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Objectively Measured Physical Activity is Related to Cognitive Function in Older Adults

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Abstract

Background/Objectives—To explore the relationship between cognitive functioning and the time spent at different intensities of physical activity (PA) in free-living older adults.

Design, Setting—Cross sectional analyses of participants enrolled in a randomized controlled trial set in continuing care retirement communities.

Participants—215 older adults residing in 7 continuing care retirement communities in San Diego County: average age 83 years, 70% female and 35% with graduate level education.

Measurements—PA was measured objectively by hip worn accelerometers with data aggregated to the minute level. Three cut points were used to assess low-light, high-light, and moderate-to-vigorous intensity PA (MVPA). Trail Making Tests A and B were completed and time for each test (sec) and test B-minus-A time (sec) were used as measures of cognitive functioning. Variables were log transformed and entered into linear regression models adjusting for demographic factors (age, education, gender) and other PA intensity variables.

Results—Low-light PA was not related to any Trails test score. High-light PA was significantly related to Trails A, B and B-minus-A; but only in unadjusted models. MVPA was related to Trails B and B-minus-A after adjusting for demographic variables.

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Conflict of Interest

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Conclusion—These data suggest there may be a dose response between PA intensity and cognitive functioning in older adults. The stronger findings supporting a relationship between MVPA and cognitive functioning are consistent with previous observational and intervention studies.

Keywords

Physical Activity; Cognition; Older Adults

INTRODUCTION

The United States is experiencing a dramatic increase in the number of people who live to old age. Epidemiologic studies suggest that lifespan and health are determined by genetic and environmental factors (e.g., behaviors), with genetics accounting for approximately 35% of years-lived and modifiable environmental factors contributing 65%. ([http://report.nih.gov/nihfactsheets/Pdfs/DisabilityinOlderAdults\(NIA\).pdf](http://report.nih.gov/nihfactsheets/Pdfs/DisabilityinOlderAdults(NIA).pdf)). Research has also demonstrated that disease and disability are not an inevitable part of aging. Evidence from the Health and Retirement Study (<http://hrsonline.isr.umich.edu/>) indicates that the probability of being cognitively impaired at a given age has been decreasing from the mid-1990s to 2004, although the growing population size of older adults means that the absolute number of cognitively impaired individuals has increased.

Scientists are identifying factors that contribute to healthier aging and longer life expectancy. There is clear evidence that physical activity (PA) can contribute to healthy aging and reduce morbidity and mortality rates.¹ PA also appears to be one of the most promising preventive strategies against cognitive impairment in the elderly population.² Although the underlying mechanisms are unknown, potential mechanisms include neurogenesis, reductions in neuronal cell death, angiogenesis, reduced inflammation, and changes to neurotransmitter balance.³

Evidence from laboratory studies, prospective studies, and intervention studies in older adults generally demonstrate that PA has a positive impact on brain aging as well as cognitive impairment and dementia.³ Two recent reviews of 142 observational studies of older adults reported that higher levels of PA were associated with a 40% reduction in the risk of cognitive decline.⁴⁻⁵ A review of randomized clinical trials of supervised training interventions in cognitively healthy older adults found that the treatment effect sizes across all cognitive tasks were $d = 0.16$ ($SE = 0.03$, $n = 96$) for control groups and 0.48 ($SE = 0.03$, $n = 101$) for exercise groups, with the difference between groups statistically significant.⁶

There is strong causal evidence from these trials that exercise training programs delivered in supervised laboratory settings (e.g., 30 minutes of treadmill walking, 3 times a week) have a positive impact on cognition.³ However, these trials provide little information as to whether lifestyle (i.e., low-intensity) PA influences cognition in older adults⁷. Examples of lifestyle PA include walking for errands, gardening, and housework. The effect of lifestyle PA on cognition among older adults is an important area of research, given that these types of activities may be more sustainable in daily life.

