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Does Exercise in Older Adults Predict Problem Solving? The Role of Personality

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Abstract

Research suggests that physical fitness is positively associated with cognitive functioning in older adults, and that executive functions may be associated in particular. This study explored whether personality supplemented the relationship between physical activity and problem-solving. A computerized version of the Tower of London provided number of errors and time to completion as dependent variables using a sample of 65 community-dwelling older people. The NEO-FFI assessed the Big 5 dimensions of personality. Choice reaction time was used to control for changes in speed of processing with increased age. Age remained a significant predictor of both dependent variables, with neuroticism and agreeableness also showing predictive ability. Aerobic fitness was not associated with either outcome measure, suggesting that there might be differential effects of exercise on measures of different executive functions. Personality factors appear to have a stronger association with the cognitive function that has been reported previously.

Keywords

Older Adults, Problem Solving, Executive Functions, Personality, NEO-FFI

1. Introduction

Engaging in regular exercise has increasingly been recognized as important in maintaining a sense of well-being, good general health, and a reduced risk of various forms of disease including cardiovascular disease, diabetes, osteoporosis, and osteoarthritis [1]. At the same time, Bauman, Bellow, Vita, Brown and Owen [2] reported that about half the adult Australian population had activity levels that were insufficient to achieve those health benefits. They also estimated that direct health care costs related to inactivity were in excess of Au$400 million annually and that inactivity was contributing to more than 8000 excess deaths per year. Several factors, including age and gender, are associated with engaging in exercise with lower levels of exercise among older adults and

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women [3].

Regular exercise contributes in a number of ways to good health in later life [4], both physically and psychologically. Among the physical benefits of endurance training are better cardiovascular function and reduced risk of heart disease, hypertension, diabetes, and colon cancer. Similarly, strength training helps offset losses in muscle mass and strength, while regular weight-bearing exercise can improve bone strength, reduce the risk of osteoporosis, and improve postural stability, thus reducing the risk of falling. Psychological benefits of exercise include reduced depression, improved personal control and self-efficacy, and preserved cognitive functioning [5]-[7]. Rhodes *et al.* [8] examined 27 cross-sectional and 14 longitudinal studies in older adults and found that educational level and exercise history correlated positively with regular exercise, while perceived frailty and poor health were the greatest barriers. Self-efficacy, perceived social support, and attitudes towards exercise were also correlated with regular exercise. Rhodes, Pfaeffi, and Acevedo [9] updated the earlier review with broadly similar conclusions, which now included the personality trait of conscientiousness. In terms of physical activity and cognition, the earlier meta-analysis of Colcombe and Kramer [10] reported that the largest effect sizes for the association of cognition with fitness levels were on executive-control processes, which were usually exemplified by complex tasks requiring shifting attention, problem solving, and inhibition and selection among competing responses. They concluded that exercise was one of the more reliable means to maintain or improve cognitive function in later life.

Information processing speed and problem-solving ability are the main cognitive functions that generally deteriorate with increasing age [11]. At the same time, not all individuals show significant deterioration in cognitive functioning, and it may be that these individuals maintain good cognitive functioning through regular exercise. However, starting to exercise presents challenges for those previously sedentary. Boyette *et al.* [12] concluded that health status, past exercise participation, and education were the most important factors in initiating an exercise program, while higher socio-economic status in addition to better health status and positive previous exercise history were important in maintaining regular exercise activity in later life [13].

Increasing age is accompanied by reduced cortical thickness and numbers of neurons in dorsolateral frontal cortex [14]. Age differences were found in performance on tests associated with functioning of this cortical area: the Wisconsin Card Sorting Test, Self-ordered Pointing, and Delayed Response tasks, but not on tests sensitive to ventromedial prefrontal functioning, such as fluency tests. Kramer *et al.* [15] reported that aerobic exercise selectively improved executive processes. In a review of 18 intervention studies, Colcombe and Kramer [10] reported that aerobic fitness training had the largest benefits for executive control processes, while Etnier, Nowell, Landers, and Sibley [16] reported on the influence of the length of the training, duration of training sessions and gender of participants. Of relevance to our study, Sanchez-Benavides *et al.* [17] used the Tower of London task to assess problem solving and found links between left prefrontal cortical thickness and solution time on this test. The frontal cortex contains several interacting systems, including those that involve personality functions as well as cognitive processes [18]. There are suggestions that personality characteristics are among the factors to influence participation in exercise, with some research suggesting that extroverts are more comfortable in group activities and exercise more regularly then do introverts [19]. Courneya and Hellsen [20] found that extraversion and conscientiousness were positively related to regular exercise, whereas neuroticism was negatively correlated. Rhodes and Courneya [21] narrowed the link between regular exercise and extraversion to the activity facet of extraversion rather than to greater socialization.

