Effects of Cognitively-Loaded Physical Exercise on the Cognitive Function and Physical Health in Older Adults with Mild Cognitive Impairment

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인지부하 신체운동이 경도인지장애가 있는 노인의 인지기능과 신체건강에 미치는 효과

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Abstract

Objective

Mild cognitive impairment (MCI) is characterized by a mild decline in cognitive function and the risk of progression to severe cognitive disorders, such as Alzheimer's disease. Exercise and dual-task training may be an effective method for enhancing cognitive function. This study investigated the effects of cognitively-loaded physical exercise (CLPE) on the cognitive function and physical health of individuals with MCI.

Methods

Fifty-one aged 60 years or older with MCI were randomly assigned to 30-minute CLPE (30CLPE, n=17), 60-minute CLPE (60CLPE, n=17), and control (n=17) groups. The CLPE program consisted of a twice-weekly exercise program for eight weeks. During the exercise, a dual task was performed to assess cognitive load. The control group performed a typical exercise program at a dementia center during the same period. The Korean version of the Montreal Cognitive Assessment was used to assess cognitive function and a handgrip dynamometer and pinch gauge were used to assess grip strength. The Senior Fitness Test assessed participants' physical fitness. Dynamic and static balance abilities and spatiotemporal gait variables were assessed.

Results

Significant improvements in cognitive function, upper limb strength, senior fitness, balance, and gait were observed in both the 30CLPE and 60CLPE groups. No outcome variables were significantly different between the 30CLPE and 60CLPE groups. No significant change was observed in the control group.

Conclusions

Dual-task training may improve cognitive and physical function in individuals with MCI. The results underscore the importance of maintaining exercise within an individual's manageable timeframe rather than a set time limit.

1. Introduction

Mild cognitive impairment (MCI) is a complex clinical syndrome characterized by declines in memory and cognitive functions.1 MCI is considered an intermediate stage between normal aging and dementia, with a risk of progressing to serious cognitive disorders, such as Alzheimer's disease.[1-4] Considering these risks, appropriate management of people with MCI is very important for the early detection of the disease and establishment of appropriate treatment strategies. Managing this condition in an aging society can have implications for maintaining healthy aging and reducing societal costs.

MCI is managed using both pharmacological and non-pharmacological treatments. Currently, approved drugs are effective in delaying the progression of certain types of dementia, especially Alzheimer's disease, but their overall effectiveness remains limited.[5,6] In addition, there is insufficient evidence that other pharmacological interventions, including over-the-counter supplements, improve cognitive function.[7,8] In contrast, non-pharmacological treatments can play an important role in managing the symptoms and improving the quality of life of patients with MCI. In particular, exercise interventions have attracted attention as promising non-pharmacological treatments for people with MCI.[9-11] Physical exercise has known benefits

regarding physical control, function, mood, and cardiovascular health and is a therapeutic intervention in rehabilitation programs that may enhance neuroplastic processes.[12-15] Resistance exercises have been shown to improve memory function and neuroplasticity in people with MCI.[16-19]

The dual-task approach involves simultaneous performance of physical activity and cognitive tasks. Dual-task training may be an effective treatment strategy for patients with MCI. This method simultaneously activates different brain areas, strengthens neural circuit connections and promoting neuroplasticity.[20] Consequently, it can promote the interaction between cognitive and physical functions and improve cognitive abilities. Specifically, these neurobiological changes can contribute to improvements in critical cognitive areas such as attention, memory, and problem solving, as well as increase blood flow to the brain and improve communication between nerve cells. Previous studies have shown that dual-task training positively affects cognitive function, gait, and balance.[21,22] Additionally, it has been reported that dual-task training can produce more significant gains in verbal fluency, endurance, and muscle strength in people with MCI than simple exercise.[23] These results indicate that the dual-task approach has the potential to be used as an important factor in maintaining and improving cognitive function.

Studies have reported the effectiveness of cognitively-loaded physical exercise (CLPE), which combines cognitive tasks and exercise, in people with MCI. However, studies have shown different results regarding the intensity and frequency of exercise required to improve cognitive abilities in older individuals, and there is no consensus on the optimal exercise intervention method.[24,25] Specific guidelines on the type of training and appropriate training time and duration in these programs still need to be developed.[26,27] Accordingly, this study aimed to investigate the effect of combining exercise and cognitive tasks on the cognitive function and physical health of people with MCI, and to determine the difference that exercise time makes to these effects. This study aimed to propose more effective management and treatment approaches for patients with MCI

2. Methods

2.1 Participants

Participants were recruited by posting a notice for the study at a dementia center in Seoul. The recruits were community residents aged 60 years with MCI. The notice clearly described the purpose of the study, conditions for participation, an overview of the research process, and the benefits of participating in the study. Individuals with the following conditions were excluded from the study: 1) serious physical condition; 2) serious health problems, including cardiovascular, respiratory, or musculoskeletal conditions; or 3) severe mental illness. Volunteers were screened using the Korean version of the Montreal Cognitive Assessment (MoCA-K). Volunteers with MoCA-K scores below the cut-off point (24 points) were eligible to participate in the study.28,29 This study was approved by the Institutional Review Board of Gachon University (1044396-202108-HR-175-02) and enrolled in the Clinical Research Information Service, which complies with the World Health Organization International Clinical Trials Registry Platform (registration number: KCT0009053).