Although epidemiologic studies of PA could provide dose data associated with differences in cognition, most of these studies are observational and rely on self-reports of PA.⁴⁻⁵ This is a fundamental limitation of the literature because cognitive function may affect an individual's ability to accurately report their activity.⁸ There have been few studies of objectively-assessed PA and cognitive functioning of older adults⁹ and, to our knowledge, no study has explored the role of light intensity PA as a correlate of cognitive function

independent of other PA. There is some evidence that light-intensity activity (e.g. housework, slow walking) can have health benefits,¹⁰ but it has not been well explored in relation to cognitive function. Considering that light intensity PA is the dominant PA among older adults¹¹ and few participate in meaningful amounts of moderate to vigorous PA, it is important to further examine how lower intensity PA is related to health.¹⁰ This manuscript is responsive to the recent expert consensus that there is an urgent need for more research on the dose-response relationship of physical activity with health benefits in older adults.¹² Therefore, the purpose of this study is to examine the relationship of objectively-measured light and moderate intensity PA with cognitive functioning in older adults.

METHODS

Study participants were 215 older adults living in seven continuing care retirement communities in San Diego County who were recruited to a randomized controlled trial of an intervention designed to increase levels of PA. Recruitment is on-going. Eligibility criteria were 65 years of age, ability to speak and read English, no history of falls within the past 12 months that resulted in hospitalization, ability to walk 20 meters without human assistance, completion of the Timed Up & Go Test in <30 seconds, and completion of an informed consent comprehension test. This analysis includes baseline data from both study arms for participants with complete data (n=215). Participants who were unable to complete study measures due to cognitive impairment or other limitations were excluded. This study was approved by the institutional review board and all participants provided informed consent.

We assessed physical activity with the ActiGraph GT3X+ triaxial accelerometer (ActiGraph, LLC). ActiGraphs are small, easy-to-wear devices that yield valid estimates of PA in controlled and free living environments.¹³⁻¹⁴ Data were processed using the ActiLife v6 software (Pensacola, FL). The unit of measurement for accelerometers is counts, with higher counts indicating higher intensity of movement. Laboratory and field studies have determined count per minute cut off that reflect different MET values. Participants wore the accelerometer on a belt on their hip for 6 days for a minimum of 10 hours per day. We determined non-wear time using a modified Choi algorithm¹⁵ in which 90 consecutive minutes of zero counts with a 2-minute spike tolerance was screened as non-wear. Participants were asked to re-wear the device if the wear-time criteria were not met on at least 4 days. Data were aggregated to 60 second epochs so published cut points could be applied. We defined low-light intensity PA (LLPA) as <1040 counts/minute equivalent to 1.5-2.24 METS, high-light PA (HLP) as 1040-1951 counts/minute equivalent to 2.25-2.9 METS, and moderate to vigorous PA (MVPA) as 1952 counts per minute equivalent to 3-7 METS.^{10, 16-18} Minutes in each intensity level for each participant were averaged per day.

Cognitive functioning was measured using Trail Making Tests (TMT) A and B. Participants were allowed up to 180 seconds (3 minutes) to complete Trails A by drawing connecting lines between sequential numbers from 1-25. Participants were then presented the Trails B test and given a maximum of 300 seconds (5 minutes) to complete the task. A combination of letter and numbers were presented and participants were instructed to draw a line connecting alternating letters and numbers in sequence (e.g., 1-A-2-B, etc). The time to complete each task yielded a raw score in seconds. The Trails tests have a complex multifactorial structure comprising several cognitive domains. While there is not complete agreement in the literature, it appears that Trails A requires mainly visuo-perceptual abilities, Trails B reflects working memory and task-switching ability, while Trails B times minus Trails A times (B-minus-A) provides a relatively pure indicator of executive control abilities.¹⁹