We hypothesized that personality factors would add to the predictive role of physical activity level for cognitive performance on a problem solving task in a sample of older adults that varied widely in the amount of regular exercise. The cognitive function of interest in this study is that of planning and task monitoring, which in turn relies upon the activation of the dorsolateral prefrontal cortex. Based on previous research [20], we predicted that neuroticism would be negatively associated with performance on the Tower of London, while extraversion and conscientiousness would be positively associated. We also expected that the personality measures would add to the prediction of Tower of London scores over the baseline level provided by the exercise measures.

2. Methods

2.1. Participants

The 65 participants (35 females) ranged in age from 60 to 86 years (Mean 67.2 years, *SD* = 6.02). Following approval by the James Cook University Human Research Ethics Committee, they were recruited from the local

University of the Third Age, older members of a local running club, and from among the older associates of the second author. Other participants were recruited through advertisements placed in local newsletters.

The sample was highly educated, with over 40% having a tertiary education, and another 40% had completed secondary education. The remainder was divided equally between those with primary education and those with a trade qualification. Just over 40% were classed as professional or management, 26% as clerical/administrative, 15% as trades, and the remaining 15% as other. Over 80% of the sample (n = 53) engaged in some level of regular exercise. The mean number of hours spent exercising per week was 5.7 (*SD* = 4.75, range 0 to 19.5). Over half of the sample (n = 36) said they had been exercising regularly for more than 25 years.

2.2. Materials

A short questionnaire was devised to obtain demographic information and current level and type of exercise activity. This asked how much time per week was spent exercising, nature of the exercise, amount of smoking, and alcohol use. Metabolic Equivalents (METs) were estimated using tabled information from the National Center for Chronic Disease Prevention and Health Promotion [22] to classify the exercises as light, moderate, and vigorous physical activity. Light physical activity (e.g., lawn bowls) was rated as equivalent to 2.5 METs, moderate activity (e.g., walking) to 4.5 METs, and vigorous activity (e.g., jogging or running) to 7 METs. The appropriate number of METS for the activity level was then multiplied by the number of hours per week that the participant engaged in that level activity to give a physical activity index for each participant that included both frequency and intensity.

The NEO FFI [23] was used to assess the Big 5 major domains of personality: Neuroticism, Extraversion, Openness to experience, Agreeableness, and Conscientiousness. This validated and reliable 60-item measure was selected to tap the five widely recognized domains of personality. Problem-solving ability was assessed using the Tower of London test [24] from the computerized Colorado Assessment Test (CATS) [25], which requires sequential movements of disks on pegs that are governed by rules, thus requiring both planning of future moves and monitoring of those completed. . This version of the test was used because of its portability and better standardization over the traditional version with a board and pegs. It has trials starting from three pegs and three balls increasing to five balls and five pegs over 21 trials, plus one practice trial. A starting position and a target are provided on the screen and the participant uses the computer mouse to select and move the balls. Scores are the number of excess moves over the minimum number of moves required to solve each trial (errors), and the time required to complete all trials. There was no time limit imposed. Control of overall slowing of cognitive processing speed was accomplished through measurement of choice reaction time also taken from CATS. In the choice reaction time test, the participant is to press one key on the computer game controller in response to arrows pointing in one direction, and another key if the arrow on the screen points in the opposite direction. A series of 32 trials is given, with equal numbers of left and right responses required in each of the four blocks of eight responses. These two instruments were administered on a laptop computer, using a conventional mouse and computer game controller for responses.

2.3. Procedure

Testing was completed by appointment at the participants' homes. Informed consent was first obtained, and then the demographic questionnaire, NEO-FFI, reaction time and Tower of London tests were administered in that order. Brief instructions were provided to those participants who had not used a computer or game controller before, and no one reported significant difficulty with the computer control devices.

2.4. Statistical Analysis

Prior to conducting the main analysis of hierarchical regression, the data were checked for outliers that might show undue influence in some analyses. One participant had scores on the two Tower of London measures lowered to 3 standard deviations above the sample mean. Two hierarchical multiple regressions were calculated, both of which included estimated METs per week, mean choice reaction time, age, and gender as predictors at the first level and the five NEO-FFI scores at the second-level. The first analysis was completed with time to completion of the Tower of London as the dependent variable, and the second analysis used the number of excess moves (errors) as the dependent variable.

