet of psychological well-being: negative mood. Each participant had to self-rate the occurrence of a set of 15 depressive symptoms on a dichotomous scale (yes vs no). One point could be assigned to each statement (maximum total score = 15). A score > 5 denotes the occurrence of significant depressive signs. The analysis of the Differential Item Functioning by the application of the Item Response Theory Likelihood Ratio test approach in a sample of older Italians attested that the occurrence of cognitive decline does not bias the assessment of depressive signs through GDS (Chiesi et al., 2018). Internal consistency was reported to be satisfactory (alpha = 0.75) in a sample of Italian older individuals with and without cognitive decline (Nicolini et al., 2021).

The Trail-Making Test-Part A (TMT-A, Reitan & Wolfson, 1985; Italian validation, Giovagnoli et al., 1996) was proposed to assess the efficiency of motor speed, visual scanning, and number sequencing skills. Each participant was invited to connect 25 encircled numbers scattered on an A4 sheet in ascending numerical order, without lifting the pen from the paper as fastly and accurately as possible. The time necessary to complete this task was calculated. Therefore, performance was assessed in terms of the total number of seconds taken to complete the task.

The Clock-Drawing Test (Clock, Critchley, 1953; Italian validation, Mondini et al., 2003) was designed as a measure of motor sequencing, monitoring, planning, and goal-directed behavior skills. Each participant had to draw the hands of a clock at 2:45 on a pre-drawn circle. An accuracy score ranging between 0 (i.e., worst) and 10 (i.e., excellent) was assigned to each drawing performance, following the criteria proposed by Mondini et al. (2003). Specifically, the score was determined as the total number of elements correctly located in the clock. Therefore, the occurrence of the following categories of errors was evaluated: omissions, additions, substitutions, misplacements, distortions, perseverations, and rotations.

The verbal fluency subtest of the ACE-R battery (ACE-R fluency, Mioshi et al., 2006; Italian validation, Pigliautile et al., 2012) was proposed to assess the efficiency of set-shifting, self-monitoring, and inhibition skills. Each participant had to name as many words as possible belonging to a category (i.e., semantic fluency) or starting with a certain phoneme (i.e., phonological fluency) within a certain time. Specifically, to perform the phonological fluency task, the participant had to name as many nouns starting with the letter 'F' as possible within one minute. Following the criteria provided by the authors, based on the total amount of correct responses provided by the examinee, a maximum of 7 scores were assigned (e.g., 0 scores if the correct responses were ≤ 2 vs. 7 scores if the correct responses were > 17). Moreover, in the semantic fluency condition, the examinee had to utter as many animal names as possible within 1 min. The same scoring criteria used to assess performance in the phonological fluency task were used to evaluate semantic fluency efficiency (maximum score = 7). Thus, a total combined correct score (i.e., it was calculated by adding the scores in the phonological and semantic fluency tasks) was computed to obtain an ACE-R fluency index (maximum total score = 14).

Measurement of the HGS was performed using a validated (Shechtman et al., 2005) digital hand dynamometer (DynEx, MD Systems, Westerville OH, USA) previously employed in studies involving older adults (Gaszynska et al., 2014; Porta et al., 2018). Participants were seated comfortably in a chair without resting arms with their forearm leaning on a table in a neutral position, the shoulder adducted and rotated neutrally, the elbow flexed at 90°, and the wrist between 0° and 30° of extension. From this position, each participant was asked to squeeze the dynamometer with as much force as possible, while receiving verbal encouragement. Three trials for each hand, interspersed by approximately 20 s of rest and alternating sides were usually performed. However, if the difference in scores between the three trials was more than 3 kg, the test was repeated. The final score was represented by the maximal grip score calculated from all six valid trials.

In the present study, the aforementioned tools were selected because they are experimentally robust measures of perceived psychological well-being (i.e., Psychological Well-Being and Ageing Questionnaire), depressive symptoms (i.e., GDS), executive functions (i.e., Trail-Making Test, Clock-Drawing Test, and ACE-R fluency), and motor proficiency (i.e., HGS). In addition, the instruments used in this study have been validated for the Italian geriatric population, and they can be easily and quickly administered in the clinical setting to atypically developing older individuals as well.

Procedure

Data were collected between May 20, 2019, and February 5, 2020. Participants were enrolled in the study only after receiving a diagnosis of MCI or dementia. In this regard, a team of specialists in Geriatrics, Psychology, and Neurology at the Center for Cognitive Disorders and Dementia identified individuals with cognitive impairment based on an examination protocol. This protocol encompassed the collection of information from the patient's medical history (provided by a caregiver and/or general practitioner), an interview with a family caregiver, a physical examination, the administration of a battery of instruments assessing cognitive health and degree of independence in performing activities of daily living, and a psychiatric assessment to examine the possible occurrence of major depression. If clinicians needed more information to diagnose the neurodegenerative condition, some neuroimaging tests could be prescribed.

For this study, each participant was individually tested in a quiet room at the Center for Cognitive Disorders and Dementia. To avoid the fatigue effect in our participants and to minimize the risk of missing responses, the instructions of each task were read by the examiner who also wrote down the responses provided by the examinees in the GDS, PWAQ, and ACE-R fluency conditions, respectively. The presentation order of the psychological tasks was counterbalanced across participants according to the Latin square procedure. After completion of the psychological tests and questionnaires, the HGS was presented. Each experimental session lasted approximately 50 min.

Data Analysis

Statistical analyses were conducted in SPSS Statistics Version 24 and using version 1.6 of the open-source jamovi package (The jamovi Project, 2021). The 0.05 level of significance was adopted throughout all analyses. First, descriptive statistics were computed to investigate the sociodemographic characteristics of the participants. Then, Pearson's correlation coefficients (r) were calculated to explore the nature of the relationships between each EF measure, self-reported depression and psychological well-being, and muscular strength. In addition, based on the results of the correlational analyses, eight mediation analyses were conducted to examine whether the relationships between distinct EFs (i.e., TMT-A, Clock, and ACE-R fluency) and several psychological well-being (i.e., PWAQ-tot, SC-PWAQ, EC-PWAQ) and GDS scores were mediated by HGS. In each condition, the indirect effect was tested using a bootstrap estimation approach with 5000 samples (Hayes, 2007). For brevity, only significant models will be presented in the Results section, whereas all mediation models are illustrated in the supplementary file. Moreover, an analysis of covariance (ANCOVA) and a multivariate analysis of covariance (MANCOVA) were performed to determine the effect of cognitive decline (i.e., MCI vs. dementia) on self-reported depression and psychological well-being, controlling for the impact of muscular strength (i.e., HGS). To perform these analyses, 42 participants with dementia were age and gender-matched with a subsample of peers with MCI.