The participants were assigned to three groups using a stratified randomization method. These groups comprised the 30-minute CLPE (30CLPE), 60-minute CLPE (60CLPE), and control groups.

2.2 Intervention

The CLPE program used in this study was designed to simultaneously improve participants' physical ability and cognitive function. All participants performed the exercise program under the direction of a physical therapist.

The CLPE program comprised warm-up, main, and cool-down exercises. The warm-up and cool-down exercises consisted of full-body stretching of the neck, shoulders, and lower back, and the main exercises consisted of muscle strength and balance exercises (Table 1). Exercises were performed at progressively increasing intensities each week (Table 2).

Stretching exercises are designed to relax the muscles, improve mobility, and increase body temperature. The main exercises focused on improving strength and balance, specifically targeting the core and lower-extremity muscles.

The cognitive task consisted of counting the number of movements in various ways while the participants performed the exercises (Table 3).

The control group also performed exercises twice a week for eight weeks. The control group performed a typical exercise program at a dementia center. The exercise program consisted of stretching, stationary cycling, and walking on a treadmill, performed at the individual's preferred intensity for 30 minutes. Stretching was performed for 5 min at the beginning and end of

the program. Cycling and walking were performed for 10 min each. A physical therapist instructed and managed stretching, cycling, and walking.

2.3 Measurements

2.3.1 Cognitive function

This was assessed using the MoCA-K.[28,29,32] The MoCA-K consists of 30 questions that evaluate eight cognitive domains: short-term memory, visuospatial abilities, executive functions, attention, concentration, working memory, language, and orientation to time and place. The total score is 30 points, and the cutoff score is 24 points. The MOCA-K has a sensitivity of > 90% and a specificity of > 87% for detecting MCI.

2.3.2 Grip strength

Grip strength and pinch grip strength were measured using a Jamar handgrip dynamometer (JLW Instruments, Chicago, USA) and Jamar pinch gauge (Patterson Medical, Bolingbrook, USA) with an intra-rater reliability of 0.94–0.98.[33,34] The assessment was performed on a chair without armrests. All subjects kept their shoulders close to the trunk, elbows bent at 90°, and the lower arms in a neutral position. The wrist was placed in a comfortable position to create a fist (0–30° extension, 0–15° radial deviation). The maximum grasp power was recorded as the highest value among three repeated measurements. Each trial had a 30-second rest period, and measurements were recorded in kilograms (kg).

2.3.3 Physical fitness

The Senior Fitness Test (SFT) assessed physical fitness. SFT is a highly reliable test method for older adults with cognitive decline (ICC = 0.93–0.98).35 The SFT consists of six items: 1) lower-extremity strength test, 2) upper-extremity strength test, 3) agility and dynamic balance test, 4) lower-extremity flexibility test, 5) upper-extremity flexibility test, and 6) cardiorespiratory endurance test.

2.3.4 Balance

Dynamic balance was assessed using a Functional Reach Test (FRT). The FRT has been found to be a reliable method (ICC = 0.87).36 During this evaluation, the participants were upright with the shoulder joint flexed to 90º. Following the examiner's instructions, participants bent over and extended their arms as far forward as possible.

Static balance was assessed by using an AMTI AccuSway force plate (Advanced Mechanical Technology, Inc., Watertown, MA, USA). AccuSway is an evaluation instrument with high reliability (ICC = 0.70–0.89).[37]

2.3.5 Gait

Measurements of spatiotemporal gait variables were performed using GAITRite walkway (CIR Systems Inc, USA), which has high reliability (ICC = 0.90–0.99).38 Information on the center of pressure (pressure intensity, location, and time) was analyzed as spatiotemporal gait variables using GAITRite Platinum software (GAITRite Plus version 4.7, CIR System Inc.).

2.4 Data analysis

- SPSS statistical software (version 25.0; IBM Corp., Armonk, NY, USA)
- Shapiro–Wilk test : the normality of data
- One-way analysis of variance (ANOVA) : Distributions between groups
- 3 × 2 (group × time) ANOVA : differences in the main outcome variables between the groups (30CLPE group, 60CLPE group, and control group) and time (before and after the program).
- Paired t-test and one-way ANOVA : Post-hoc tests were performed using , and
- Tukey method :statistical values were corrected using the .
- Significance level : α = 0.05

