

Exploring the factor on sensory motor function of upper limb associated with executive function in community-dwelling older adults

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ABSTRACT

Exercise, such as cardiovascular fitness training, has been shown to have utility in improving executive function but is difficult for older adults with low mobility to perform. Accordingly, there is interest in the development of regimens other than high mobility exercises for older adults with low mobility. The aim of the present study was to evaluate the association between sensory motor function of the upper limb and executive function in community-dwelling older adults. A cross-sectional study was conducted in 57 right-handed, independent, community-dwelling older adults. Sensory motor function of upper limb, including range of motion, strength, sensation, finger dexterity, and comprehensive hand function was measured in both hands. Executive function was assessed using the Delta Trail Making Test. Multiple regression analysis indicated the finger dexterity of the non-dominant hand as independently associated with executive function ($\beta = -0.414$, $P < 0.001$). The findings of the present study may facilitate the development of exercise regimens for improving executive function that are more suitable for older adults with limited physical fitness levels. As this was a cross-sectional study, further studies are required to validate the efficacy of non-dominant finger dexterity training for improving executive function in older adults.

Key Words: aged, dexterity, executive function, hand, trail making test

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INTRODUCTION

As the proportion of older adults in the general population of Japan is the highest of any country in the world,¹⁾ strategies for maintaining the health of older adults are particularly important. Executive function, a type of cognitive ability, is particularly affected by aging.²⁾ Executive function encompasses skills such as planning, task coordination and multitasking, working memory, inhibitory controls, and decision-making.³⁾ Executive function plays an important role in the ability of individuals to function independently.^{3, 4)} Moreover, executive function associates with falls and serious fall-related injuries in older adults.^{4, 5)} Therefore, it is important for older

Received: February 15, 2016; accepted: May 27, 2016

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adults to maintain or improve their executive function.

The results of a recent meta-analysis indicated that exercises such as cardiovascular fitness training and resistance training had the greatest effect on executive processes in healthy older adults.⁶ However, these exercises require participants to be highly mobile. Older adults with low mobility may have difficulty deriving the maximum benefit of these exercises due to limited locomotive ability.⁷ Thus, regimens other than high mobility exercises are necessary to improve executive function in older adults with low mobility.

A previous study reported a greater decline in finger dexterity in individuals with mild cognitive impairment.⁸ Further, patients with Alzheimer's disease have been shown to have a greater decline in gross hand function compared with neurologically-intact controls.⁹ Thus, various functions of the upper limb, such as finger dexterity, sensation, and grip strength, may be related to executive function. However, the association between sensory motor function of the upper limb and executive function has yet to be elucidated. As hand activities can be performed in a sitting position, even older adults with low mobility are able to perform hand activities. The evaluation of the association between sensory motor function of the upper limb and executive function is important for the development of management strategies aimed at slowing the progression of executive function decline in older adults.

The aim of the present study was to evaluate the association between sensory motor function of the upper limb and executive function in community-dwelling older adults. We consider that the present study provides useful information on intervention to improve executive function.

MATERIALS AND METHODS

Participants

A cross-sectional study was conducted to examine the association between sensory motor function and executive function in community-dwelling older adults. Participants were recruited from a community group at a community center in Gifu, Japan. Approximately 90% of participants in the community group were females. Participants were community-dwelling older adults with independent ambulation. Inclusion criteria were as follows: (1) age 65 years or older; (2) no neurological disease associated with hand impairment; (3) no previous trauma or fracture to the upper extremity or advanced hand osteoarthritis; and (4) right-handedness as assessed by the Edinburgh Handedness Inventory. All study participants provided written informed consent. The institutional review board at the Seijoh University approved the present study.

Demographic and Health Related Information

Demographic and health related data including age, sex, global cognition, and depression were evaluated at the initiation of the present study. Global cognition was assessed using the 30-point Mini-Mental State Examination (MMSE). As depression has been shown to be associated with poor executive function,¹⁰ symptoms of depression were assessed using the Geriatric Depression Scale (GDS).

Sensory Motor Function and Executive Function Assessment

A detailed examination of sensory motor function of upper limb was performed in both the dominant and non-dominant hands of all study participants.

Reduced range of motion of the wrist may put older adults at a greater risk of developing cumulative trauma disorders.¹¹ Wrist joint flexion was measured using a standard goniometer.

The lateral pinch is the most commonly used grip bilaterally.¹² Lateral pinch strength was

measured using a pinch gauge (B&L Engineering, Santa Ana, CA, USA) with participants seated, shoulders adducted to 0 degrees, and elbows flexed to 90 degrees. Lateral pinch measurements were recorded as the average of two repetitions in kilograms (kg).

Grip strength was measured using a Smedley-type hand-held dynamometer (Matsumiya Ika Seiki Seisakusho Co., Ltd., Tokyo, Japan) with participants seated, shoulders adducted, and elbows extended to 0 degrees. Grip strength measurements were recorded as the average of two repetitions in kg.