Results

First, several descriptive statistics were calculated on participants' characteristics. The results are reported in Table 1.

Then, Pearson's product-moment correlations were computed between EFs, psychological well-being, depressive symptoms, and handgrip strength scores. Table 2 illustrates these findings.

Table 1 Anthropometric and Demographic Characteristics of Participants

	n	%	M	SD
Age (years)			77.7	5.6
Height (cm)			159.6	8.9
Body Mass (kg)			63.3	13.1
Years of Education			8.1	4.4
Gender				
Female	75	63		
Male	44	37		
Marital Status				
Single	10	8.4		
Married/partnered	60	50.4		
Divorced/widowed	49	41.2		

$N = 119$

In addition, a series of mediation analyses revealed that HGS mediated between some measures of EFs and several self-reported psychological well-being and depression scores, respectively. Specifically, ACE-R fluency score was a significant predictor of HGS, b = 0.209, SE = 0.08, p = 0.01 (path a in Figs. 1 and 2) and HGS significantly predicted PWAQ-tot (b = 0.534, SE = 0.134, p < 0.001) and SC-PWAQ (b = 0.23, SE = 0.04, p < 0.001), respectively (path b in Figs. 1 and 2). The mediation hypotheses for these psychological well-being outcomes are supported. After controlling for HGS (path c' in Figs. 1 and 2), ACE-R fluency remained a significant predictor of PWAQ-tot (b = 0.349,

Table 2 Zero-Order Correlations among Mental Health, Executive Functions, and Handgrip Strength Measures

	1	2	3	4	5	6	7	8	9
1. PWAQ-tot	—								
2. SC-PWAQ	0.858 ***	—							
3. PS-PWAQ	0.788 ***	0.576 ***	—						
4. EC-PWAQ	0.784 ***	0.629 ***	0.471 ***	—					
5. GDS	-0.485 ***	-0.309 ***	-0.641 ***	-0.284 **	—				
6. Clock	0.082	0.212 *	-0.029	0.112	.087	—			
7. TMT-A	-0.272 *	-0.331 **	-0.172	-0.292 **	.229*	-0.443 ***	—		
8. ACE-R fluency	0.278 **	0.412 ***	0.083	0.290 **	- .07	0.595 ***	-0.326 **	—	
9. HGS	0.367 ***	0.458 ***	0.262 **	0.196 *	.30**	0.200 *	-0.321 **	0.209*	—

N = 119. 1 = Total Well-Being, 2 = Coping, 3 = Personal Satisfaction, 4 = Emotional Competence, 5 = Geriatric Depression Scale, 6 = Clock Drawing test, 7 = Trail-Making Test, part A, 8 = Verbal Fluency Subtest of the ACE-R Battery, and 9 = Handgrip Strength

* $p < .05$ two-tailed, ** $p < .01$ two-tailed, *** $p < .001$ two-tailed

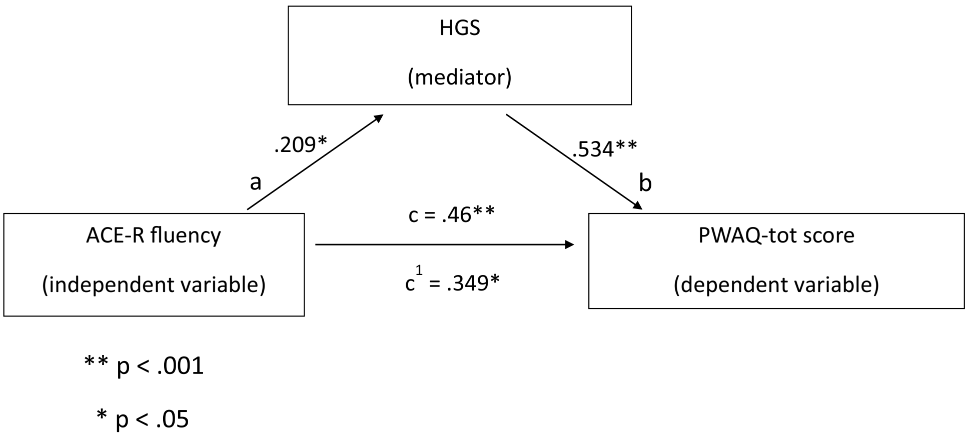

Fig. 1 The Mediating Role of Handgrip Strength between Verbal Fluency and Total Well-Being

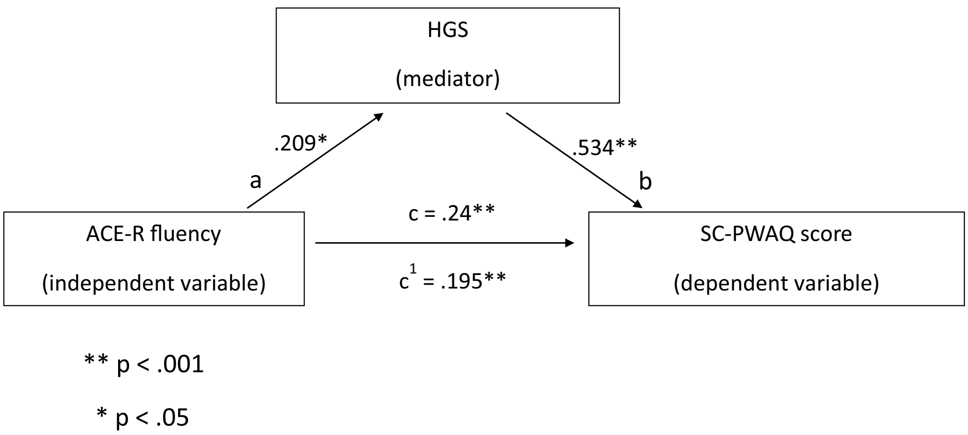

Fig. 2 The Mediating Role of Handgrip Strength between Verbal Fluency and Coping

SE = 0.13, p = 0.007) and SC-PWAQ (b = 0.195, SE = 0.04, p < 0.001). Moreover, in both the total well-being and coping conditions, the indirect coefficient was significant: PWAQ-tot, b = 0.11, SE = 0.052, 95% CI = 0.022, 0.232, p = 0.035; SC-PWAQ, b = 0.048, SE = 0.022, 95% CI = 0.009, 0.10, p = 0.032. Standardized effect sizes indicated that approximately 24.2% of the variance in the PWAQ-tot condition and 19.7% of the variance in the SC-PWAQ condition were explained by ACE-R fluency and HGS. Figure 1 and 2 illustrate these outcomes.

