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Light physical activity is positively associated with cognitive performance in older community dwelling adults

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Abstract

Objectives: To evaluate the associations between an objective measure of different intensities of physical activity, upper- and lower-limb muscle strength and psychomotor performance and set-shifting domains of cognitive executive function in older adults.

Design: A cross-sectional study.

Methods: From the Tasmanian Older Adult Cohort Study, 188 community-dwelling older adults (53.7% female; mean age ± SD 63.98 ± 7.3 years) undertook 7-day physical activity behaviour monitoring using an accelerometer. Dynamometers were used to assess leg extension strength. The Trail Maker Tests were used to measure psychomotor processing speed and set-shifting performance.

Results: When controlling for age, smoking history, alcohol intake, educational achievement and neuropsychological functioning, higher levels of light physical activity, but not sedentary behaviour or moderate or vigorous physical activity, was found to be associated with better set-shifting performance. Neither physical activity behaviour or muscle strength were found to be associated with psychomotor performance. In addition, older age, greater alcohol intake, and lower levels of educational attainment, verbal learning and memory performance were significantly associated with lower scores on the set-shifting task; whereas older age and reduced neuropsychological functioning were associated with lower psychomotor processing speed scores.

Conclusions: Light physical activity is associated with higher executive functioning in community-dwelling older adults and this strengthens the evidence supporting exercise as a neuroprotective agent. Further studies are needed to understand why light physical activity behaviour positively influences executive functioning, and how such physical activity can be implemented into the daily routine of older adults.

Keywords: Cognition, exercise, executive function, accelerometer, muscle strength.

1. Introduction

Participation in physical activity (PA) by older adults reduces the risk of chronic disease, and encourages the maintenance of muscle strength[1] and functional independence.[2] It is also possible that regular PA might delay the age-related decline in cognitive function.[2]

The collective evidence demonstrates PA positively influences cognition across a range of domains.[3] A meta-analysis of prospective studies that examined the association between PA and cognitive decline in older adults found a low to moderate level of PA significantly (-35%) reduced the risk of decline.[4] Others found an inverse relationship between increased muscle strength[5] and cardiorespiratory fitness[6] and cognitive decline.

Questionnaires and other self-report measures have historically been used to derive population-based measurements of habitual PA, despite their limited reliability and validity.[7] Objective measures of PA are furthering our understanding of the association between cognition and PA, and there is emerging evidence cognitive function is improved by both light[8] and moderate-to-vigorous PA.[8,9]

Further population-based studies are required to clarify the association between cognition, muscle strength and objectively measured PA behaviours. In an ageing Australian population, understanding this association might aid the development of interventions aimed towards delaying or slowing the rate of cognitive decline. The aim of this study was to investigate cross-sectional associations between different intensities of PA, muscle strength and executive functioning as indexed by set-shifting and psychomotor performance in older adults. It was hypothesized that more active and stronger participants would have enhanced set-shifting and faster psychomotor speed whereas increased sedentary time would be associated with poorer set-shifting and psychomotor performance.

2. Method

Participants were drawn from the Tasmanian Older Adult Cohort (TASOAC), an ongoing, prospective, population-based study of community-dwelling older adults. An equal number of men and women between the ages of 50 and 79 years were randomly selected from the electoral roll in Southern Tasmania (population 229,000), with a response rate of 57%. Exclusion criteria included contraindication for magnetic resonance imaging and institutionalisation. Of the 1,100 enrolled in the study, 1,099 attended a clinic for baseline assessment between March 2002 and September 2004. Phase 2 follow-up data was collected for 875 participants approximately 2.7 years later, and Phase 3 data was collected for 767 participants approximately 5 years later. Our study consists of 111 females (64.23 ± 7.095 years) and 99 males (mean ± SD, age 63.92 ± 7.326 years) that had complete Phase 2 accelerometer, cognition and muscle strength measures. The study was approved by the Southern Tasmanian Health and Medical Human Research Ethics committee, and written informed consent was obtained from all participants.