Hand sensation was measured using the Moberg pick-up test.¹³⁾ The Moberg pick-up test was performed by asking participants to pick up small objects using their fingers and placing them into a box as fast as possible with eyes closed. Participant performances were timed with a stopwatch.

Finger dexterity was measured using the Purdue Pegboard test (Lafayette Instrument Co., Lafayette, USA). The Purdue pegboard is a test of finger dexterity that has been widely used in clinical settings.¹⁴⁾ It consists of a board with four cups across the top and two vertical rows of 25 small holes down the center. Participants were instructed to place as many pins as possible in the vertical columns of holes on a board within 30 seconds. Pins were placed in the dominant and non-dominant hand, and scores were recorded as the number of pegs placed in 30 seconds.

The Jebsen–Taylor hand function test (Jebsen test) was used to comprehensively evaluate hand function. The Jebsen Test is a commonly-used, standardized test for assessing functional hand use.¹⁵⁾ The Jebsen Test is comprised of seven tasks that reflect ADL, including writing, simulated page turning, picking up small common objects, simulated feeding, stacking checkers, picking up large light objects, and picking up large heavy objects.¹⁶⁾ However, as writing is highly dependent on hand dominance, the writing task component was not included in the present study.¹⁷⁾ The time required to execute each task was measured. Results were reported as the sum of the time taken to complete the six tasks.

Executive function was assessed using the Trail Making Test (TMT). The TMT consists of two parts. TMT-A requires the individual to draw lines sequentially connecting 25 encircled numbers distributed on a sheet of paper. Task requirements are similar for TMT-B, except the person must alternate between numbers and letters (e.g., 1, A, 2, B, 3, C, etc.).¹⁸⁾ To control for the effect of motor function of the upper limb and information processing speed, delta TMT (Δ TMT) times was calculated by subtracting the time to perform part A from the time to perform part B. The Δ TMT times is considered a more accurate measure of executive function than the performance of Part B alone.¹⁹⁾ The time required to execute the TMT-A and B tests were measured. The maximum amount of time allowed to complete the TMT-B was 600 seconds.²⁰⁾ Participants that exceeded the 600 seconds limit for TMT-B were excluded from the study analysis.

Statistical Analyses

Data were collected and analyzed using SPSS ver. 21.0 (SPSS Inc., IBM Company, Tokyo, Japan). Pearson's correlation coefficients were used to investigate the associations between Δ TMT times and dependent measures. A stepwise multivariate linear regression model, with elimination of variables with P-values < 0.10, was used²¹⁾ to evaluate the association between sensory motor function of the upper limb and executive function. Δ TMT times was entered as a dependent variable. Sensory motor function variables, age, gender, MMSE score and GDS score, were entered as independent variables.

RESULTS

A total of 70 older adults with a mean age of 83.9 years (standard deviation [SD], 5.7 years) participated in the present study. However, 13 participants exceeded the 600 seconds limit for the performance of TMT-B and were excluded from the study analysis. The final sample consisted of 57 people with a mean age of 84.0 years (SD, 5.4 years). Participant demographics and executive and sensory motor functions are presented in Table 1. There were no missing data in the present study. The mean (SD) Δ TMT was 178.6 (\pm 105.6) seconds. In correlation analyses, Δ TMT times were found to be significantly correlated with finger dexterity in dominant ($r = -0.266$, $P = 0.046$) and non-dominant hands ($r = -0.480$, $P < 0.001$), MMSE scores ($r = -0.348$, $P = 0.008$), and age ($r = -0.313$, $P = 0.018$). There was no significant correlation with GDS ($r = 0.096$, $P = 0.479$), degrees of flexion in the wrist joint for the dominant ($r = -0.196$, $P = 0.144$) and non-dominant hands ($r = -0.225$, $P = 0.093$), pinch strength in the dominant ($r = -0.080$, $P = 0.555$) and non-dominant hands ($r = -0.083$, $P = 0.538$), grip strength in the dominant ($r = -0.141$, $P = 0.295$) and non-dominant hands ($r = -0.220$, $P = 0.100$), and the hand sensation in the dominant ($r = 0.157$, $P = 0.244$) and non-dominant hands ($r = 0.134$, $P = 0.320$). Table 2 shows the factors found to be significantly associated with Δ TMT times according to stepwise multiple regression analysis. Non-dominant finger dexterity ($\beta = -0.414$, $P = 0.001$) was the only factor that remained significantly correlated with executive function in the final model.

DISCUSSION

The findings of the presents study demonstrate sensory motor function of the upper limb factor is correlated with executive function, and finger dexterity of the non-dominant hand, cognition using MMSE, and age are associated with decreased executive function according to Δ TMT times. In addition, multiple regression analysis indicated that the finger dexterity of the non-dominant hand as independently associated with executive function.