Furthermore, when the processing speed measure was used as an independent variable, TMT-A score was a significant predictor of HGS, b = —0.335, SE = 0.10, *p* < 0.001 (path a in Figs. 3 and 4), and HGS significantly predicted both SC-PWAQ (b = 0.163, SE = 0.05, *p* < 0.001) and GDS (b = -0.34, SE = 0.12, *p* = 0.003) (path b in Figs. 3 and 4). After controlling for HGS (path c' in Figs. 3), the direct effect of TMT-A on SC-PWAQ approached significance (b = -0.114, SE = 0.06, *p* = 0.051), whereas the effect of TMT-A on GDS was not significant, b = 0.133, SE = 0.11, *p* = 0.238, (path c' in Figs. 4). However, in both the SC-PWAQ and GDS conditions, the indirect coefficient was significant: SC-PWAQ (b = -0.05, SE = 0.025, 95% CI = —0.107,—0.013, p = 0.031) and GDS (b = 0.112, SE = 0.05, 95% CI = 0.029, 0.227, *p* = 0.027). Standardized effect sizes indicated that 32.3% of the variance in the SC-PWAQ condition, and 45.7% of the variance in the GDS condition were explained by TMT-A and HGS. These findings are summarized in Fig. 3 and 4.

Moreover, the ANCOVA that was conducted to explore the impact of cognitive decline on GDS score, using HGS as a covariate, documented only the significant effect of the covariate [$F(1,81) = 9.60$, p = 0.003, $\eta^2 = 0.108$], whereas the main effect of cognitive impairment was not significant [$F(1,81) = 2.51$, $p = 0.117$]. GDS scores reported by patients with MCI (M = 5.05, SD = 4.08) were like those of peers with dementia (M = 3.95, SD = 2.86).

Finally, when a MANCOVA was conducted, multivariate tests showed significant main effects of cognitive impairment (Wilks' λ = 0.695, df = 4;78, *p* < 0.001) and HGS (Wilks' λ = 0.765, df = 4;78, *p* < 0.001). The main effect of cognitive impairment was significant in the PWAQ-tot [$F(1,81) = 11.676$, $p = < 0.001$, $\eta^2 = 0.116$], SC-PWAQ [$F(1,81) = 21.504$, $p = < 0.001$, $\eta^2 = 0.249$], and EC-PWAQ [$F(1,81) = 6.192$, $p = 0.015$, $\eta^2 = 0.068$] conditions, but not in the PWAQ-PS [$F(1,81) = 0.913$, $p = 0.342$] one. Table 3 illustrates the mean scores for the groups with MCI and dementia in each psychological well-being and depression condition.

Fig. 3 The Mediating Role of Handgrip Strength between Trail-Making Test (Part A) and Coping

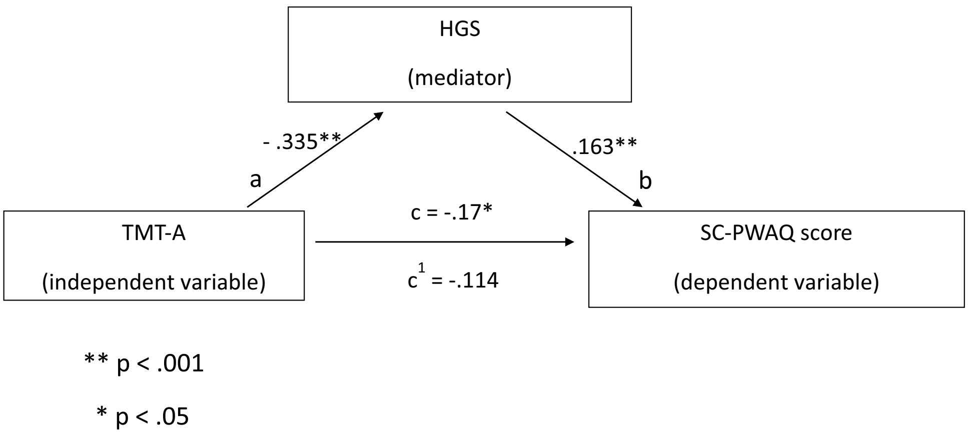

Fig. 4 The Mediating Role of Handgrip Strength between Trail-Making Test (Part A) and Depression

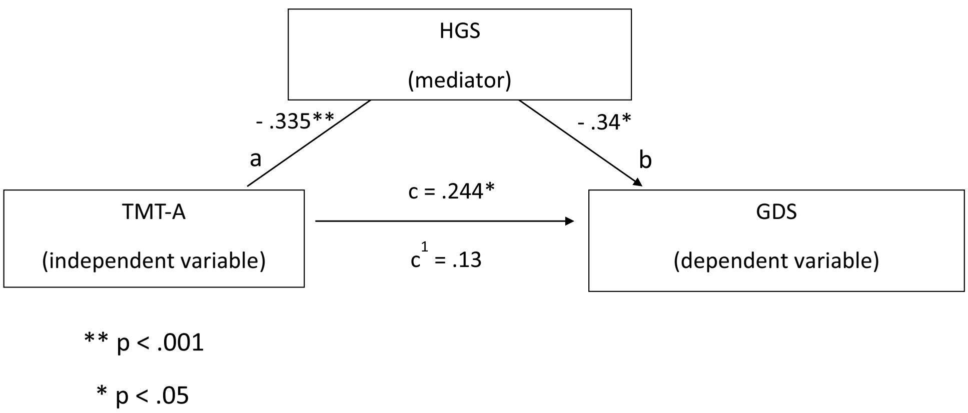

Table 3 Mean Scores in the Psychological Well-Being and Depression conditions of participants

	Cognitive imimpairment	PWAQ-tot	SC-PWAQ	PS-PWAQ	EC-PWAQ	GDS
Mean	MCI	111 (16)	24.3 (5.47)	35 (6.65)	30.5 (4.57)	5.05 (4.08)
	Dementia	100 (15.1)	18.8 (4.84)	33.7 (5.21)	27.8 (5.16)	3.95 (2.86)

$n = 84$. PWAQ-tot = Total Psychological Well-Being, SC-PWAQ = Coping, PS-PWAQ = Personal Satisfaction, EC-PWAQ = Emotional Competence and GDS = Depression. Standard deviations are reported in parentheses

Discussion

The World Health Organization (WHO, 2020) estimated that approximately 115.4 million people will be diagnosed with dementia by 2050. According to Roberts and Knopman (2013), MCI occurs in up to 20% of individuals aged 65 years and older, whereas approximately 40% of the oldest-old age group (i.e., > 84 years) is estimated to be affected with dementia (Lucca et al., 2015).