The waist-to-hip ratio (WHR) is a surrogate obesity indicator that has been shown to be a more effective predictor of mortality and cardiovascular disease than other anthropometric measures, such as body mass index.[10] It is determined by dividing the participants average waist circumference by their average hip circumference. The measurements were taken either directly over the skin or over light clothing, measured to the 0.1 cm and repeated. A third measurement was taken if there was more than a 2 cm difference between the first two measures. With the participant standing with their feet together and arms relaxed by their side, the waist measurement was taken at the level of the mid-point between the inferior margin of the last rib and the crest of the ilium in the mid-axillary plane and is taken at the end of a normal expiration. This hip circumference measure is taken at the level of the greatest posterior protuberance of the buttocks and with the participants gluteal muscles in relaxed.

Level of educational attainment was based on recognised Australian educational standards and obtained in a structured interview in response to the following question: What is the highest qualification you have completed? The respondents were to select one of the following: 1) No formal qualifications; 2) School or Intermediate Certificate; 3) Higher School or Leaving Certificate; 4) Trade/apprenticeship; 5) Certificate/diploma; 6) University Degree; or 7) Higher University Degree. Smoking history was assessed by determining if the participant was, or had previously been, a ‘regular smoker’ (viz. someone that had smoked at least 7 cigarettes, cigars or pipes weekly for at least 3 months). Self-reported alcohol intake (g/day) was measured using the validated Cancer Council Victoria Dietary Questionnaire for Epidemiological Studies.[11]

Isometric leg strength of the hip extensors and quadriceps was assessed in both legs simultaneously (to the nearest kilogram) using a dynamometer (TTM Muscular Metre, Tokyo, Japan). The best score from two attempts was recorded. This test has previously been described in detail.[12]

The Trail Maker Test (TMT), a widely used neuropsychological assessment, was used to assess set-shifting and psychomotor speed.[13] The TMT is a two-part (TMT-A and TMT-B) assessment of general brain function. The TMT-A requires participants to connect numbers with a line, whilst the TMT-B requires both letters and numbers to be connected. TMT-A assesses visuo-perceptual and motor abilities, whilst the TMT-B assesses working memory and task-switching skills.[13] Participants were administered a pen and paper version of the TMT according to the established guidelines[14] in a laboratory-based setting. Faster completion of the test indicated better performance.

A revised version of the Hopkins Verbal Learning Test-Revised (HVLT-R)[15] has high utility as a screening instrument for amnestic mild cognitive impairment and early Alzhiemer's disease (AD).[16] Participants were administered the HVLT-R according to the established guidelines[14] in a laboratory- based setting. The performance measures were a total number of words recalled for each of 3 learning trials (HVLT total recall; range 0 – 36) and the total number of words recalled in a delayed trial (HVLT delayed recall; range 0-12).

Accelerometer-determined PA was assessed using an ActiGraph GT1M (Actigraph, Pensacola, FL) which provides information on the frequency, intensity, and duration of PA using a built-in single axis accelerometer which measures vertical accelerations at the hip at a sampling frequency of 30 Hz. Actigraph accelerometers and software are a valid and reliable means of measuring PA.[17] Each participant was instructed to wear an accelerometer for 7 consecutive days following their clinic visit. Participants were provided with a daily diary where they recorded the time they put the accelerometer on in the morning and took it off at the end of each day, as well as the duration and reason for any periods where they took the accelerometer off (non-wear time).