3. Results

Table 1 reports means and standard deviations for the exercise data by age group, while **Table 2** reports means and standard deviations for the main variables of the study as well as their correlations with one another. **Table 1** shows that a high proportion of the sample exercises regularly for several hours of the week.

Table 3 reports the results of the two regression analyses. With both dependent variables, the first level analysis was statistically significant, with the addition of the NEO FFI scales significantly increasing the amount of variance accounted for at the second level, as predicted by our third hypothesis. For time to completion, $R^2 = 0.309$ ($F = 6.61$, 4, 60 *df*, $p < 0.001$) for the first level of predictor variables. The increase in the value of R^2 was statistically significant when the NEO-FFI scores were added at the second-level ($R^2 = 0.434$, $F = 4.69$, 9, 55 *df*, $p < 0.001$). For the number of excess moves, $R^2 = 0.263$ ($F = 5.36$, 4, 60 *df*, $p = 0.001$) for the first set of predictors, and with the addition of the NEO-FFI scores, the increase in the variance accounted for R^2 was also statistically significant ($R^2 = 0.373$, $F = 3.64$, 9, 55 *df*, $p = 0.001$). Our first hypothesis concerning Neuroticism was partially supported, with the NEO FFI Neuroticism scale associated with the number of moves. Contrary to the second hypothesis, there were no associations for Conscientiousness, but the Agreeableness scores were associated with both Tower of London measures.

In order to determine whether the results could alternatively be attributed to better problem-solving ability being associated with cardiovascular fitness, a second set of multiple regression analyses were run using the Tower of London scores as predictors, and estimated METs per week as the dependent variable. For time to solve, the final regression was not statistically significant ($R^2 = 0.201$, $F = 1.76$, 8, 56 *df*, $p = 0.106$). With num-

Table 1. Regularity of exercise and metabolic equivalents across age groups.

Age Group	Regular Exercise (%)	Hours per Week	Estimated MET Level
60 - 64	78.6	6.25	35.95
65 - 69	75	5.91	32.89
70 - 74	91.7	5.65	28.5
75 - 79	85.7	5.29	25.79
80 - 86	100	3.5	15.75

Table 2. Means, standard deviations and inter correlations of measures used.

Variable	Mean	Standard Deviation	2	3	4	5	6	7	8	9	10
Age (years)	67.2	6.07	0.43	−0.18	0.48	0.48	0.14	−0.2	−0.15	0.22	−0.07
2 Reaction Time (seconds)	837.7	237.96	--	−0.08	0.3	0.44	0.04	−0.31	−0.21	−0.1	−0.4
3 MET Level	32.1	29		--	0.01	−0.07	−0.11	0.36	0.16	−0.04	0.23
4 Excess Moves	18.7	16.7			--	0.72	0.23	−0.01	−0.02	0.29	−0.1
5 Time to Complete (seconds)	631	359.21				--	0	−0.07	0.05	0.32	−0.22
6 NEO FFI N	45.1	8.44					--	−0.22	0.15	−0.19	−0.07
7 NEO FFI E	49.9	9.68						--	25	0.17	0.22
8 NEO FFI O	51.6	11.29							--	−0.08	0.01
9 NEO FFI A	54.2	10.02								--	0.09
10 NEO FFIC	50.2	9.71									

Note: NEO FFI: NEO Five Factor Inventory; N—Neuroticism, E—Extraversion, O—Openness to Experience, A—Agreeableness; C—Conscientiousness. Correlations > 0.25 are significantly different from zero at 0.05 and those > 0.325 are significantly different from zero at 0.01 with 60 *df*.

Table 3. Final results of hierarchical regression analyses for time to complete and number of excess moves on Tower of London task.

Variable	Time to Complete			Excess Moves		
	Beta	Probability	*t*	Beta	Probability	*t*
Step 1:		$R^2 = 0.309$			$R^2 = 0.263$	
Estimated METs	0.013	0.942	0.11	0.096	0.424	0.81
Reaction time	0.322	0.023	2.34*	0.19	0.196	1.31
Age	0.318	0.012	2.60*	0.354	0.008	2.76*
Gender	−0.035	0.754	−0.32	−0.018	0.878	−0.15
Step 2:		$R^2_{Change} = 0.125$			$R^2_{Change} = 0.110$	
Neuroticism	−0.036	0.746	−0.33	0.252	0.034	2.17*
Extraversion	0.004	0.975	0.03	0.107	0.403	0.84
Openness to Experience	0.202	0.072	1.84	0.021	0.859	0.18
Agreeableness	0.301	0.009	2.69*	0.267	0.027	2.27*
Conscientiousness	−0.105	0.37	−0.9	−0.048	0.698	−0.39

