Cognitive function in middle-aged and older adults participating in synchronized swimming-exercise

ETSUKO MAESIMA, MD, PhD\textsuperscript{1,2)*}, YUKA OKUMURA, MSc\textsuperscript{2}, JURI TATSUMI, MSc\textsuperscript{3}, SAYAKA TOMOKANE, MSc\textsuperscript{1}, AKIKO IKE SHIMA, MSc\textsuperscript{3}

\textsuperscript{1) Department of Health and Sport Management, Osaka University of Health and Sport Sciences: 1-1 Asashirodai, Kumatori-cho, Sennan-gun, Osaka 590-0496, Japan
\textsuperscript{2) Graduate School of Health and Sport Sciences, Osaka University of Health and Sport Sciences, Japan
\textsuperscript{3) Institute of Liberal Arts, Otemon Gakuin University, Japan

Abstract. [Purpose] The purpose of the present study was to examine cognitive function in middle-aged and older adults regularly engaging in synchronized swimming-exercise. [Subjects and Methods] Twenty-three female synchronized swimmers ranging in age from 49 to 85 years were recruited for the present study. The duration of synchronized swimming experience ranged from 1 to 39 years. The control group consisted of 36 age- and gender-matched community-dwelling middle-aged and older adults (age range: 49 to 77 years). Cognitive function was evaluated using the Japanese version of the Montreal Cognitive Assessment (MoCA-J) and compared between the synchronized swimmers and control participants. [Results] No significant differences in mean total MoCA-J scores were observed between the synchronized swimmers and control participants (23.2 ± 3.1 and 22.2 ± 3.6, respectively). Twenty-nine subjects in the control group and 17 in the synchronized swimming group scored below 26 on the MoCA-J, indicative of mild cognitive impairment. Significant differences in delayed recall—but not in visuospatial/executive function, naming, attention, language, abstraction, or orientation—were also observed between the two groups. [Conclusion] The results of the present study suggest that synchronized swimming has beneficial effects on cognitive function, particularly with regard to recent memory.

Key words: Synchronized swimming, Cognitive function, Montreal Cognitive Assessment

INTRODUCTION

The number of older adults affected by dementia has been rising significantly in Japan and a number of other countries\textsuperscript{1,2). Mild cognitive impairment (MCI)\textsuperscript{3–6} is considered to be a preclinical stage of dementia. Studies have revealed that approximately 10% to 15% of people with MCI progressed to dementia annually\textsuperscript{7–9). In order to reduce the number of people who experience cognitive dysfunction, it is important to delay, or even reverse, the progression of MCI to dementia. Dementia is common in individuals of advanced age. While aging is regarded as the greatest risk factor for cognitive dysfunction\textsuperscript{10), several studies have indicated that habitual exercise and physical activity may have a beneficial effect on the prevention of dementia\textsuperscript{11–15).}

A wide variety of exercises, such as walking, have been recommended for older adults in efforts to maintain and promote health. Aquatic exercises in particular are recommended for older adults with obesity and osteoarthritis\textsuperscript{16–18). One such aquatic exercise regimen is synchronized swimming, which is suitable for older adults, as the swimmer may stand on the floor of a shallow pool\textsuperscript{19).}}
While a number of studies have indicated that land-based exercise exerts a beneficial effect on cognitive function in older adults\(^{11-14}\), no studies to date have examined the effect of synchronized swimming on cognitive function in older adults. We examined cognitive function in middle-aged and elderly synchronized swimmers.

### SUBJECTS AND METHODS

The study participants were recruited from among 23 women practicing synchronized swimming-exercise at a sport club in Fukushima-ku, Osaka City, Japan (SS group). All participants provided written informed consent, after having gained a full understanding of the present study. The study was approved by the ethics committee of the Osaka University of Health and Sport Sciences (approval number 15-21).