Data Analysis

Descriptive analyses examined sample differences by study covariates and physical activity intensity categories. Variables are presented as mean $\pm$ standard deviation or medians and interquartile ranges where appropriate. Probability plots were used to assess data distributions. Minutes per day were divided by 30 so that we could model the impact of 30 minutes/day of each level of PA²⁰. This modeling approach provides a more intuitive parameter estimate in comparison to modeling the impact of 1 minute/day of PA on cognition. Although the guidelines for older adults include any PA as beneficial, for specific health outcomes only MVPA is recommended as studies exploring lower levels of activity are lacking. Because of non-normal distributions, Trails A and B cognition test completion times were logarithmically transformed prior to modeling. Regression models were fitted to assess associations between physical activity intensity categories and TMT times. First, models were used to estimate the separate effects on cognition for each category of physical activity: LLPA, HLP, and MVPA. Both unadjusted and adjusted models (controlling for age, gender, and education) are presented. The final model also adjusts for the other categories of PA to examine the independent effects of specific PA intensity categories. We also calculated total MET hours/day and used linear regression to determine the association of total MET hours per day with each of the cognition tests, adjusted for age, gender, education and accelerometer wear time. Regression coefficients and 95% confidence intervals (95% CI) were computed for all models. Regression coefficients were exponentiated (i.e., back-transformed) to permit presentation of results on the original TMT scores (seconds). Normality plots of residuals assessed the fits for these models. Because of the wide age range in this study and the inclusion of an older adult sample not usually studied, we explored interaction effects by age. A p value of 0.1 was considered significant for the interaction analyses. Analyses were conducted using SAS 9.3 (Cary N.C.).

RESULTS

Study sample demographics by age are presented in Table 1. Participants had a mean age of 83 years, 71% were female, and 70% had a college degree. Average ActiGraph wear time was almost 6 days. Compared to adults aged 85-105 years, those aged 65-84 years averaged more minutes per day in the three intensity levels of PA and required less time to complete Trails A and B cognition tests. Only 10% met physical activity guidelines of 30 minutes per day MVPA.

Correlations between adjacent PA intensity categories were higher than non-adjacent categories. The strongest association was between HLP and MVPA ($r = 0.6$), whereas the weakest correlation was between LLPA and MVPA ($r = 0.18$). Minutes per day spent in any category of PA were negatively correlated with time to complete the TMTs, although only PA's of High-Light intensity or greater were statistically significant.

Table 2 presents models of the association of PA with cognition. Due to the logarithmic transformations, the model results were exponentiated and the parameters shown in Table 2 are interpreted as the percentage decrease in seconds required to complete the cognitions tests per 30 minutes/day of PA.

This analysis found no statistically significant associations of LLPA with the cognition tests. HLP was significantly associated with a faster time to complete Trails A, but only in the unadjusted ($p=0.0003$) and the sex/age/education adjusted models ($p=0.035$). HLP was significantly associated with faster time to complete Trails B ($p=0.003$) and Trails B-minus-A in unadjusted models only ($p=0.016$).

Thirty minutes per day of MVPA was statistically significantly associated with 21% faster time to complete Trails B in the unadjusted models ($p=0.0005$), 14% faster time in the age/sex/education adjusted model ($p=0.0213$), and 7% faster time in the model that added adjustment for other categories of PA ($p=0.047$). The strongest, statistically significant associations were observed between MVPA and Trails B-minus-A, which is an indicator of executive function. For example, assuming that on average, 72 seconds were required to complete Trails B-minus-A test, results from the adjusted model indicate that older adults who regularly participated in 30 minutes of MVPA required only 61 seconds to complete that cognition test (i.e., 15% faster time) ($p=0.029$). We tested for an interaction of age with any intensity of physical activity and cognition tests and there was no evidence for effect modification by age. Table 3 presents the p values for each interaction tested.

