

# The Association between Lower Extremity Muscular Strength and Cognitive Function in a National Sample of Older Adults

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**Background:** We evaluated the association between lower extremity muscular strength and cognition among older adults in the United States.

**Methods:** Data from the 1999-2002 National Health and Nutrition Examination Survey was used to identify 1508 older adults, between 60-85 years. Muscle strengthening activities were assessed via self-report. Participation in physical activity was determined from self-report data. The DSST was used to assess participant executive cognitive functioning tasks of pairing and free recall. A Kin-Com MP isokinetic dynamometer (Chatanooga Group Inc.) was used to assess lower extremity strength, expressed as absolute strength (N), relative strength (N/body weight in kg), and high (< 245.75 N) vs. low ( $\leq$  245.75 N) absolute strength based on the median levels of strength.

**Results:** Lower extremity strength ( $\beta = 0.01$ ; 95% CI: 0.0008-0.03;  $p = 0.039$ ) was associated with higher cognitive performance, independent of age, muscle strengthening activities, physical activity and other covariates. In an adjusted multivariate logistic regression model, those with high (vs. low) strength had a 34% reduced odds of having low cognitive function (OR = 0.66; 95% CI: 0.46-0.93;  $p = 0.02$ ).

**Conclusion:** In this nationally representative sample of older adults, there was a positive association between elevated lower extremity muscular strength and cognitive functioning.

**Key Words:** Epidemiology, Health promotion, Physical activity, Weight-lifting

## INTRODUCTION

The aging mind is susceptible to decrements in memory and central executive functioning [1]. Tasks involving fluid intelligence are especially vulnerable to age-related cognitive decline [2]. Although the mental health benefits of aerobic-based physical activity have been touted in the literature [3-7], less is known about the potential for resistance training activities to corroborate the relationship between physical activity engagement and attenuation of late-life cognitive decline [1,8]. Ozkaya et al. [9] extended past work demonstrating the positive association between physical activity and cognitive functioning, yet found no statistically

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significant difference between groups of elderly individuals who either engaged in an aerobic, or resistance training intervention. Although, the physiological training effects of exercise and cognition may operate independently. While aerobic training is believed to augment cerebral blood flow and enhance neuromuscular activity [10], resistance training may influence early information processing, namely cognitive aspects of attention and working memory, via positive alterations in blood flow, neurotransmitter activity, and central nervous system function [9]. Thus, aerobic and resistance activities may be independently associated with parameters of cognitive functions, exerting protective and restorative effects on distinct neurological mechanisms

Muscle strengthening activities (MSA) have been shown to increase strength and lean muscle mass in elderly populations [11]. Cognitive parameters are also suggested to benefit from regular participation in resistance training [9,12]. Possible explanations for these effects include increased blood perfusion to the brain, which may be a limiting factor in central nervous system functioning [13]. Limitations in perfusion, compounded by increased blood viscosity, are believed to be detrimental to overall health status, including brain health [14]. Improvements linked with MSA may be volume and intensity dependent; although cognition may be significantly enhanced at both moderate and high intensities [15]. Lower limb strength has been predicated as a mediating variable influencing optimal cognitive performance [16]. Lower limb strength likely enhances the ability to maintain faster walking speeds, which may be instrumental in attenuating the rate of dementia and prospective cognitive decline [17]. Quan et al. [17] conducted a meta-analysis, demonstrating that for every gait speed decrease of 360 m/hr, elderly adults were at a 13% elevated risk of dementia. Previous work has described the need for extended research on this topic [18]; thus, the purpose of this study was to further evaluate the rationale for an association to exist between lower extremity muscular strength and cognition in older adults. However, we also aim to further address a gap in the literature by evaluating this association independent of aerobic-based PA and engagement in muscle strengthening activities (MSA). The latter is important as previous research demonstrates an association between MSA and cognition [19], and emerging work high-

lights the potential dissociation between MSA and strength gains [20]. Additionally, we address this topic using a national sample and an objective measure of lower extremity strength, which is less common in the literature.

## MATERIALS AND METHODS

Data from the 1999-2002 NHANES were used. NHANES is an ongoing survey conducted by the National Center for Health Statistics, a major section of the Centers for Disease Control and Prevention. NHANES evaluates a representative sample of non-institutionalized U.S. civilians, selected by a complex, multistage probability design. All procedures for data collection were approved by the National Center for Health Statistics ethics review board, and all participants provided written informed consent prior to data collection.

