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Original Article

Coordination performance and falls history among elderly with mild cognitive impairment

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Abstract

The objectives of the study were to compare coordination and falls history between elderly subjects with mild cognitive impairment (MCI) and without MCI and to determine the correlation between coordination and falls among the elderly with MCI. The recruited participants were 28 elderly people with MCI and 28 elderly people without MCI. Falls and coordination measured by the Nine Hole Peg Test (NHPT) and Foot Tapping (FT) were investigated. Significant differences were found in coordination measured by the NHPT and FT between the elderly participants with and without MCI. Higher numbers of fallers were found in the group of participants with MCI compared with the other group. Coordination measured by FT was significantly correlated with falls history in the MCI group. Declining coordination could be one factor contributing to falls in a population compared to elderly people without MCI. Foot Tapping should be included as a routine assessment for individuals with MCI.

Keywords: coordination, falls, elderly, mild cognitive impairment

1. Introduction

Mild cognitive impairment (MCI) is typically defined as predementia or middle stage between normal cognitive function and dementia (Roberts & Knopman, 2013; Stephan *et al.*, 2013). Even though most symptoms of MCI present as cognitive impairments, impaired physical performance was also reported among people with MCI (Ansai *et al.*, 2017; Borges, Radanovic, & Forlenza, 2015a; Delbaere *et al.*, 2012; De Paula *et al.*, 2016; Franssen, Souren, Torossian, & Reisberg, 1999; Harlein, Dassen, Halfens, & Heinze, 2009; Kawa, Bednorz, Stępień, Derejczyk, & Bugdol, 2017; Kluger *et al.*, 1997; Makizako *et al.*, 2013; Schroter *et al.*, 2003; Seijo-Martinez, Cancela, Ayan, Varela, & Vila, 2016; Yan, Rountree, Massman, Doody, & Li, 2008) which could constitute factors that increase the risk of falls in the population (Ansai *et al.*, 2017; Borges *et al.*, 2015a). A related study reported that people with MCI had 1.72 times higher chance of falls compared with generally older people (Delbaere *et al.*, 2012). Only a few studies have investigated the risk of falls in people with MCI (Allali & Verghese, 2017; Ansai *et al.*, 2017; Bortoil, Piovezan, Piovesan, & Zonta, 2015; Delbaere *et al.*, 2012; Liu-Ambrose, Ashe, Graf, Beattie, & Khan, 2008; Muir, Gopaul, & Montero Odasso, 2012). Of those few studies, impaired balance, mobility, and gait performance were reportedly associated with a higher risk of falls in the population. Altered coordination was also found to be a risk factor contributing to falls in older people (Harlein, Dassen, Halfens, & Heinze, 2009) since coordination is an important component that contributes to activities or task performances. In addition, arm coordination was found to be associated with performance to postural adjustment after external perturbations (Nam, Kim, & Lim, 2017), and effective balance control performance requires intact coordination movement (Horak, 1997). Moreover, stepping strategy is one of the important movement strategies used to prevent falls or loosing balance

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in situations with great perturbation (Dijkstra, Horak, Kamsma, & Peterson, 2015; Horak, 2006). Coordination performance declines among the elderly population both in upper and lower extremities compared with younger adults (Guan & Wade, 2000). Only a few studies have investigated coordination among older people with MCI. The results of the studies demonstrated that people with MCI moved slower and less smoothly (De Paula *et al.,* 2016; Franssen *et al.,* 1999; Kawa *et al.,* 2017; Kluger *et al.,* 1997; Schroter *et al.,* 2003; Yan *et al.,* 2008). However, most of the studies assessed only fine hand coordination (De Paula *et al.,* 2016; Kawa *et al.,* 2017; Schroter *et al.,* 2003; Yan *et al.,* 2008) but not foot coordination. Foot coordination abilities could be part of static balance (ankle strategy) and dynamic balance (foot clearance) (Blenkinsop, Pain, & Hiley, 2017; Dionyssiotis, 2012) including the ability to use a 'Stepping' strategy to prevent falls while standing (Dijkstra, Horak, Kamsma, & Peterson, 2015; Horak, 1997; Horak, 2006). Foot tapping contains the elements of speed of repeated movements and the studies demonstrated high levels of inter-rater/intra-rater reliability (Gunzler, Pavel, Koudelka, Carlson, & Nutt, 2009). Little is known about the correlation between coordination and falls in the elderly population with MCI. A better understanding of coordination impairment in the elderly population with MCI would help in developing effective fall prevention interventions.