Note: *−$p < 0.05$; Total $R^2 = 0.434$, adjusted $R^2 = 0.342$ for Time to Complete; Total $R^2 = 0.373$, adjusted $R^2 = 0.271$ for Excess Moves.

ber of excess moves as the criterion variable, the regression also failed to reach statistical significance (R^2 = 0.195, F = 1.69, 8, 56 *df*, p = 0.121).

4. Discussion

Age, and not measures of physical activity, proved to be the best single predictor of cognitive performance in terms of both the variables of time to complete and number of excess moves, contrary to our hypothesis. The measure of physical activity that was used is based on self-reported regular exercise activity and not fitness as directly assessed. Nonetheless, the results here are consistent with previous reports [26] [27]. Unlike intervention studies, however, the current results are based upon self-reported, often habitual patterns of exercise and not shorter-term exercise interventions with individuals who are otherwise sedentary. Reaction time, a common measure of information processing speed, was also a significant predictor for completion time. This result is consistent with the many reports of slower processing speed being associated with increasing age (see Salthouse [11] for a review).

As predicted, the addition of the personality scores increased the predictability of both the measures of problem solving. The personality characteristic of Neuroticism proved to be significantly associated with the number of errors completed on the Tower of London, as predicted. While such results have not been widely reported before for performance on cognitive tasks, some similar findings have been reported. For example, only older adults showed correlations between NEO FFI Neuroticism scores and poorer performance on the Iowa Gambling Test [28]. In general, decisions made under conditions of heightened affect, as are likely in people scoring high on Neuroticism measures, are likely to be less optimal decisions [29], although the relationship is not simple and is a function of the particular bias used [30] Interestingly, Agreeableness proved to be the only personality characteristic to be a significant predictor of both cognitive measures, contrary to the expectations from the literature that Extraversion and Conscientiousness would be predictive. In both cases, the association with Agreeableness was positive, implying that higher levels of Agreeableness were associated with both longer completion times and more errors. While Agreeableness tends to increase with increasing age [31], its relationship with cognitive performance in this study was unexpected. Clearly future research should explore these issues in more depth.

Among the limitations of the study, it must be acknowledged that the present sample is not representative of the general population of older adults. In addition to all being volunteers, the sample was above average in education, was generally socially active and a high proportion of them were well above average in terms of the degree of exercise in which they regularly engaged. As a group, however, they would be more expected to show a link between cardiovascular fitness and cognitive ability than a less selected sample. A moderation analysis of the relationship between personality and fitness may have allowed stronger inferences. Future research could adopt that approach. The sample is also smaller than is desirable for a regression analysis [32]. The relative magnitude of the regression weights reported in **Table 3** suggests, however, that even doubling the sample size would not result in major differences.

Alternative methods of assessing physical activity may have led to different results. The resources available for the study did not permit the use of cardiac stress tests to obtain VO_2 max values, but as an example, the Rockport Walking Test [33] might have provided different estimates and is a simple, validated measure of activity that also does not assess maximal aerobic capacity.

The results of this study, in which only a dozen participants did not exercise at all, cannot be seen as providing support for other reports that regular exercise is associated with less cognitive decline associated with aging [34] [35]. However, many other studies have reported significant improvements in cognitive functioning in association with regular aerobic exercise [36] [37]. Convincing evidence is also provided by other research, such as that by Yaffe, Barnes, and Nevitt [38], who found exercise to have a significant protective effect on cognitive functioning in a longitudinal study of several thousand older adults. More evidence for the benefits of exercise on brain functioning is seen in the MRI research [10] [17], which showed robust reductions in tissue density as a function of age in the frontal, parietal, and temporal cortices; but also substantially reduced tissue loss in these areas in individuals with greater levels of fitness.

5. Conclusion

In conclusion, these results are consistent with the extensive body of research showing declines in performance on complex cognitive tasks with increasing age. Cardiovascular fitness did not appear significant in the prediction of either measure of executive function from the Tower of London task, whereas processing speed was associated with completion time. At the same time, Neuroticism and Agreeableness were shown to be significantly associated with performance on a problem-solving task. This implies that additional factors may be important for adequate performance in later life in addition to those traditionally associated with cognitive aging.

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