The number of counts was collected in 1-minute epochs. Sedentary activity was classified as less than 250 counts per minute (cpm), light (251-1951 cpm), moderate (1952-5724 cpm) and vigorous ($\geq$ 5725 cpm). This corresponds to less than 1.5 metabolic equivalents [METS]), 1.5 - 2.9

METS), 3 - 5.9 METS, ≥ 6 METS respectively. The sedentary activity cut-off was proposed by Matthew,[18] and cut-offs for the other categories of PA were as per the Freedson equation.[19] For each of the 7 days, the accelerometer registered the amount of time (min/day) the participant spent in light, moderate, and vigorous activity. Sedentary time was then calculated using the total wear time reported in the daily diary minus any non-wear time, light, moderate, and vigorous activity. Sedentary, light, moderate and vigorous activity were then averaged by the total number of valid days (a valid day was one in which the accelerometer was worn for > 10 hours) to produce an average time spent in each activity category per day. Participants had to have at least 5 valid days to be included in the analysis. Therefore for the analysis each participant had a value (min/day) of sedentary, light, moderate, and vigorous which was the average over the time the accelerometer was worn.

Multiple regression analyses, using SPSS version 22© software, were employed to explore the cross-sectional association between TMT parts A and B and sedentary, light, moderate, and vigorous levels of PA and leg muscle strength. Interactions and indirect effects were assessed using the MODPROBE and INDIRECT macros for SPSS, respectively.[20,21] Sample outliers were identified using boxplots, kernel density estimation with rug plots and standard scores for the variables. The assumption of normality was assessed by examining residuals scatter plots for the dependent variables. Power analysis[22] indicated that with alpha set at 0.05 and Power at 0.80, a minimum of 127 participants would be required to reliably detect small-to-medium effects, which are of similar magnitude to those found in previous PA and cognition research.[3,23]

3. Results

Twenty outlier cases (9.5% of the sample, 10 Female) that had a standard score of 3 or greater were removed from the analyses. Another two cases (0.95% of the sample) were removed because of missing HVLT-R data, resulting in 188 participants being included in the analyses (see Table 1 for participant characteristics). The sample analysed differed little from the initial sample prior to exclusions (see Methods). Examination of residuals scatter plots for TMT variables showed that the assumption of normality was met. The Variance Inflation Factors for the predictor variables were less than 2.5 and the Tolerances were greater than 0.2, indicating that there was no multicollinearity.

The correlation matrix (see Table 2) shows that no significant correlations were found between total wear time minutes, TMT-A performance and sedentary behaviour, light PA, moderate PA or vigorous PA. However, the correlations between TMT-B performance, total wear time minutes, light PA and moderate PA were significant. More time spent engaged in PA was associated with faster TMT-B completion times. The correlation between TMT-A performance and the level of education attained was not significant. However, the correlation between TMT-B performance and level of education attained was significant, with higher levels of education attainment associated with faster TMT-B completion times. Additionally, the correlations between level of education attained and sedentary behaviour and light PA were significant. A higher level of education attained was associated with more sedentary behaviour, and less time engaged in light PA. Additionally, Table 2 shows that the level of redundancy between the different categories of PA was acceptable.

TMT-A was regressed on age, gender, level of education attained, WHR, history of cigarette smoking, alcohol intake, and HVLT total recall. The model was significant, accounting for 9.4% of TMT-A, $F(7, 180) = 2.66$, $p = <0.012$, $R^2 = 0.094$. Age and HVLT total recall were the only significant factors associated with TMT-A performance ($B = 0.277$, 95% CI [0.036, 0.518], $p = 0.024$ and $B = -0.378$, 95% CI [-0.750, -0.007], $p = 0.046$, respectively). The non-significant variables were removed and total wear time minutes, leg muscle strength, and sedentary, light, moderate, and vigorous levels of PA were simultaneously added. Again, the model was significant, accounting for 9.5% of TMT-A, $F(7, 180) = 2.684$, $p = <0.011$, $R^2 = 0.095$, $R2\Delta = 0.014$, $p = 0.743$. Age and HVLT total recall remained the only statistically significant predictors ($B = 0.326$, 95% CI [0.072, 0.579], $p = 0.012$ and $B = -0.504$, 95% CI [-0.849, -0.158], $p = 0.005$, respectively). Total wear time minutes, leg muscle strength, sedentary behaviour, and light, moderate, and vigorous PA added a trivial amount to the variability of TMT-A performance. It is well established that psychomotor speed declines with normal aging,[24] so the regression model for TMT-A will not be reported further.