Synchronized swimming was performed in a shallow pool from 1.2 to 1.3 meters in depth and the participants were allowed to touch the bottom of the pool with their hands and feet during the performance. Participants who had participated in the Olympic Games or the domestic competitions for seniors were excluded. Participants practiced synchronized swimming twice a week for 90 minutes under the supervision of an instructor, who had been a member of the Japanese synchronized swimming team. The ages of participants in the SS group ranged from 49 to 85 years (mean age: 69.8 ± 11.6 years), and the duration of synchronized swimming experience ranged from 1 to 39 years (mean year: 23.9 ± 12.6 years).

Control participants were recruited age-matching women with exercise custom other than synchronized swimming. They were 36 individuals participating in a health promotion program at our university in 2015, and provided written informed consent as controls (age range: 49–77 years; mean age: 67.0 ± 6.0 years). Among the participants in the control group, 16 participants exercised three or four times a week, 17 exercised once or twice a week, and 3 exercised one to three times a month. In addition, three participants engaged in aquatic exercises other than synchronized swimming.

Cognitive functions was compared between the two groups using the Japanese version of the Montreal Cognitive Assessment (MoCA-J)\(^{20}\). The MoCA is a brief cognitive test containing test items related to memory, language, executive function, working memory (attention), visuospatial recognition, abstract thinking, and orientation\(^{21}\). The sensitivity and specificity of the MoCA-J in screening for MCI has been demonstrated\(^{20}\). The assessment takes only approximately 10 minutes to complete, and a number of studies have demonstrated the effectiveness of MoCA-J as a screening tool for MCI\(^{21-23}\). The maximum MoCA-J score is 30. Total scores of less than 26 points may be indicative of mild cognitive impairment.

Information on the presence of neurological disease, psychiatric disease, alcoholism, and hospitalization was collected via an interview. None of the participants in either group exhibited any such history.

Results are expressed as the mean ± SD. Unpaired t-tests were used to compare results between the SS group and control group when data were normally distributed, while U tests were performed when the data were not normally distributed. Two-sided p values of <0.05 were considered to indicate a statistically significant difference. Statistical analyses were performed using SPSS Statistics ver. 23.0.

### RESULTS

No significant differences in education level were observed between the control and SS groups (12.1 ± 2.0 and 12.2 ± 1.8 years, respectively). In addition, no significant differences in total MoCA-J scores were observed between the two groups (22.2 ± 3.6 and 23.2 ± 3.1, respectively). Twenty-nine participants in the control group and 17 in the SS group scored below 26 on the MoCA-J and were suspected of having MCI (Table 1). With regard to MoCA-J sub-scores, significant differences in delayed recall (p=0.005) were noted between the two groups. However, no significant differences were observed with regard to measures of but not in visuospatial/executive function, naming, attention, language, abstraction, or orientation (Table 2).

### DISCUSSION

No significant differences in years of education or total MoCA-J scores were observed between the SS group and the control group in the present study. The results of total MoCA-J scores in the present study align with those of a previous
report involving 1,552 participants (mean age: 72 years; Mini-Mental State Examination score ≥24 points) living in Sasaguri, Fukuoka Prefecture, in which mean the MoCA-J score was 22.4 ± 3.024). However, in the comparison of MoCA-J sub-score in the present study, delayed recall scores, which are considered indicative of recent memory function, were significantly higher in the SS group than in the control group.

Suzuki et al.25) conducted an exercise-based intervention program that included exercise, calculation, word-chain game, and multiple tasks using a ladder diagram program (90 minutes two times per week for 6 months) with participants aged 65 years or older experiencing MCI. Significant differences in Mini-Mental State Examination, Wechsler Memory Scale-Logical Memory I, Word Fluency Test-category, and Word Fluency Test-letter scores were observed following this intervention. In synchronized swimming, participants must swim and act in a coordinated manner with other swimmers while performing to music. In other words, the swimmers are required to perform multiple coordinated tasks in an aquatic setting to be more complex than those of the multicomponent exercise program developed by Suzuki et al.25). We speculated engaging in those tasks exerted positive effects on memory function. Moreover, it has been reported that group music intervention delayed the deterioration of cognitive function, particularly short-term recall among aging adults with mild and moderate dementia.26) Performing to music in synchronized swimming might be one of the reason that delayed recall scores were significantly higher in the SS group than in the control group.