The general goal of the current study was to elucidate the nature of the relationships between a set of EFs, HGS, and several measures of psychological well-being and negative mood evaluated in a sample of cognitively impaired older individuals. Unlike previous studies in which functional health was self-rated (e.g., Carmel et al., 2017; Fastame, 2021), this investigation objectively assessed hand muscular strength, using a validated (Shechtman et al., 2005) digital hand dynamometer, which has been used successfully in previous research conducted with older participants (Gaszynska et al., 2014; Porta et al., 2018).

Overall, our findings extend previous evidence reported in the literature. The correlational analyses carried out in this study generally support the hypotheses regarding the existence of significant relationships between distinct EFs and HGS in cognitively impaired older participants (McGough et al., 2013; Tseng et al., 2013). Specifically, following Cohen (1988), low to moderate significant correlations were found between the HGS index and each EF measure. Thus, consistently with McGough et al. (2013), the efficiency of motor speed, visual scanning, and number sequencing abilities (i.e., assessed through the TMT-A) was positively associated with the HGS measure. Moreover, extending the findings of Camargo et al. (2016), those participants exhibiting better verbal fluency also presented better hand muscular strength. However, a novel outcome was that greater motor sequencing, monitoring, planning, and goal-directed behavior skills (i.e., assessed through the Clock Drawing Test) were associated with better HGS. Overall, in agreement with a stream of research demonstrating that brain structures underpinning EFs (e.g., prefrontal cortex) also regulate the planning of motor behaviors (e.g., Tabara et al., 2015), the current findings show that older individuals who exhibited more efficient EFs also exhibited better HGS. This evidence supports the findings of Kose et al. (2016), according to which older individuals with MCI exhibiting worse mobility skills (e.g., assessed through the TUG task), lower Trail-Making Test performance, and bilateral medial temporal also displayed whole gray matter atrophy.

Moreover, in line with previous evidence, significant associations were found between the HGS score and self-reported depressive symptoms (Ashdown-Franks et al., 2019; Taekema et al., 2010), and each psychological well-being index (Metz, 2000). Extending previous evidence (Siltanen et al., 2019), it should be noticed that a moderate correlation was also found between the handgrip measure and the coping index. Furthermore, as expected (Nieto et al., 2020), low to moderate correlations were also found between each EF and the coping measure. Overall, these outcomes suggest that older people who displayed better self-monitoring, motor sequencing, monitoring, planning, and goal-directed behavior skills also exhibited better manual strength and reported being more competent in dealing with daily stressful events. However, unlike previous evidence documented in cognitively healthy older individuals (Toh et al., 2020), we found no significant associations between EFs and personal satisfaction. Additionally, the participants with MCI and those with dementia reported similar levels of personal satisfaction; according to the Italian norms provided by De Beni et al. (2007), these can be considered average. Moreover, the HGS index was significantly associated with self-reported depressive signs and personal satisfaction. Overall, extending previous findings (e.g., Fastame, 2021; Fastame et al., 2020), the current results highlighted that self-reported psychological well-being in late adulthood is strictly related to the actual functional status. However, a series of mediational analyses unearthed our most innovative findings, revealing the significant mediating contribution of HGS to the association between EFs (e.g., motor speed, set-shifting, self-monitoring skills) and several measures of well-being. Extending previous evidence (Siltanen et al., 2019; Veronese et al., 2017), it was shown that self-reported depression and coping were explained by the HGS and EF efficiency assessed through the TMT-A (i.e., a measure of motor speed, visual scanning, and number sequencing abilities). Moreover, verbal fluency (i.e., assessed via the ACE-R fluency subtest) and HGS also explained a significant portion of the variance in the total well-being and coping conditions. Overall, these findings extend those recently reported by Siltanen et al. (2019), documenting that reduced EFs and motor efficiency displayed in cognitively impaired older individuals contributed to reducing their perceived mental health. Moreover, the results obtained here confirm the validity of HGS — which is inexpensive and simple to measure — as a biomarker that may help identify the onset of cognitive decline in clinical and epidemiological settings (Bohannon, 2019; McGrath et al., 2019). Furthermore, following previous research (Hessenberg et al., 2020; Mose, 2016), we also documented that different EF measures (i.e., ACE-R fluency and TMT-A) were significant predictors of HGS. Thus, it can be concluded that even when cognitive decline occurs, the efficiency of control processes is essential to maintain hand muscular strength, and that the maintenance of both motor and higher-order cognitive resources is necessary to handle everyday problems, and therefore, to maintain adequate levels of perceived psychological well-being.

Additionally, extending previous studies (Bombin et al., 2012; Carmel et al., 2017; Siltanen et al., 2019), when HGS was used as a covariate, participants displaying less cognitive impairment also self-reported better total psychological well-being, coping, and higher emotional competence. Compared to the national norms for healthy older people provided by De Beni et al. (2007), our participants with the most severe cognitive decline had very low levels of coping, emotional competence, and total well-being, whereas the participants with MCI reported medium levels in the aforementioned measures. However, extending previous research conducted in the same Italian region (e.g., Fastame et al., 2020), the degree of cognitive impairment did not influence the self-assessed negative mood of our participants, that is, compared to the national GDS norms, participants with MCI and dementia self-reported fewer signs of depression.