TMT-B was regressed on age, gender, level of education attained, WHR, history of cigarette smoking, alcohol intake, and HVLT total recall. The data fit the model well. It was significant, accounting for 31.4% of TMT-B performance, $F(7, 180) = 11.786$, $p = <0.001$, $R^2 = 0.314$. Gender and WHR (B = -0.669, 95% CI [-12.703, 11.368], p = 0.913 and B = -7.816, 95% CI [-58.932, 43.299], p = 0.763, respectively) were not significant and their unique contributions to the variability in TMT-B performance were trivial, so they were removed from the model.

Next, total wear time minutes, leg muscle strength, and sedentary, light, moderate, and vigorous levels of PA were simultaneously added. It was significant and accounted for 36.2% of TMT-B performance, $F(10, 177) = 10.027$, $p = <0.001$, $R^2 = 0.362$. This represented a significant increase of 4.8% from the first model, $R^2\Delta = 0.048$, $p = 0.024$. Leg muscle strength and total wear time were not significant minutes (B = 0.58, 95% CI [-.037, .153], p = 0.232 and B = -.056, 95% CI [-.117, .006], p = 0.077, respectively) and their unique contributions to the variability in TMT-B performance were trivial (0.5% and 1% of the variance, respectively). They were removed from the model. The model continued to account for 35.6% of variability in TMT-B performance, $F(9, 178) = 10.940$, $p = <0.001$, $R^2 = 0.356$, $R^2\Delta = 0.043$, $p = 0.022$. The final model for TMT-B is presented in Table 3. Light PA was significant and uniquely accounted for 2.6% of the variability in TMT-B performance. A one minute increase in time spent performing light PA was associated with a 0.114 second reduction in the time taken to complete the TMT-B when all other factors were held constant. Sedentary, moderate, and vigorous levels of PA were non-significant variables. However, they were not removed from the model, as PA is a naturally occurring continuous variable that was categorized to facilitate comparison with previous research in the area of interest. The remaining factors (age, HVLT total recall, level of education attained, alcohol intake, and smoking) were significant and each uniquely accounted for a small amount of variability in TMT-B performance (see Table 3). The most notable was level of education attained, which accounted for 8.2% of the variability in TMT-B performance. Finally, variance common to multiple factors accounted for 10.37% of the variability in TMT-B performance. There were no significant interactions or indirect effects at the criterion alpha level of 0.05.

4. Discussion

The utility of accelerometers to objectively measure PA behaviour distinguishes this study as one of the few that accurately quantifies the associations between cognitive functioning, muscle strength, and PA behaviour. In our cross-sectional analysis of older adults, older age and reduced cognitive functioning was negatively associated with psychomotor speed. However, there was no significant association between PA behaviour or muscle strength and psychomotor speed. Alternatively, when controlling for smoking history, alcohol intake, level of education attained and cognitive functioning, our regression model identified light PA to be positively associated with set-shifting ability. The relatively small amount of variability in cognitive function accounted for by light PA is consistent with the effects found in previous research.[3] An increase in time taken to complete the set-shifting task was associated with older age, increased alcohol intake, a history of smoking, lower levels of educational attainment and reduced neuropsychological functioning.

Our finding that objectively measured light PA was associated with enhanced set-shifting ability is consistent with previous evidence that demonstrated light-intensity PA is associated with higher levels of domain-specific (word fluency) executive function.[8] It is an important finding in the context of the appropriateness of the prescription of light-intensity PA to older adults that may be deconditioned or are new to exercise and thus restricted to light exercise only. Our finding also support previous reports of an association between cardiorespiratory fitness and global cognitive performance and TMT-B performance in non-demented individuals.[25] Though it is notable that we found an association even when age was controlled for, which was not the case in the Burns et al. study.[25]

Exercise confers benefits by preserving frontal, parietal and temporal cortex grey matter volume[26] and hippocampal volume[27] in older adults. Larger hippocampi and higher fitness levels have been correlated with better spatial memory performance,[27] and there is good evidence that higher levels of PA can reduce the likelihood of developing cognitive impairment.[28] Collectively, PA appears to influence the brain in a manner that translates to preserving cognitive function. How this occurs, and what specific cognitive processes are influenced by the various modes and intensities of PA is beyond the scope of this study and requires further investigation.