Voelcker-Rehage et al.22) reported that not only physical fitness, as indexed by cardiovascular fitness and muscular strength, but also aspects of motor fitness, such as movement speed, balance, motor coordination, and flexibility exhibit associations with executive control and perceptual speed. They further demonstrated physical and motor fitness to be differentially related to various cognitive processes using functional brain magnetic resonance imaging. Given that most synchronized swimmers exhibit good cardiopulmonary function, muscle strength, and flexibility27), it is also possible that enhanced physical fitness may exert direct positive effect on cognitive function.

According to a report by Suzuki et al.28), 12 months of multicomponent exercise significantly improved cognitive function in older adults with amnestic MCI. In particular, positive effects were observed for general cognitive function, immediate memory, and language ability. We therefore consider that synchronized swimming exerted beneficial effects on cognitive function in the participant who experienced synchronized swimming for one year.

In conclusion, the results of the present study suggest that synchronized swimming may improve cognitive function in older adults, particularly with regard to recent memory.

Conflict of interest
No relevant disclosures.

ACKNOWLEDGEMENT

This study was supported in part by Kumatori Town, Osaka, Japan.
REFERENCES

1) McCurry J: Japan will be model for future super-ageing societies. Lancet, 2015, 386: 1523. [Medline] [CrossRef]

2) Prince M, Bryce R, Albanese E, et al.: The global prevalence of dementia: a systematic review and metaanalysis. Alzheimers Dement, 2013, 9: 63–75.e2. [Medline] [CrossRef]

3) Petersen RC, Smith GE, Waring SC, et al.: Mild cognitive impairment: clinical characterization and outcome. Arch Neurol, 1999, 56: 303–308. [Medline] [CrossRef]

4) Petersen RC: Mild cognitive impairment as a diagnostic entity. J Intern Med, 2004, 256: 183–194. [Medline] [CrossRef]

5) Winblad B, Palmer K, Kivipelto M, et al.: Mild cognitive impairment—beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. J Intern Med, 2004, 256: 240–246. [Medline] [CrossRef]

6) Ganguli M, Snitz BE, Saxton JA, et al.: Outcomes of mild cognitive impairment by definition: a population study. Arch Neurol, 2011, 68: 761–767. [Medline] [CrossRef]

7) Bruscoli M, Lovestone S: Is MCI really just early dementia? A systematic review of conversion studies. Int Psychogeriatr, 2004, 16: 129–140. [Medline] [CrossRef]

8) Mitchell AJ, Shiri-Feshki M: Rate of progression of mild cognitive impairment to dementia—meta-analysis of 41 robust inception cohort studies. Acta Psychiatr Scand, 2009, 119: 252–265. [Medline] [CrossRef]

9) Petersen RC, Doody R, Kurz A, et al.: Current concepts in mild cognitive impairment. Arch Neurol, 2001, 58: 1985–1992. [Medline] [CrossRef]

10) Bonaconsa M, Colavito V, Pifferi F, et al.: Cell clocks and neuronal networks: neuron ticking and synchronization in aging and aging-related neurodegenerative disease. Curr Alzheimer Res, 2013, 10: 597–608. [Medline] [CrossRef]

11) Larson EB, Wang L, Bowen JD, et al.: Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. Ann Intern Med, 2006, 144: 73–81. [Medline] [CrossRef]

12) Verdelho A, Madureira S, Ferro JM, et al. LADIS Study: Physical activity prevents progression for cognitive impairment and vascular dementia: results from the LADIS (Leukoaraiosis and Disability) study. Stroke, 2012, 43: 3331–3335. [Medline] [CrossRef]