The linear regression models of total MET hours/day showed no significant association of physical activity with the cognition tests (i.e., seconds required to complete Trails A, B and B-A). Specifically, the regression coefficient (95% CI) for MET hours was 0.98 (0.97-1.00) for Trails A; 0.99 (0.97-1.01) for Trails B; and 1.00 (0.97-1.02) for B-A.

DISCUSSION

Overall, our analysis found only modest and generally non-significant associations of low intensity PA with cognitive function. We found that higher intensity PA was associated with better cognitive function. Specifically, 30 minutes per day of MVPA was associated with approximately 20% greater speed demonstrated in executive control processes such as planning, scheduling, working memory, interference control, and task coordination. It is notable that when all intensity levels of physical activity were combined into a single measure of MET hours/day, no associations were seen between physical activity and cognition. That is, the null findings for total MET hours/day obscured the significant impacts of moderate-to-vigorous activity on cognition. These results highlight the informational limitations of using a single measure of physical activity compared to examining the impacts of time spent at different intensities of physical activity. To the best of our knowledge, this is the first study to examine relationships between objectively-measured light and moderate intensity PA and cognitive functioning among older adults.

Our results are similar to the study of accelerometer-measured activity and the Trails B test among 2736 older women by Barnes et al.⁹ The authors of this large study reported that compared to the lowest quartile of total PA (which included both sedentary, light, moderate and vigorous activities together), women in the highest quartile of PA scored 20 (± 3) seconds faster on Trails B, a difference associated with 30 minutes of MVPA per day from our study. The Barnes study used a wrist worn accelerometer whereas we employed a hip worn monitor. Only laboratory studies have compared these two placement sites and no studies have been conducted with older adults. Wrist devices will be more sensitive to PA involving the arms which may be important for older adults with functional impairments that restrict lower limb (ambulatory) activity.

Our results are consistent with a review of randomized clinical trials²¹ that concluded that an exercise regimen of aerobic exercise at least 3 times per week for 60 minutes had a positive effect on cognition.²¹ The robust results between MVPA and the Trails B-minus-A results (a measure of executive function) are supported by a review on fitness, aging and neurocognitive function.²² Executive control processes decline substantially as a function of aging as do the brain regions that support them.²³ Therefore, our results suggest that even processes that are susceptible to aging may be amenable to a physical activity intervention. If the mechanism for cognitive change is dependent on blood flow it is possible that higher intensity PA is required to activate this response⁶.

A strength of our study was the inclusion of an older population (range = 65-105 years of age) that is at considerable risk of declines in both PA²⁴ and cognition.²⁵ In addition, the use of an objective measure of PA is critical to avoid the potential effects of impaired cognition on self-reported PA as well as over-reporting bias. For example, self-report from national surveys indicate that 25–33% of the population met the recommended 30 minutes of MVPA on five or more days per week; compared to the finding that less than 3% of US older adults met these guidelines when accelerometers were used.²⁴ These divergent findings confirm the necessity of using objective measures of PA when making absolute recommendations about the duration and intensity of PA needed to affect health outcomes.

Limitations of the study include the cross-sectional design and that results may not generalize to populations who are not well-educated non-Hispanic Caucasians. Clinical trials in this retirement community setting would further strengthen the evidence for a relationship between lifestyle PA and cognition. In addition, interventions in such settings may have more sustainable effects due to the existing facilities infrastructure and social support²⁶. Further, the sample size was small and therefore more vulnerable to random error in sampling and measurement. Studies with larger samples could also adjust for health conditions in analyses. We also excluded people from the study with cognitive impairments that affected their ability to participate in a PA intervention. This introduces a systematic sampling bias which further reduces the generalizability of findings. In addition, the TMTs are limited in terms of precision and the degree to which they represent specific domains of cognitive functioning. Finally, accelerometer-measured activity does not provide information on types of specific activities (e.g., walking versus weight lifting) and underestimates PA intensity in which the hips have limited movement (e.g., bicycling, chair-based exercise, etc.).