These results suggest that the maintenance of objectively assessed cognitive and functional health is crucial not only because they impact independence in daily life, but also because they contribute to the promotion of perceived psychological well-being and negative mood of atypically developing older individuals. Therefore, by embracing an applied approach, the current findings highlight the importance of assessing the efficiency of cognitive (e.g., EFs) and functional (e.g., HGS, mobility) health in late adulthood. Specific actions are necessary to ensure that people at risk of dementia are properly followed to plan early interventions aimed at either reducing or relieving the impact of their cognitive decline (for a review, see Wu et al., 2016). Additionally, extending previous evidence regarding cognitively intact community dwellers (Fastame, 2021; Fastame et al., 2018), while considering the interplay among perceived psychological well-being and depression, motor proficiency, and the central executive, these findings suggest the implementation of multidimensional interventions boosting the physical and cognitive health of cognitively impaired older people. In the literature (e.g., Barnes et Yaffe, 2011; Lustig et al., 2009), the beneficial effects of physical interventions (e.g., aerobic activity) in preserving the different dimensions (e.g., global cognitive efficiency, motor functioning, independence in performing the adaptive daily activities) of healthy aging have been reported. Therefore, the appropriate assessment and enhancement of the motor and cognitive functions of cognitively impaired older individuals should be promoted in clinical settings.

Some research limitations also need to be discussed. First, the sample size of this investigation was limited, therefore, future research is needed using wider samples. Second, only community-based participants were enrolled in this investigation; therefore, the current findings cannot be generalized to institutionalized participants. Third, this study was based on cross-sectional data; therefore, no causal conclusion can be drawn. Future research should overcome these limitations by using a longitudinal design to collect repeated-measures data to examine the effect of age-related factors in shaping the interrelationships between perceived psychological well-being, objectively assessed motor efficiency, and EFs in people displaying mild to severe cognitive decline at the baseline. Fourth, a limited battery of tasks assessing perceived psychological well-being and depressive symptoms, motor skills, and EFs skills was used in this study. Therefore, future research should investigate whether further motor measures mediate the relationship between other EFs (e.g., updating tasks) and psychological well-being (e.g., hedonic well-being, flourishing) indexes. Finally, it should be noted that the participants in this study were recruited from Sardinia, an Italian region characterized by areas of extraordinary longevity and better mental health (e.g., Fastame, 2021; Fastame et al., 2020). Therefore, future research is essential to elucidate whether the current outcomes can be replicated in other socio-cultural contexts characterized by areas of normal and exceptional longevity (i.e., Blue Zones), such as Okinawa in Japan or Nicoya in Costa Rica.

Conclusions

In conclusion, the early identification of age-related cognitive and motor deficits and their impact on psychological well-being may be crucial in the implementation of preventive measures for improving the quality of life in late adult lifespan, especially when adverse health events (e.g., cardiovascular diseases, sarcopenia) occur. Evidence suggests elevated risks of falling, institutionalization, and even mortality in older individuals who exhibit cognitive and motor impairment (e.g., Von Bonsdorff et al., 2006). Therefore, based on the findings highlighted in this study, — and as already suggested by Covell et al. (2015) and Kose et al. (2016) — the objective assessment of motor functioning should be routinely included in the protocols used in clinical settings designed to predict the risk of MCI and dementia. An adequate evaluation of the patient's motor and cognitive strengths and weaknesses is essential for planning an appropriate and individualized intervention; this, as required by the WHO, must be aimed at preserving the quality of life of cognitively impaired older individuals.

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Authors' Contributions I.M., V.P., D.V., G.A., and I. Ma. recruited the participants, collected the data, and were responsible for the scoring and the preparation of the input databases. M.C.F. and M.P. conceived the study. M. P. was in charge of overall direction and planning and M.C.F. took the lead in conducting the data analyses and writing the manuscript. M.P. contributed to the preparation and review of the draft manuscript. M.C.F. and M.P. revised the manuscript. All authors discussed the results, commented on the manuscript, and approved the final version of it.

Data Availability The data that support the findings of this study are not publicly available due to privacy or ethical restrictions.

Declarations

Ethical Approval The study was conducted in accordance with the 1964 Helsinki Declaration and its later amendments.

Informed Consent All participants and/or their guardians were informed about the study procedure and consented to take part in the study.

Conflicting Interests The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Adamo, D. E., Anderson, T., Koochaki, M., & Fritz, N. E. (2020). Declines in grip strength may indicate early changes in cognition in healthy middle-aged adults. *PLoS ONE, 15*(4), e0232021. https://doi.org/10.1371/journal.pone.0232021

Amboni, M., Barone, P., & Hausdorff, J. M. (2013). Cognitive contributions to gait and falls: Evidence and implications. *Movement Disorders, 28*(11), 1520–1533. https://doi.org/10.1002/mds.25674

Ashdown-Franks, G., Stubbs, B., Koyanagi, A., Schuch, F., Firth, J., Veronese, N., & Vancampfort, D. (2019). Handgrip strength and depression among 34,129 adults aged 50 years and older in six low-and middle-income countries. *Journal of Affective Disorders, 243*, 448–454. https://doi.org/10.1016/j.jad.2018.09.036

Auyeung, T. W., Kwok, T., Lee, J., Leung, P. C., Leung, J., & Woo, J. (2008). Functional decline in cognitive impairment–the relationship between physical and cognitive function. *Neuroepidemiology, 31*(3), 167–173. https://doi.org/10.1159/000154929

Barnes, D. E., & Yaffe, K. (2011). The projected effect of risk factor reduction on Alzheimer's disease prevalence. *The Lancet Neurology, 10*(9), 819–828. https://doi.org/10.1016/S1474-4422(11)70072-2

Blankevoort, C. G., Van Heuvelen, M. J., Boersma, F., Luning, H., De Jong, J., & Scherder, E. J. (2010). Review of effects of physical activity on strength, balance, mobility and ADL performance in elderly subjects with dementia. *Dementia and Geriatric Cognitive Disorders, 30*(5), 392–402. https://doi.org/10.1159/000321357

Bohannon, R. W. (2019). Grip Strength: An indispensable biomarker for older adults. *Clinical Interventions in Aging, 14*, 1681–1691. https://doi.org/10.2147/CIA.S194543

Bohannon, R. W. (2015). Muscle strength: Clinical and prognostic value of hand-grip dynamometry. *Current Opinion in Clinical Nutrition & Metabolic Care, 18*(5), 465–470. https://doi.org/10.1097/MCO.0000000000000202