Although there is a lack of data regarding the correlation between dexterity and executive function in healthy older adults, Ashendorf *et al.*²²⁾ reported that the performance on a pegboard test was associated with executive function, which was corroborated by the results of the present study. The purdue peg board test evaluates the ability of individuals to place as many pins as possible in the vertical columns of holes on a board within 30 seconds. Low finger dexterity scores may be due to cognitive delay rather than finger dexterity. However, if cognitive delay rather than finger dexterity has a greater effect on Δ TMT times, the results of the Jebsen test and Moberg pick up test measuring motor speed in the same manner as the purdue peg board test may also be significantly associated with Δ TMT times.

Additional brain regions are required to accurately perform a new motor task with the non-dominant hand.²³⁾ The initial phases of motor skill learning are associated with widespread activation in the prefrontal cortex, which has been associated with executive function.²⁴⁾ As participants do not routinely use their non-dominant hand in skilled tasks of daily living, a non-dominant hand motion would involve the initial phases of motor skill learning. Therefore, it may difficulty for participants with reduced activation of the prefrontal cortex to perform skilled finger dexterity using their non-dominant hand. These reasons may explain the finding that non-dominant finger dexterity may be associated with executive function in community-dwelling older adults.

Physical exercise improves executive function, in addition to physical performance, in older adults.²⁵⁾ However, physical exercise requires whole body motion. These types of exercise may be difficult for frail older adults or those with hip and knee joint osteoarthritis or who have recently

Table 1 Demographic and health-related information, Sensory motor function of the upper limb, and executive function of study participants

Characteristics	n = 57
Age, years, mean \pm SD	84.0 \pm 5.4
Gender (females), %	89.5
MMSE score, mean \pm SD	26.0 \pm 3.0
GDS score, mean \pm SD	4.4 \pm 2.7
TMT-A, seconds, mean \pm SD	77.6 \pm 26.6
TMT-B, seconds, mean \pm SD	256.2 \pm 124.3
Δ TMT, seconds, mean \pm SD	178.6 \pm 105.6
Flexion degrees of wrist joint, mean \pm SD	
Dominant	48.7 \pm 12.8
Non-dominant	49.0 \pm 12.4
Pinch strength, kg, mean \pm SD	
Dominant	4.4 \pm 1.0
Non-dominant	4.2 \pm 1.0
Grip strength, kg, mean \pm SD	
Dominant	17.5 \pm 5.1
Non-dominant	16.2 \pm 5.1
Hand sensation, seconds, mean \pm SD	
Dominant	31.2 \pm 10.6
Non-dominant	29.7 \pm 9.5
Finger dexterity, number, mean \pm SD	
Dominant	11.0 \pm 2.8
Non-dominant	10.3 \pm 2.3
Comprehensive hand function, seconds, mean \pm SD	
Dominant	32.5 \pm 6.3
Non-dominant	34.6 \pm 6.2

SD, standard deviation; MMSE, Mini-Mental State Examination; GDS, Geriatric Depression Scale; TMT, Trail Making Test

Dominant indicates right hand, and Non-dominant indicates left hand.

Table 2 Factors associated with executive function by stepwise multiple regression analysis

Factor	β	P-value	R ²	F
Non-dominant finger dexterity	-0.414	0.001	0.341	10.657
MMSE	-0.338	0.003		
Age	0.192	0.097		

MMSE, Mini-Mental State Examination

experienced a hip fracture. On the other hand, many older adults with low physical mobility may be able to perform activities for finger dexterity because assessment of these activities can be performed in a sitting position. The findings of the present study may aid the development of future exercise regimens for improving executive function, which may be more suitable for older adults with limited levels of physical fitness.

The present study had some limitations. First, the limited sample size provided an insufficient capability to examine multiple outcomes and interactions between predictors. A large cohort study is required to fully elucidate predictors contributing to executive function. Second, the present study was a cross-sectional study. Therefore, further studies are required to confirm the mechanisms underlying the executive function for non-dominant hand dexterity and the efficacy of finger dexterity training for improving executive function. Third, the sample predominantly included women. Although it has been reported that gender was not significantly correlated with TMT scores while assessing executive function,¹⁸⁾ this may limit the ability to generalize our findings to community-dwelling older adults. Finally, global cognition that was assessed using MMSE in the present study was high. Because the finger dexterity of the non-dominant hand in older people changes based on cognitive function,²⁶⁾ the association between finger dexterity and executive function that was found in this study may be different in older people with moderate or severe Alzheimer's disease. Therefore, further studies are required to confirm the difference in the association between finger dexterity and executive function according to the degree of cognitive function decline. In conclusion, the association between sensory motor function of the upper limb factor and executive function in community-dwelling older adults has yet to be fully elucidated. The results of the present study demonstrate non-dominant finger dexterity as independently associated with executive function. Further studies are required to fully elucidate the mechanisms underlying the effect of executive function on non-dominant hand dexterity and evaluate the efficacy of non-dominant finger dexterity training for improving executive function in older adults.

ACKNOWLEDGEMENTS

This work has been supported by the Grant-in Aid for Research from Seijoh University.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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