In conclusion, these data suggest that light levels of PA such as those associated with housekeeping and other activities of daily living appear to have little association with cognitive functioning in older adults. Interventions to enhance these types of activity would more clearly demonstrate whether there is any beneficial effect. However, MVPA is associated with cognition, particularly executive control processes. Future prospective and intervention studies should investigate the types of activities that are associated with improvements in specific cognitive domains, particularly across diverse older populations.

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Table 1

Characteristics of older adults participating in a study of accelerometer-measured physical activity and health.

	65-84 Years of Age	85 Years of Age	Total Sample
Number of participants	121	94	215
Age, mean ($\pm$SD)	78.8 (4.2)	89.3 (3.8)	83.4 (6.6)
Gender (% female)	67.8	74.5	70.7
Education (%)			
Less than college degree	27.6	32.2	29.6
Completed college	32.8	37.8	35.0
Graduate school	39.7	30.0	35.4
Actigraph wear days, mean ($\pm$SD)	5.8 (1.1)	5.5 (0.9)	5.7 (1.02)
Physical Activity, mean ($\pm$SD)			
Low-Light (minutes/day)	210.6 (57.8)	192.3 (61.7)	202.6 (60.1)
High-Light (minutes/day)	24.3 (13.0)	15.8 (14.1)	20.6 (14.1)
Moderate/Vigorous (minutes/day)	14.8 (17.0)	5.3 (9.3)	10.6 (14.9)
Cognition Tests, median (IQR)			
Trails A time (seconds to complete)	47.7 (19.0)	53.8 (30.4)	47.8 (24.0)
Trails B time (seconds to complete)	103.0 (67.3)	160.0 (131.9)	121.0 (201.4)
Trails B-A (seconds to complete)	58.13 (60.75)	90.33 (113.78)	71.87 (88.29)

Table 2

Regression models of the association between physical activity and seconds required to complete the trails cognition tests in a sample of older adults.

Model ^a	Categories of Accelerometer-Assessed Physical Activity (30 Minutes per Day)		
	Low-Light (N=215)	High-Light (N=215)	Moderate/Vigorous (N=215)
	β (95% CI)	β (95% CI)	β (95% CI)
Trails A (Visuoperceptual abilities)			
Adjusted for age, gender, education	0.98 (0.95-1.00)	0.89 (0.80-0.99)	0.93 (0.83-1.03)
Adjusted for age, gender, education & other categories of physical activity	0.98 (0.96-1.01)	0.94 (0.81-1.08)	0.97 (0.86-1.09)
Trails B (Working memory & task switching abilities)			
Adjusted for age, gender, education	0.98 (0.95-1.01)	0.91 (0.80-1.05)	0.86 (0.75-0.98)
Adjusted for age, gender, education & other categories of physical activity	0.99 (0.95-1.02)	1.03 (0.86-1.23)	0.85 (0.73-1.00)
Trails B-A (Executive control processes)			
Adjusted for age, gender, education	0.98 (0.94-1.03)	0.91 (0.74-1.11)	0.81 (0.66-0.97)
Adjusted for age, gender, education & other categories of physical activity	0.99 (0.94-1.04)	1.06 (0.82-1.38)	0.85 (0.63-0.99)

^aTrails cognition tests were log-transformed prior to analyses. The backtransformed parameters (β) shown above are interpreted as percent of mean times (seconds) required to complete the cognition test associated with 30 minutes per day of physical activity.

Table 3

Model	Interaction models (activity category*age)		
	Low-Light*age	High-Light*age	Moderate/Vigorous*age
	P value	P value	P value
Trails A (Visuoperceptual abilities)			
Adjusted for activity category, age, gender, education	0.70	0.74	0.93
Trails B (Working memory & task switching abilities)			
Adjusted for activity category, age, gender, education	0.54	0.84	0.36
Trails B-A (Executive control processes)			
Adjusted for activity category, age, gender, education	0.75	0.95	0.82