Bombin, I., Santiago-Ramajo, S., Garolera, M., Vega-González, E. M., Cerulla, N., Caracuel, A., et al. (2012). Functional impairment as a defining feature of: Amnestic MCI cognitive, emotional, and demographic correlates. *International Psychogeriatrics, 24*(9), 1494–1504. https://doi.org/10.1017/S1041610212000622

Boyle, P. A., Buchman, A. S., Wilson, R. S., Leurgans, S. E., & Bennett, D. A. (2010). Physical frailty is associated with incident mild cognitive impairment in community-based older persons. *Journal of the American Geriatrics Society, 58*(2), 248–255. https://doi.org/10.1111/j.1532-5415.2009.02671.x

Buchman, A. S., Wilson, R. S., Boyle, P. A., Bienias, J. L., & Bennett, D. A. (2007). Grip strength and the risk of incident Alzheimer's disease. *Neuroepidemiology, 29*(1–2), 66–73. https://doi.org/10.1159/000109498

Caldas, É. C., Rezende, L. A., Oliveira, K. D. S., Pinheiro, H. A., Melo, G. F. D., & Vilaça, K. H. C. (2017). Muscle strength, lower extremity functional performance and body composition in elderly women with mild cognitive impairment. *Fisioterapia Em Movimento, 30*(4), 753–759. https://doi.org/10.1590/1980-5918.030.004.ao10

Camargo, E. C., Weinstein, G., Beiser, A. S., Tan, Z. S., DeCarli, C., Kelly-Hayes, M., et al. (2016). Association of Physical Function with clinical and subclinical brain disease: The Framingham offspring study. *Journal of Alzheimer's Disease, 53*(4), 1597–1608. https://doi.org/10.3233/JAD-160229

Carmel, S., Raveis, V. H., O'Rourke, N., & Tovel, H. (2017). Health, coping and subjective well-being: Results of a longitudinal study of elderly Israelis. *Aging & Mental Health, 21*(6), 616–623. https://doi.org/10.1080/13607863.2016.1141285

Cezar, N. O. D. C., Ansai, J. H., Oliveira, M. P. B. D., Silva, D. C. P. D., Vale, F. A. C., Takahashi, A. C. D. M., & Andrade, L. P. D. (2021). Changes in executive function and gait in people with mild cognitive impairment and Alzheimer disease. *Dementia & Neuropsychologia, 15*(1), 60–68. https://doi.org/10.1590/1980-57642021dn15-010006

Chiesi, F., Primi, C., Pigliautile, M., Baroni, M., Ercolani, S., Paolacci, L., et al. (2018). Does the 15-item Geriatric Depression Scale function differently in old people with different levels of cognitive functioning? *Journal of Affective Disorders, 227*, 471–476. https://doi.org/10.1016/j.jad.2017.11.045

Chou, M. Y., Nishita, Y., Nakagawa, T., Tange, C., Tomida, M., Shimokata, H., et al. (2019). Role of gait speed and grip strength in predicting 10-year cognitive decline among community-dwelling older people. *BMC Geriatrics, 19*(1), 1–11. https://doi.org/10.1186/s12877-019-1199-7

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (*2nd edition*). Lawrence Earlbaum Associates.

Covell, G. E. S., Hoffman-Snyder, C. R., Wellik, K. E., Woodruff, B. K., Geda, Y. E., Caselli, R. J., et al. (2015). Physical activity level and future risk of mild cognitive impairment or dementia: A critically appraised topic. *The Neurologist, 19*(3), 89–91. https://doi.org/10.1097/NRL.0000000000000013

Critchley, M. (1953). *The parietal lobes*. Hafner Press

De Beni, R., Borella, E., Carretti, B., Marigo, C., & Nava, L. A. (2007). *BAC. Portfolio per la valutazione del benessere e delle abilità cognitive nell'età adulta e avanzata* [*The assesment of well-being and cognitive abilities in adulthood and aging*]. Giunti OS.

de Oliveira Silva, F., Ferreira, J. V., Plácido, J., Chagas, D., Praxedes, J., Guimarães, C., et al. (2019). Stages of mild cognitive impairment and Alzheimer's disease can be differentiated by declines in timed up and go test: A systematic review and meta-analysis. *Archives of Gerontology and Geriatrics, 85*, 1–8. https://doi.org/10.1016/j.archger.2019.103941

Fastame, M. C. (2021). Life Satisfaction in Late Adult Span: The Contribution of Family Relationships, Health Self-Perception and Physical Activity. *Aging Clinical and Experimental Research, 33*, 1693–1698. https://doi.org/10.1007/s40520-020-01658-1

Fastame, M. C., Hitchcott, P. K., & Penna, M. P. (2018). The impact of leisure on mental health of Sardinian elderly from the 'Blue Zone': Evidence for ageing well. *Aging Clinical and Experimental Research, 30*(2), 169–180. https://doi.org/10.1007/s40520-017-0768-x

Fastame, M. C., Mulas, I., & Pau, M. (2020). Mental health and motor efficiency of older adults living in the Sardinia's Blue Zone: a follow-up study. *International Psychogeriatrics*, 1-12. https://doi.org/10.1017/S1041610220001659

Fritz, N. E., McCarthy, C. J., & Adamo, D. E. (2017). Handgrip strength as a means of monitoring progression of cognitive decline–a scoping review. *Ageing Research Reviews, 35*, 112–123. https://doi.org/10.1016/j.arr.2017.01.004

Gaszynska, E., Godala, M., Szatko, F., & Gaszynski, T. (2014). Masseter muscle tension, chewing ability, and selected parameters of physical fitness in elderly care home residents in Lodz, Poland. *Clinical Interventions in Aging, 9*, 1197–1203. https://doi.org/10.2147/CIA.S66672

Gates, N., Valenzuela, M., Sachdev, P. S., & Singh, M. A. F. (2014). Psychological well-being in individuals with mild cognitive impairment. *Clinical Interventions in Aging, 9*, 779–792. https://doi.org/10.2147/CIA.S58866

Galderisi, S., Heinz, A., Kastrup, M., Beezhold, J., & Sartorius, N. (2015). Toward a new definition of mental health. *World Psychiatry, 14*, 231–233. https://doi.org/10.1002/wps.20231

Giovagnoli, A. R., Del Pesce, M., Mascheroni, S., Simoncelli, M., Laiacona, M., & Capitani, E. (1996). Trail making test: Normative values from 287 normal adult controls. *The Italian Journal of Neurological Sciences, 17*(4), 305–309.