2. Materials and Methods

The study employed a cross-sectional study design and was approved by the human research ethics committee of Thammasat University (COA No.179/2559), in accordance with the Declaration of Helsinki and all participants (and their caregivers when applicable) signed an informed written consent form.

2.1 Participants

Participants were community dwelling elderly people aged ≥60 years and able to walk independently without any gait aids for at least 10 meters. The Montreal Cognitive Assessment (MoCA-Thai version) (add one point if ≤12 years education) revealed scores from 17–21/30 in the MCI group, and scores from 22–30/30 in the non-MCI group (Freitas, Simoes, Alves, & Santana, 2013). In the MCI group, the diagnosis of amnestic MCI (aMCI) was defined using Petersen's five criteria (Petersen *et al.,* 2001): 1) subjective memory complaints/declines/deficits; 2) objective memory impairment adjusted by matching age and education related healthy cognitive function; 3) normal general cognitive function; 4) ability to perform activities of daily living; and 5) no dementia. The exclusion criteria were in three parts. Part I was a diagnosis of dementia or having Mini-Mental State Examination-Thai (MMSE-Thai 2002) score <14/23 and older people who had not graduated from any school; <17/30 and older people who studied in elementary school; and <22/30 and older people who completed elementary school (Thai Cognitive Test Development Committee 1999, 2002). Part II was a diagnosis of cognitive dysfunction apart from MCI, or a diagnosis of depression classified by Thai Geriatric Depression Scale (TGDS-15) (Wongpakaran, Wongpakaran, & Van Reekum, 2013). Part III was having knee proprioception sense impairment.

The sample size was calculated from this formula:

$$n = [(r+1)/r] \times [(\sigma^2 (Z_\beta + Z_{\frac{\alpha}{2}})^2)/(difference)^2]$$

with an error of 5%, power of 80% and a mean difference of foot tapping from a previous study in MCI (Kluger *et al.,* 1997). The total number of participants in both groups totaled 56 subjects: 28 with MCI and 28 without MCI.

2.2 Procedure of the study

Potential participants were screened to exclude the following conditions: 1) depressive conditions screened by Thai geriatric depression scale (TGDS), 2) dementia screened by MMSE, and 3) knee proprioception impairment by digital inclinometer. The participants were classified into two groups, MCI and non-MCI, by the MoCA and Petersen's criteria. The participants were asked personal and medical information, level of physical activity, and falls history in the previous 12 months, i.e. number, causes and direction of falls. In the non-MCI group, the participants were matched to the participants with MCI for age (±5 years old), sex, and education level.

Each participant was assessed for fine coordination using the Nine-Hole Peg Test (NHPT). The participants were instructed to sit in a chair, lean against the backrest, and place their forearm on the table. The examiner asked the participants to pick up the pegs and put them in the holes until the holes were all filled and then remove the pegs out of the board and return them to the container as fast as possible. The participants performed the test twice with each hand. The total time of each hand was recorded. The total time of both hands was used for the data analysis (De Paula *et al.,* 2016).

The Foot Tapping test (FT) was used to measure foot coordination. The participants were instructed to seat in a chair without an armrest, lean against the backrest, and tap their foot as much as possible within five sec. Each foot was tested separately. Participants performed three trials for each foot. The average number of taps tested for a total of six trials (both sides) were recorded and classified in seven levels: 1 = twenty taps, 2 = 16 to 19 taps, 3 = 13 to 15 taps, 4 = 9 to 12 taps, 5 = 5 to 8 taps, 6 = 1 to 4 taps, and 7 = unable to perform (Franssen *et al.,* 1999).

Test-retest reliability of coordination assessments was examined prior to commencement of the study. Fifteen healthy adults were examined 1 week apart and the intra-rater reliability results for the NHPT and FT were 0.948 and 0.830, respectively.

2.3 Statistical analysis

All data were analyzed using the SPSS, Version 20. The Mann-Whitney U test was used to determine the statistical difference of coordination between the two groups. The chi-square test was used to determine the difference of experiencing falls between the two groups. In addition, point-biserial correlation was used to measure the correlation between coordination and falls among the elderly with MCI.