13) Ottenbacher AJ, Snih SA, Bindawas SM, et al.: Role of physical activity in reducing cognitive decline in older Mexican-American adults. J Am Geriatr Soc, 2014, 62: 1786–1791. [Medline] [CrossRef]

14) Ihara M, Okamoto Y, Hase Y, et al.: Association of physical activity with the visuospatial/executive functions of the montreal cognitive assessment in patients with vascular cognitive impairment. J Stroke Cerebrovasc Dis, 2013, 22: e146–e151. [Medline] [CrossRef]

15) Laurin D, Verreault R, Lindsay J, et al.: Physical activity and risk of cognitive impairment and dementia in elderly persons. Arch Neurol, 2001, 58: 498–504. [Medline] [CrossRef]

16) cadmus L, Patrick MB, Maciejewski ML, et al.: Community-based aquatic exercise and quality of life in persons with osteoarthritis. Med Sci Sports Exerc, 2010, 42: 8–15. [Medline] [CrossRef]

17) Lim JY, Tchai E, Jang SN: Effectiveness of aquatic exercise for obese patients with knee osteoarthritis: a randomized controlled trial. PM R, 2010, 2: 723–731, quiz 793. [Medline] [CrossRef]

18) Gaught AM, Carneiro KA: Evidence for determining the exercise prescription in patients with osteoarthritis. Physiotherapy, 2013, 41: 58–65. [Medline] [CrossRef]

19) Tanaka M, Tanaka C, Kitagawa K: Differing effects of aquatic movement in either deep or shallow water on the physical responses among middle-aged, female and recreational synchronized swimmers. Jpn J Phys Fit Sports Med, 2015, 64: 357–365. [CrossRef]

20) Fujiwara Y, Suzuki H, Yasunaga M, et al.: Brief screening tool for mild cognitive impairment in older Japanese: validation of the Japanese version of the Montreal Cognitive Assessment. Geriatr Gerontol Int, 2013, 22: e146–e151. [Medline] [CrossRef]

21) Raji MA, Kuo YF, Snih SA, et al.: Cognitive status, muscle strength, and subsequent disability in older Mexican Americans. J Am Geriatr Soc, 2005, 53: 1462–1468. [Medline] [CrossRef]

22) Voelcker-Rehage C, Godde B, Staudinger UM: Physical and motor fitness are both related to cognition in old age. Eur J Neurosci, 2010, 31: 167–176. [Medline] [CrossRef]

23) Lee JY, Cho SJ, Na DL, et al.: Brief screening for mild cognitive impairment in elderly outpatient clinic: validation of the Korean version of the Montreal Cognitive Assessment. J Geriatr Psychiatry Neurol, 2008, 21: 104–110. [Medline] [CrossRef]

24) Narazaki K, Matsuo E, Honda T, et al.: Physical fitness measures as potential markers of low cognitive function in Japanese community-dwelling older adults without apparent cognitive problems. J Sports Sci Med, 2014, 13: 590–596. [Medline] [CrossRef]

25) Suzuki T, Shimada H, Makizako H, et al.: A randomized controlled trial of multicomponent exercise in older adults with mild cognitive impairment. PLoS One, 2013, 8: e61483. [Medline] [CrossRef]

26) Chu H, Yang CY, Lin Y, et al.: The impact of group music therapy on depression and cognition in elderly persons with dementia: a randomized controlled study. Biol Res Nurs, 2014, 16: 209–217. [Medline] [CrossRef]

27) Troup IP: The physiology and biomechanics of competitive swimming. Clin Sports Med, 1999, 18: 267–285. [Medline] [CrossRef]

28) Suzuki T, Shimada H, Makizako H, et al.: Effects of multicomponent exercise on cognitive function in older adults with amnestic mild cognitive impairment: a randomized controlled trial. BMC Neurol, 2012, 12: 128. [Medline] [CrossRef]