Gu, D., Feng, Q., Sautter, J. M., Yang, F., Ma, L., & Zhen, Z. (2017). Concordance and discordance of self-rated and researcher-measured successful aging: Subtypes and associated factors. *Journals of Gerontology Series b: Psychological Sciences and Social Sciences, 72*(2), 214–227. https://doi.org/10.1093/geronb/gbw143

Hayes, A.F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd edition). Guilford Publications.

Hesseberg, K., Tangen, G. G., Pripp, A. H., & Bergland, A. (2020). Associations between Cognition and Hand Function in Older People Diagnosed with Mild Cognitive Impairment or Dementia. *Dementia and Geriatric Cognitive Disorders Extra, 10*(3), 195–204. https://doi.org/10.1159/000510382

Kim, K. H., Park, S. K., Lee, D. R., & Lee, J. (2019). The Relationship between Handgrip Strength and Cognitive Function in Elderly Koreans over 8 Years: A Prospective Population-Based Study Using Korean Longitudinal Study of Ageing. *Korean Journal of Family Medicine, 40*(1), 9–15. https://doi.org/10.4082/kjfm.17.0074

Kose, Y., Ikenaga, M., Yamada, Y., Morimura, K., Takeda, N., Ouma, S., et al. (2016). Timed Up and Go test, atrophy of medial temporal areas and cognitive functions in community-dwelling older adults with normal cognition and mild cognitive impairment. *Experimental Gerontology, 85*, 81–87. https://doi.org/10.1016/j.exger.2016.09.019

Lucca, U., Tettamanti, M., Logroscino, G., Tiraboschi, P., Landi, C., Sacco, L., et al. (2015). Prevalence of dementia in the oldest old: The Monzino 80-plus population based study. *Alzheimer's & Dementia, 11*(3), 258–270. https://doi.org/10.1016/j.jalz.2014.05.1750

Lustig, C., Shah, P., Seidler, R., & Reuter-Lorenz, P. A. (2009). Aging, training, and the brain: A review and future directions. *Neuropsychology Review, 19*(4), 504–522. https://doi.org/10.1007/s11065-009-9119-9

Makizako, H., Shimada, H., Doi, T., Yoshida, D., Ito, K., Kato, T., et al. (2011). The association between decline in physical functioning and atrophy of medial temporal areas in community-dwelling older adults with amnestic and nonamnestic mild cognitive impairment. *Archives of Physical Medicine and Rehabilitation, 92*(12), 1992–1999. https://doi.org/10.1016/j.apmr.2011.07.195

McGough, E. L., Cochrane, B. B., Pike, K. C., Logsdon, R. G., McCurry, S. M., & Teri, L. (2013). Dimensions of physical frailty and cognitive function in older adults with amnestic mild cognitive impairment. *Annals of Physical and Rehabilitation Medicine, 56*(5), 329–341. https://doi.org/10.1016/j.rehab.2013.02.005

McGrath, R., Robinson-Lane, S. G., Cook, S., Clark, B. C., Herrmann, S., O'Connor, M. L., & Hackney, K. J. (2019). Handgrip Strength Is Associated with Poorer Cognitive Functioning in Aging Americans. *Journal of Alzheimer's Disease: JAD, 70*(4), 1187–1196. https://doi.org/10.3233/jad-190042

Metz, D. H. (2000). Mobility of older people and their quality of life. *Transport Policy, 7*(2), 149–152. https://doi.org/10.1016/S0967-070X(00)00004-4

Mihalko, S. L., & McAuley, E. (1996). Strength training effects on subjective well-being and physical function in the elderly. *Journal of Aging and Physical Activity, 4*(1), 56–68. https://doi.org/10.1123/japa.4.1.56

Mioshi, E., Dawson, K., Mitchell, J., Arnold, R., & Hodges, J. R. (2006). The Addenbrooke's Cognitive Examination Revised (ACE-R): A brief cognitive test battery for dementia screening. *International Journal of Geriatric Psychiatry, 21*(11), 1078–1085. https://doi.org/10.1002/gps.1610

Mondini, S., Mapelli, D., Vestri, A., & Bisiacchi, P. (2003). *ENB esame neuropsicologico breve* [*Brief neuropsychological exam*]. Raffaello Cortina.

Montero-Odasso, M., Verghese, J., Beauchet, O., & Hausdorff, J. M. (2012). Gait and cognition: A complementary approach to understanding brain function and the risk of falling. *Journal of the American Geriatrics Society, 60*(11), 2127–2136. https://doi.org/10.1111/j.1532-5415.2012.04209.x

Nieto, M., Romero, D., Ros, L., Zabala, C., Martínez, M., Ricarte, J. J., et al. (2020). Differences in coping strategies between young and older adults: The role of executive functions. *The International Journal of Aging and Human Development, 90*(1), 28–49. https://doi.org/10.1177/0091415018822040

Nicolini, P., Abbate, C., Inglese, S., Rossi, P. D., Mari, D., & Cesari, M. (2021). Different dimensions of social support differentially predict psychological well-being in late life: Opposite effects of perceived emotional support and marital status on symptoms of anxiety and of depression in older outpatients in Italy. *Psychogeriatrics, 21*(1), 42–53. https://doi.org/10.1111/psyg.12633

Pigliautile, M., Ricci, M., Ercolani, S., Radicchi, R., Mangialasche, F., Monastero, R., et al. (2012). Studio di validazione dell'ACE-R in lingua italiana nella popolazione degli young-old e degli old-old [Italian Validation study of the ACE-R in the young-old and old-old population]. *Giornale Di Gerontologia, 60*, 134–141.

Porta, M., Pilloni, G., Corona, F., Fastame, M. C., Hitchott, P. K., Penna, M. P., & Pau, M. (2018). Relationships between objectively assessed functional mobility and handgrip strength in healthy older adults. *European Geriatric Medicine, 9*(2), 201–209. https://doi.org/10.1007/s41999-018-0025-7

Reitan, R. M., & Wolfson, D. (1985). *The Halstead-Reitan Neuropsychological Test Battery: Therapy and clinical interpretation*. Neuropsychological Press.