3. Results

3.1 Participant characteristics

The recruited participants were 28 elderly individuals with MCI and 28 elderly individuals without MCI and the ages ranged from 60 to 80 years. Participants in both groups were matched for age, sex, and level of education. Table 1 gives the participant characteristics of both groups. No significant differences were found between the two groups for most of the characteristics. However, work status, MMSE, the MoCA, and depression scale revealed significant differences between the two groups ($P \leq 0.05$).

3.2 Falls history

Falls history including number of fallers, number of falls, cause of falls, direction of falls, injuries of falls, and locations where falls occurred were recorded and compared between the two groups of elderly people with and without MCI. The elderly participants with MCI presented a higher number of fallers and reported a greater number of falls ($P \leq 0.05$) compared with the elderly participants without MCI (Table 2).

3.3 Coordination assessment

Table 3 presents the comparison of coordination measures between the two groups. The results showed significant differences regarding coordination measured by both the NHPT and FT ($P \leq 0.01$). Correlation results between coordination performance and falls history (faller and non-faller) among the elderly participants with MCI are shown in Table 4. A significant correlation (low level) was found between falls history and coordination measured by FT (r=0.399, $P \leq 0.05$), but no correlation was observed between falls history and coordination measured by NHPT.

4. Discussion

This study investigated coordination performance and falls history between elderly people with and without MCI and correlation of coordination and falls history of the elderly people with MCI. Significant differences were found in work status, scores of the MMSE-Thai, the MoCA-Thai, TGDS-15, coordination measures (NHPT and FT), and falls history in the previous 12 months. In addition, a significant correlation was observed between FT and falls history among the elderly with MCI.

Table 1. Characteristics of the elderly participants with and without mild cognitive impairment.

Characteristics variable	Elderly with MCI (n=28)	Elderly without MCI (n=28)	P-value
Age	67.71±5.97	67.39±5.80	0.84[b]
Gender: Female, n (%)	17 (60.7)	17 (60.7)	1.00[a]
Marital status & family, n (%)			
- Single	1 (3.6)	1 (3.6)	
- Married	17 (60.7)	21 (75)	0.70[a]
- Divorced	2 (7.1)	1 (3.6)	
- Widow	8 (28.6)	5 (17.9)	
Education level, n (%)			
- No education	1 (3.6)	1 (3.6)	
- Elementary school (grade 1-3)	0 (0)	0 (0)	
- Elementary school (grade 4-6)	23 (82.1)	23 (82.1)	1.00[a]
- Junior high school	0 (0)	0 (0)	
- Senior high school	1 (3.6)	1 (3.6)	
- Bachelor's degree	2 (7.1)	2 (7.1)	
- Master's degree or Doctor of Philosophy	0 (0)	0 (0)	
Work status: Working, n (%)	2 (7.1)	8 (28.6)	0.04[a*]
Hand dominant: Right side, n (%)	24 (85.7)	26 (92.9)	0.34[c]
Weight (kilogram)	62.72±14.03	61.25±10.66	0.95[b]
Height (centimeter)	159.42±10.33	159.04±7.91	0.84[b]
BMI (kg/m^2)	24.68±5.25	24.39±4.98	0.96[b]
Number of medical conditions, median (range)	1 (0–2)	1 (0–3)	0.16[b]
Number of medications, median (range)	1 (0–4)	1 (0–5)	0.10[b]
PASE (hr/week)	39.83±16.99	45.03±22.38	0.43[b]
MMSE-Thai	25.79±2.27	27.61±1.69	<0.01[b**]
MoCA-Thai	18.82±1.34	24.82±2.29	<0.01[b**]
TGDS-15	2.82±1.34	2.07±1.61	0.04[b*]

Data are presented as mean±SD unless indicated otherwise.
SD = standard deviation, BMI = body mass index, PASE = physical activity scale of elderly Mini mental state examination –Thai version (MMSE) and Montreal cognition assessment–Thai version (MoCA) have maximum score =30, Thai geriatric depression scale (TGDS-15) has maximum score = 15. Statistical analysis: [a] = Pearson Chi-square test, [b] = Mann Whitney U test, [c] = fisher exact test. Significant difference between two groups at ** $P \leq 0.01$, * $P \leq 0.05$

Table 2. Comparisons of falls history between elderly participants with and without mild cognitive impairment.