The absence of significant associations between cognitive function and moderate and vigorous PA contrasts previous research by Kerr et al. (2013), who found only moderate-to-vigorous intensity PA was significantly associated with cognitive functioning.[9] The contrasting results may be explained by a number of methodological differences: Kerr et al. classified PA behaviour into low-light, high-light, and moderate-to-vigorous intensity PA; the study participants had an older average age (83 years); 70% were university educated and all were residing in retirement communities. Neither study found any interactions, however Kerr et al. used an alpha level of 0.10, whereas we used a more stringent alpha of 0.05. Had we used the same alpha level as Kerr et al., we would have reported significant interaction effects. Furthermore, although Kerr et al. transformed their data for analysis and then back-transformed them so the results would be in a meaningful metric, they reported mean values.[9] However, back transformation gives the geometric mean, which is a close approximation of the median.[29] We report mean values. These differences make it difficult to directly compare the two studies.

Another finding of interest is that the level of education attained was the largest unique contributor to the total variability in set-shifting performance. A faster TMT-B completion time was found to be associated with a higher level of education attainment. Furthermore, the correlation between HVLT total recall score and the level of education attained was significant and positive. These findings are consistent with previous research, which has shown a higher level of education attainment is associated with better performance on neuropsychological tests.[23] Possibly of greater interest though, is the contrast between the positive bivariate association between the level of education attained and sedentary behaviour and the inverse association between the level of education attained and light PA.

Additionally, although total wear time was not a significant predictor and accounted for little of the variability in TMT-B scores in the regression models, it had a strong positive bivariate association with sedentary PA. That is, as wear time increased so did sedentary PA. The other PA categories only had weak to moderate associations with total wear time. It is also notable that approximately one-third of the accounted for variability in TMT-B performance was shared by the factors. These results highlight the complexity of the associations between variables that impact on cognitive functioning in older adults, and further research is necessary to disentangle them.

This study has several limitations. It is possible that the wearable accelerometers influenced the PA behaviours of the participants, though unlike other activity monitors, the accelerometers used in this study do not provide the wearer with feedback and thus minimise any motivating impact they might have on the participants PA behaviours. We also acknowledge that the ActiGraph GT1M may underestimate light activity and overestimate sedentary behaviour.[30] Whilst our findings cannot be applied to institutionalised older adults or those over 80 years of age, they can be applied to community dwelling older Australian adults who are under 80 years of age. Finally, the cross-sectional design of the present study does not allow for strong claims about causality. That is, notwithstanding our findings, we are unable to determine the potential direction of the association between PA behaviour and cognitive functioning.

5. Conclusion

This study found light PA is associated with higher levels of cognitive functioning in a sample of older adults. The significance of this finding should not be underestimated, as this is one of the few studies of its type to employ an objective measure of PA behaviours. Notwithstanding the existing evidence of the benefits of PA for cognitive functioning, our findings have important implications for the appropriate prescription of exercise to preserve older adult's executive functioning. For older adults new to exercise, or with pre-existing comorbidities, the initial engagement in PA should be at a light level, including low-intensity aerobic-based activities such as walking and gardening. Future studies should focus on determining the influence of PA behaviour on cognitive functioning over time and establish exercise prescription guidelines for the neuroprotection of older adults.

Practical Implications

- Higher levels of light PA may help older adults to preserve their executive functioning.

- A greater intensity of PA and increased sedentary time may not necessarily enhance cognitive functioning.
- Elderly individuals who are deconditioned or new to exercise might benefit physically and cognitively from light PA.