Participants were excluded if they had missing data on the study variables or if they self-reported having coronary artery disease, congestive heart failure, stroke or a heart attack. The analyzed sample included 1,508 older adults between 60 and 85 years.

The Digit Symbol Substitution Test (DSST) [21] was used to assess cognitive function among older adults 60+ years of age. The DSST, a component of the Wechsler Adult Intelligence Test and a test of visuospatial and motor speed-of-processing, has a considerable executive function component and is frequently used as a sensitive measure of frontal lobe executive functions [22,23]. The DSST was used to assess participant cognitive function tasks of pairing (each digit 1-9 has a symbol it is associated with) and free recall (allowing participants to draw more figures in the limited time due to remembering pairs). Participants were asked to draw as many symbols as possible that were paired with numbers within 2 min. Following the standard scoring method, one point is given for each correctly drawn and matched symbol, and one point is subtracted for each incorrectly drawn and matched symbol, with a maximum score of 133.

Cognition was expressed as a continuous variable as well as dichotomized as the median level (cognition score of 45) to define high vs. low cognitive function. Notably, there are no established norms for the DSST; thus, the median-split method was used.

A Kin-Com MP isokinetic dynamometer (Chatanooga

Group Inc.) was used to assess lower extremity strength of the right leg. Following 3 warm-up repetitions, participants performed 3 maximal isokinetic contractions at a speed of 60° per second. With the strength values corrected for gravity, the peak force produced over the 3 repetitions was recorded for analysis. The specific isokinetic knee extensor test performed at 60° per second on the dynamometer has an interclass correlation coefficient of 0.89 using the Shrout and Fleiss equation [24].

In our analysis, lower extremity strength was expressed as absolute strength (N), relative strength (N/body weight in kg), and high (<245.75 N) vs. low ( $\leq$ 245.75 N) absolute strength based on the median levels of strength.

Covariates included: age (continuous; yrs), gender, race-ethnicity (Mexican American, non-Hispanic white, non-Hispanic black, other), measured body mass index (continuous; kg/m<sup>2</sup>), C-reactive protein (continuous; mg/dL; marker of inflammation), self-reported smoking status (current, former, never), measured mean arterial pressure (continuous; mmHg; average of 4 blood pressure measurements), self-reported physical activity (meeting guidelines vs. not; based on  $\geq$ 2000 MET-min-month [25]) and self-re-

ported engagement in muscle strengthening activities (continuous; mean sessions/month). These covariates were chosen as they have been demonstrated in the literature to associate with lower extremity strength and/or cognition [19,26,27].

Statistical analyses (Stata, v. 12.0) accounted for the complex survey design used in NHANES. Multivariable linear and logistic regression analysis was used to examine the association between strength (independent variable) and cognitive function. To look at the interaction effects of strength and the covariates on cognitive function, we employed a multiplicative interaction model. That is, we created a cross-product term of strength and the covariate, and included the cross-product term along with the main effects, in the model. Statistical significance was set at a nominal alpha of 0.05.

## RESULTS

Table 1 displays the weighted characteristics of the sample. Participants, on average, were 70 years old; absolute muscular strength was 258.1 N; mean MSA sessions were 2.9 sessions/month MSA; CRP was 0.46 mg/dL; mean arterial pressure was 93.7 mmHg; and 11.1% had diabetes.

Regarding the main findings (Table 2), lower extremity strength ( $\beta = 0.02$ ; 95% CI: 0.0008-0.03;  $p = 0.039$ ) was associated with higher cognitive performance. That is, for every 1 N increase in strength, there was a corresponding 0.01 increase in DSST. Similarly, relative strength was also associated with cognitive function ( $\beta = 1.04$ ; 95% CI: 0.029-2.06;  $p = 0.044$ ). In an adjusted multivariate logistic regression model, those with high (vs. low) strength had a 34% reduced odds of having low cognitive function (OR = 0.66; 95% CI: 0.47-0.93;  $p = 0.02$ ). Regarding the interaction analyses, the association between strength and cognitive function was not contingent upon gender ( $p = 0.66$ )

**Table 1.** Weighted characteristics of the study variables (N=1508)

Variable	Point Estimate (SE)
MSA, # of sessions/month	2.9 (0.3)
Absolute Muscular Strength (newtons)	258.1 (4.7)
Age, mean years	69.5 (0.3)
Body mass index, mean kg/m <sup>2</sup>	27.7 (0.2)
CRP, mean mg/dL	0.46 (0.02)
Mean Arterial Pressure mmHg	93.72 (0.6)
Gender, % Female	56.9
Race-Ethnicity, %	
Non-Hispanic white	83.7
Current Smoker, %	11.2
Diabetic, %	11.1

CRP: C-reactive protein. SE: Standard error.