Falls history	Elderly with MCI (n=28)	Elderly without MCI (n=28)	P-value
Number of fallers	9 (32.2)	2 (7.1)	0.02[b*]
Number of falls in previous 12 months, median (range)	0 (0–4)	0 (0–1)	0.02[c*]
Cause of recent falls [a]			
- Collapsed	0 (0)	0 (0)	
- Stumbled	4 (45)	1 (50)	
- Dizzy or loss of conscious	0 (0)	0 (0)	0.89[b]
- Fell down	0 (0)	0 (0)	
- Slipped	5 (55)	1 (50)	
Direction of recent falls [a]			
- Left	2 (22)	1 (50)	
- Right	2 (22)	0 (0)	0.17[b]
- Front	3 (34)	1 (50)	
- Back	2 (22)	0 (0)	
Injuries of falls [a]			
- No injury	3 (33)	1 (50)	
- Bruise	4 (45)	1 (50)	0.12[b]
- Bone fracture	2 (22)	0 (0)	
Area of fall [a]			
- Indoor	4 (45)	2 (100)	0.06[b]
- Outdoor	5 (55)	0 (0)	

Data are presented as n (%) unless indicated otherwise.
Statistical analysis: [a] = Number of participants (elderly with MCI (n=9) and elderly without MCI (n=2), [b] = Pearson Chi-square test, [c] = Mann Whitney U test. Significant difference between two groups at * P≤0.05

Table 3. Comparison of coordination performance between elderly participants with and without mild cognitive impairment.

Coordination performance	Elderly with MCI (n=28)	Elderly without MCI (n=28)	P-value
Nine Hole Peg Test [a] (seconds)	93.37±11.87	85.09±9.87	<0.01 **
Foot Tapping [b] (scores level)	4 (3–5)	4 (1–5)	<0.02 **

Statistical analysis: Mann Whitney U test, [a] = performed twice with each hand, total time of both sides and [b] = performed three times with each foot, average number of taps of six trials (both sides). Significant difference between two groups at ** P≤0.01, * P≤0.05

Table 4. Correlation between coordination and falls history among elderly with mild cognitive impairment.

Correlation coefficient (*r*)	Falls history
Nine Hole Peg Test	0.231
Foot Tapping	0.399*

Statistical analysis: point-biserial correlation. Significant correlation between two groups at * P≤0.05

Findings of the current study revealed that the group of elderly participants with MCI presented a higher number of fallers and reported a higher number of falls in the previous 12 months compared with the group of elderly without MCI. The results were consistent with a related study on the incidence of falls in the MCI group. The study reported that the MCI group presented a higher risk of falls compared with the elderly people without MCI (Delbaere *et al.,* 2012). These results were similar to results from two related studies (Ansai *et al.,* 2017; Borges *et al.,* 2015a). The increased number of fallers and number of falls among the elderly with MCI in the study by Borges and colleagues (Borges *et al.,* 2015a) as well as the current study was possibly due to decreased balance performance. The decreased balance performance when performing the Timed Up-and-Go test in single and dual tasks among the elderly with MCI reported in those studies could consequently lead to a higher prevalence of falls (Borges *et al.,* 2015a; Borges *et al,* 2015b). Montero-Odasso (Montero-Odasso, 2017) explained that the elderly with cognitive impairment would have declined attention and executive function required for maintaining balance and performing normal gait. Therefore, relationships were found among cognitive impairment, dementia, gait change, and falls risk (Yogev-Seligmann *et al.,* 2008). Related studies also gave evidence that the incidence of falls in the MCI group was consistent with the severity of cognitive impairment (Borges *et al.,* 2015a; Seijo-Martinez *et al.,* 2016).

In our study, the NHPT was used to measure upper limb coordination. Significant differences were found between the MCI and non-MCI groups. The MCI group took longer to perform the test than the elderly participants without MCI. A study by De Paula and colleagues (De Paula *et al.,* 2016) assessed fine coordination performance using the NHPT among people with MCI. Their results were consistent with the current study in that the multiple-domain aMCI group was slower than the healthy control group (De Paula *et al.,* 2016). The reason could be partly explained because multiple brain regions are linked for great performance of coordination timed tasks. The connection could be interrupted among people with cognitive impairment (Sun *et al.,* 2014) who present with poor coordination performance in terms of speed and accuracy (Scheller *et al.,* 2013). Moreover, the study by De Paula and colleagues (De Paula *et al.,* 2016) also showed that participants with Alzheimer's disease were significantly slower compared with aMCI and healthy control groups. These would support the findings that fine movement would decline among elderly people with MCI and lead to greater progress in dementia.