Rijk, J. M., Roos, P. R., Deckx, L., van den Akker, M., & Buntinx, F. (2016). Prognostic value of handgrip strength in people aged 60 years and older: A systematic review and meta-analysis. *Geriatrics & Gerontology International, 16*(1), 5–20. https://doi.org/10.1111/ggi.12508

Roberts, H. C., Syddall, H. E., Sparkes, J., Ritchie, J., Butchart, J., Kerr, A., et al. (2014). Grip strength and its determinants among older people in different healthcare settings. *Age and Ageing, 43*(2), 241–246. https://doi.org/10.1093/ageing/aft118

Ryff, C. D. (1989). Happiness is everything, or is it? Explorations on the meaning of psychological well-being. *Journal of Personality and Social Psychology, 57*(6), 1069–1081.

Salthouse, T. A. (2019). Trajectories of normal cognitive aging. *Psychology and Aging, 34*(1), 17–24. https://doi.org/10.1037/pag0000288

Savica, R., Wennberg, A., Hagen, C., Edwards, K., Roberts, R. O., Hollman, J. H., et al. (2017). Comparison of gait parameters for predicting cognitive decline: The Mayo Clinic Study of Aging. *Journal of Alzheimer's Disease, 55*(2), 559–567. https://doi.org/10.3233/JAD-160697

Shechtman, O., Gestewitz, L., & Kimble, C. (2005). Reliability and validity of the DynEx dynamometer. *Journal of Hand Therapy, 18*(3), 339–347.

Shin, H. Y., Kim, S. W., Kim, J. M., Shin, I. S., & Yoon, J. S. (2012). Association of grip strength with dementia in a Korean older population. *International Journal of Geriatric Psychiatry, 27*(5), 500–505. https://doi.org/10.1002/gps.2742

Siltanen, S., Rantanen, T., Portegijs, E., Tourunen, A., Poranen-Clark, T., Eronen, J., & Saajanaho, M. (2019). Association of tenacious goal pursuit and flexible goal adjustment with out-of-home mobility among community-dwelling older people. *Aging Clinical and Experimental Research, 31*(9), 1249–1256. https://doi.org/10.1007/s40520-018-1074-y

Sternäng, O., Reynolds, C. A., Finkel, D., Ernsth-Bravell, M., Pedersen, N. L., & Dahl Aslan, A. K. (2016). Grip Strength and Cognitive Abilities: Associations in Old Age. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 71*(5), 841–848. https://doi.org/10.1093/geronb/gbv017

Sun, Q., Xu, S., Guo, S., You, Y., Xia, R., & Liu, J. (2021). Effects of Combined Physical Activity and Cognitive Training on Cognitive Function in Older Adults with Subjective Cognitive Decline: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Evidence-Based Complementary and Alternative Medicine*. https://doi.org/10.1155/2021/8882961

Syddall, H., Cooper, C., Martin, F., Briggs, R., & Aihie Sayer, A. (2003). Is grip strength a useful single marker of frailty? *Age and Ageing, 32*(6), 650–656. https://doi.org/10.1093/ageing/afg111

Taekema, D. G., Gussekloo, J., Maier, A. B., Westendorp, R. G., & de Craen, A. J. (2010). Handgrip strength as a predictor of functional, psychological and social health. A prospective population-based study among the oldest old. *Age and Ageing*, *39*(3), 331–337. https://doi.org/10.1093/ageing/afq022

Tabara, Y., Okada, Y., Ohara, M., Uetani, E., Kido, T., Ochi, N., et al. (2015). Association of postural instability with asymptomatic cerebrovascular damage and cognitive decline: The Japan Shimanami health promoting program study. *Stroke, 46*(1), 16–22. https://doi.org/10.1161/STROKEAHA.114.006704

The jamovi project (2021). *Jamovi (version 1.6).* Retrieved from https://www.jamovi.org

Toh, W. X., Yang, H., & Hartanto, A. (2020). Executive function and subjective well-being in middle and late adulthood. *The Journals of Gerontology: Series B, 75*(6), e69–e77. https://doi.org/10.1093/geronb/gbz006

Tseng, B. Y., Uh, J., Rossetti, H. C., Cullum, C. M., Diaz-Arrastia, R. F., Levine, B. D., et al. (2013). Masters athletes exhibit larger regional brain volume and better cognitive performance than sedentary older adults. *Journal of Magnetic Resonance Imaging, 38*(5), 1169–1176. https://doi.org/10.1002/jmri.24085

VandenBos, G. R., & American Psychological Association (2015). *APA Dictionary of Psychology (2nd edition)*. American Psychological Association.

Veronese, N., Stubbs, B., Trevisan, C., Bolzetta, F., De Rui, M., Solmi, M., et al. (2017). Poor physical performance predicts future onset of depression in elderly people: Progetto Veneto Anziani Longitudinal Study. *Physical Therapy, 97*(6), 659–668. https://doi.org/10.1093/ptj/pzx017

Von Bonsdorff, M., Rantanen, T., Laukkanen, P., Suutama, T., & Heikkinen, E. (2006). Mobility limitations and cognitive deficits as predictors of institutionalization among community-dwelling older people. *Gerontology, 52*(6), 359–365. https://doi.org/10.1159/000094985

Wilson, R. S., Boyle, P. A., Segawa, E., Yu, L., Begeny, C. T., Anagnos, S. E., & Bennett, D. A. (2013). The influence of cognitive decline on well-being in old age. *Psychology and Aging, 28*(2), 304–313. https://doi.org/10.1037/a0031196

World Health Organization (WHO, 2020). *Healthy Ageing and the Sustainable Development Goals*. Accessed 05 August 2020 from https://www.who.int/ageing/sdgs/en/.

Wu, Y. T., Fratiglioni, L., Matthews, F. E., Lobo, A., Breteler, M. M., Skoog, I., & Brayne, C. (2016). Dementia in western Europe: Epidemiological evidence and implications for policy making. *The Lancet Neurology, 15*(1), 116–124. https://doi.org/10.1016/S1474-4422(15)00092-7

Yesavage, J. A., & Sheikh, J. I. (1986). 9/Geriatric depression scale (GDS) recent evidence and development of a shorter version. *Clinical Gerontologist, 5*(1–2), 165–173. https://doi.org/10.1300/J018v05n01_09