**Table 2.** Association between muscular strength and cognition

	$\beta$ (95% CI) with Cognition as Outcome		OR (95% CI) with Low Cognition as Outcome
	Absolute Strength (1 N increase)	Relative Strength (1 N/kg increase)	Odds of Having Low Cognition (Absolute Strength)
Lower Extremity Strength	0.02 (0.0008, 0.03)	1.04 (0.03, 2.06)	0.66 (0.47, 0.93)

or age group ( $p = 0.22$ ).

## DISCUSSION

Previous research has accomplished much in publicizing the numerous physical and mental health benefits of aerobic-based physical activity [3-6,9]. It is widely accepted that decreased time spent engaging in sedentary behaviors is associated with improved quality of life, and reduced risk of morbidity and all-cause mortality [25]. The purpose of our study was to broaden the existing knowledge of the impact of physical activity on health and cognition by evaluating the plausibility for lower extremity strength to exert an independently beneficial effect on cognitive functioning, irrespective of number of MSA sessions per month, or self-reported aerobic-based physical activities, among a large cohort of older Americans. The main finding our study was that among elderly individuals, those with increased lower extremity strength demonstrated higher performance on a test of executive cognitive functioning and reduced their risk of having low cognitive function by 34%.

MSA may provide elderly men and women with an alternative modality of physical activity, as individuals with mobility concerns may be unable to safely and comfortably engage in aerobic activities, as demonstrated by reduced physical activity levels among those with mobility limitations [28]. Older adults may experience significant reductions in balance, thus maximizing fall risk and consequent injury. MSA can be performed by those who have difficulty standing or walking, and is especially attractive for lower-extremity strength improvements, as many of these exercises can be performed in a seated or reclined position. Even among adults who are able to participate in aerobic activity, MSA may be a complementary addition to habitual physical activity routines, as the maintenance of functional strength may attenuate the degree of longitudinal decline in lower extremity skeletal muscle power production. Physiological mechanisms contributing to age-related declines in strength include skeletal muscle atrophy, asynchronous neuromuscular firing, as well as morphological changes in remaining muscle fibers [29-31]. Further, increased intramuscular adiposity poses a risk to dynamic firing capacity of aging musculature [32,33].

Cognitive parameters are also suggested to improve with augmented lower limb strength. These parameters may manifest regardless of volume of MSA engagement, but rather gross accumulation of strength [16,17]. That is, although MSA engagement was only 3 sessions per month on average in this national sample, higher absolute and relative strength remained associated with cognition, even with low MSA participation. Thus, gains in strength may be more protective against accelerated cognitive decline than MSA behavior. However, future research employing a more robust measure of MSA will be needed to confirm or refute this assertion. Nevertheless, the benefits of regular resistance activity on cognition should not be overlooked. Increased cerebral blood flow, improved quality of life, and preservation of gait speed are all safeguards against age-associated mental deterioration [9,12,13,17].

In conclusion, this study underscores the independent association between lower extremity strength and cognition within the broader United States older adult population. Thus, physical therapists are encouraged to promote behaviors that increase lower extremity strength. The novelty of our findings extend previous research exploring the relation between physical activity and cognition through the lens of cumulative frequency of aerobic activity, to include components of resistance training and absolute and relative strength. We examined the plausibility for lower extremity strength to influence cognition, irrespective of engagement in aerobic activity, MSA, age group, or gender. Lower extremity strength was associated with higher cognition among this sample of older adults, highlighting the importance for tailored development of resistance programs suitable for the elderly population. Beyond the novelty of our findings, strengths of this study include the objective measures of cognitive function and lower extremity strength. However, future work should overcome the limitations of our study, which includes the cross-sectional study design and subjective measures of physical activity and MSA.

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