No significant correlation was observed between the NHPT and falls history. One possible explanation could be because the NHPT measures fine movement as well as coordination of the upper extremities while the incidence of falls tends to be more related to lower extremity function compared with upper extremity function. However, a related study demonstrated that arm coordination could present a relationship with balance due to the possibility that arm coordination could be associated with performance related to posture correction or postural adjustment in circumstances involving external perturbations (Fasano, Plotnik, Bove, & Berardelli, 2012). De Paula and colleagues (De Paula *et al.,* 2016) reported a correlation between NHPT and self-care activities of daily living results among people with MCI. This could imply that NHPT could exhibit an indirect relationship to balance performance particularly in situations requiring postural adjustment.

FT is used to measure lower limb coordination. In this study, the elderly participants with MCI took longer to perform the test compared with the elderly participants without MCI. Few studies have assessed coordination using FT among people with MCI (Franssen *et al.,* 1999; Kluger *et al.,* 1997). The results of the current study were similar to the results from the study by Franssen and colleagues (Franssen *et al.,* 1999) which revealed significant differences between the MCI and the non-cognitive impairment groups. The similar results were possibly due to similarities between the two studies, i.e. eligibility criteria of participants in the MCI group as well as the method used to assess FT which was counting the number of steps performed within 5 sec. Cai and colleagues (Cai, Chan, Yan, & Peng, 2014) explained that participants with MCI have decreased general plasticity and a delayed central nervous system process leading to a decline in limb coordination and balance performance. However, one related study by Kluger and colleagues (Kluger *et al.,* 1997) used the FT speed test and found no significant differences between cognitively normal elderly individuals and those in the MCI group. One possible explanation for the different results could be dissimilar measurements. That study measured FT speed within 15 sec with a total number of taps of both sides, while the current study measured within 5 sec with the average number of taps of both sides which was changed to a score level.

A significant correlation was found between FT and falls history among the elderly with MCI. Since coordination abilities could be part of balance and falls risk factors among elderly people (Dionyssiotis, 2012), the current results could imply that coordination, measured by FT, influenced balance performance and consequently increased falls risk.

The results of coordination and falls history in the current study together with related studies (Ansai *et al.,* 2017; Borges *et al.,* 2015a; De Paula *et al.,* 2016; Franssen *et al.,* 1999) provided evidence that not only the memory domain would be affected in particular aMCI, but other cognitive functions, i.e. attention and executive function, could possibly be altered (McGough *et al.,* 2011; Yogev-Seligmann *et al.,* 2008), which could result in decreased coordination performance and contribute to a higher risk of falls.

In addition, impaired lower extremity coordination can result from several possible impairments, especially power of the dorsiflexor muscle or muscle around the foot (Zajac, Neptune, & Kautz, 2002, 2003). Furthermore, efficient activation of the dorsiflexor muscle is important for foot clearance and ankle strategy to maintain balance (Dijkstra, Horak, Kamsma, & Peterson, 2015; Horak, 2006). Therefore, the FT score level correlated with the history of falls.

Our current study had limitations. The study classified participants in the MCI group using Petersen's criteria, which includes only aMCI but does not cover all subtypes of MCI, i.e. aMCI: single or multiple domains and non-aMCI: single or multiple domains. In addition, this study employed a cross-sectional study design. The present study compared coordination and falls history between two groups at one moment in time and the assessor was not blinded to the groups of participants. Further studies should be conducted using a longitudinal study design to provide information concerning the impact of the changes among the elderly with and without MCI.

5. Conclusions

The results of this study presented significant differences in coordination measures between elderly people with and without MCI. The elderly participants with MCI took longer to perform the NHPT and revealed a lower number of taps of the FT test compared with the results of the elderly without MCI. Additionally, the current study showed a higher number of fallers in the group of elderly participants with MCI.

The elderly participants with MCI had lower coordination performance compared with older people without MCI. An assessment of coordination as well as falls risk prevention should be considered in the clinical screening of people with MCI which may partly assist in the prevention of falls in this population.

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