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Table 1

Participants characteristics (n = 188).

	Value
TMT-A, mean seconds to completion (±SD)	37.320 (12.021)
TMT-B, mean seconds to completion (±SD)	93.100 (36.217)
Age, mean years (±SD)	63.98 (7.3)
Gender, percent female	53.7
HVLT Total Recall (range = 11-36), mean score (±SD)	25.510 (5.106)
Level of education attained (range = 1-7), mean level (±SD)	3.290 (1.747)
WHR, mean cm/cm (±SD)	1.123 (0.110)
Alcohol intake, mean g/day (±SD)	14.007 (15.498)
Has the person ever smoked, percent smoked	1.511(0.501)
Leg strength, mean kg (±SD)	97.580 (51.131)
Sedentary PA, mean min/day (±SD)	581.670 (93.844)
Light PA, mean min/day (±SD)	228.560 (69.292)
Moderate PA, mean min/day (±SD)	31.490 (21.923)
Vigorous PA, mean min/day (±SD)	0.390 (1.318)
Wear time minutes (±SD)	843.37 (75.587)

Table 2

Bivariate correlations for variables entered into the multiple regressions (n = 188).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	TMT-A	1														
2	TMT-B	.469**	1													
3	Age	.206**	.281**	1												
4	Gender	-.082	-.042	.006	1											
5	HVLT total recall	-.227**	-.349**	-.164*	.314**	1										
6	Level of education attained	-.063	-.315**	.075	-.113	.195**	1									
7	WHR	-.108	-.121	-.073	.597**	.251**	-.012	1								
8	Alcohol intake	.125	-.218**	-.123	-.277**	.089	.106	-.102	1							
9	Has the person ever smoked	.019	-.137	.078	.158*	.022	-.124	.184*	-.160*	1						
10	Leg strength	.013	-.047	-.198**	-.753**	-.137	.093	-.406**	.268**	-.119	1					
11	Sedentary PA	.082	.050	.147*	-.008	.001	.184*	-.098	-.045	-.104	-.024	1				
12	Light PA	-.039	-.242**	-.261**	.008	.092	-.172*	.122	.053	.168*	.120	-.621**	1			
13	Moderate PA	-.047	-262**	-.329**	-.138	.135	.043	.163*	.063	.018	.276**	-.384**	.412**	1		
14	Vigorous PA	.030	-.114	-.124*	-.104	.057	.105	.055	.136	-.002	.184*	.084	.008	.247**	1	
15	Total wear time minutes	.051	-.241**	-.156*	-.046	.127	.084	.039	.015	.018	.164*	.555**	.274**	.199**	.203**	1

alpha = 0.05. Note: *<0.05, **<0.01.

Table 3

Summary of the multiple regression analysis results for TMT-B (set-shifting performance) (n = 188).

Factor	B	SE	t	95% Confidence Interval for B		S^2
				Lower Bound	Upper Bound	
Age	0.963	0.331	2.912	0.310	1.616	0.031
HVLT total recall	-1.455	0.447	-3.253	-2.337	-0.572	0.038
Level of education attained	-6.348	1.336	-4.752	-8.984	-3.712	0.082
Alcohol intake	-0.380	0.144	-2.630	-0.664	-0.095	0.025
Has the person ever smoked	-13.593	4.558	-2.982	-22.589	-4.598	0.032
Sedentary PA	-0.051	0.031	-1.629	-0.112	0.011	0.010
Light PA	-0.114	0.043	-2.690	-0.198	-0.030	0.026
Moderate PA	-0.180	0.121	-1.484	-0.419	0.059	0.008
Vigorous PA	0.402	1.487	0.270	-2.533	3.337	0.0003

alpha = 0.05. Note: S^2 is the squared semi-partial correlation. Whereas, R^2 is the percent of variability in the dependent variable that is accounted for by a linear combination of all factors in the regression model, S^2 is the percent of variability in the dependent variable that is uniquely accounted for by a single factor.