3. Results

3.1 General characteristics

Variables	30CLPE (n = 17)	60CLPE (n = 17)	Control (n = 17)	p-value
Age (years)	71.95 ± 5.05	69.00 ± 5.62	70.94 ± 5.77	0.291
Sex (M/F)	3 / 14	2 / 15	3 / 14	0.862
Height (cm)	155.96 ± 6.26	154.32 ± 8.08	156.48 ± 6.00	0.634
Weight (kg)	61.90 ± 8.72	57.41 ± 8.54	59.43 ± 7.93	0.381
Body mass index (kg/m^2)	25.44 ± 3.19	24.06 ± 2.71	24.26 ± 2.85	0.349
Skeletal muscle mass (kg)	21.11 ± 3.28	19.31 ± 2.98	21.91 ± 3.42	0.114
Body fat mass (kg)	24.56 ± 6.75	21.22 ± 5.43	20.80 ± 4.49	0.192
Total body water (L)	28.95 ± 4.04	26.60 ± 3.67	29.48 ± 4.24	0.302
Systolic pressure (mmHg)	137.67 ± 10.36	131.18 ± 15.14	135.22 ± 10.48	0.138
Diastolic pressure (mmHg)	78.11 ± 7.05	73.41 ± 9.99	76.26 ± 6.52	0.275
Heart rate (bpm)	80.00 ± 10.04	77.29 ± 8.27	81.26 ± 7.69	0.315
MoCA-K (score)	22.15 ± 3.53	22.82 ± 3.40	21.00 ± 1.58	0.708

Data are presented as mean ± standard deviation or number.
30CLPE, 30-minute Cognitively-Loaded Physical Exercise group; 60CLPE, 60-minute Cognitively- Loaded Physical Exercise group; M, male; F, female; MoCA-K, Korean version of the Montreal Cognitive Assessment.

3.2 Cognitive function, Upper limb strength & Physical fitness

Variables	Pre	Post	Within *p*-value	Between *p*-value	G × T *p*-value	η^2_p
MoCA-K (score)						
30CLPE	22.24 ± 3.18	25.81 ± 3.03††	< 0.001			
60CLPE	22.82 ± 3.40	27.29 ± 2.57†††	< 0.001	0.001	< 0.001	0.31
Control	22.00 ± 2.15	22.02 ± 3.10	0.208			
Grip (kg)						
30CLPE	23.32 ± 6.78	25.21 ± 6.40	< 0.001			
60CLPE	21.17 ± 7.62	22.8 ± 8.07	< 0.001	0.452	0.134	0.08
Control	24.75 ± 5.58	25.44 ± 5.39	0.121			
Pinch (kg)						
30CLPE	6.38 ± 1.29	6.96 ± 1.20	0.001			
60CLPE	5.65 ± 1.10	6.38 ± 1.58	0.000	0.409	0.004	0.20
Control	6.80 ± 1.26	6.73 ± 0.90	0.987			
244 cm up & go (sec)						
30CLPE	9.02 ± 1.38	8.24 ± 1.33	< 0.001			
60CLPE	8.99 ± 1.72	7.79 ± 1.72	< 0.001	0.567	< 0.001	0.30
Control	8.49 ± 1.86	8.40 ± 2.07	0.100			
30-sec chair stand (n)						
30CLPE	17.58 ± 3.95	18.41 ± 4.02	0.553			
60CLPE	17.41 ± 6.09	23.65 ± 9.48†	< 0.001	< 0.001	0.009	0.30
Control	15.47 ± 4.96	16.75 ± 3.90	0.333			
Arm curl (n)						
30CLPE	23.46 ± 5.44	30.54 ± 5.85††	< 0.001			
60CLPE	25.53 ± 6.04	32.53 ± 6.48†††	< 0.001	< 0.001	< 0.001	0.36
Control	23.18 ± 7.06	22.87 ± 7.15	0.213			
2-min step walk (n)						
30CLPE	115.35 ± 17.82	127.61 ± 16.72††	< 0.001			
60CLPE	111.29 ± 21.58	124.06 ± 17.24††	< 0.001	< 0.001	0.016	0.24
Control	101.12 ± 20.78	99.63 ± 25.32	0.614			
Back scratch (cm)						
30CLPE	-14.73 ± 15.74	-9.15 ± 9.54	< 0.001			
60CLPE	-9.59 ± 10.82	-6.17 ± 8.51	0.012	0.541	0.016	0.16
Control	-9.12 ± 9.22	-9.05 ± 8.45	0.961			
Chair sit & reach (cm)						
30CLPE	15.26 ± 6.95	19.60 ± 9.05	< 0.001			
60CLPE	14.53 ± 5.29	19.93 ± 5.65	< 0.001	0.072	< 0.001	0.3
Control	14.03 ± 10.09	13.98 ± 9.56	0.718			

Data expressed mean ± standard deviation.
MoCA-K, Korean version of the Montreal Cognitive Assessment; 30CLPE, 30-minute Cognitively-Loaded

Variables	Pre	Post	Within *p*-value	Between *p*-value	G × T *p*-value	η^2_p
Static - EO sway area (mm^2)						
30CLPE	2.32 ± 0.89	1.50 ± 0.69	0.001			
60CLPE	2.21 ± 1.10	1.10 ± 0.63†	0.001	0.029	0.002	0.24
Control	2.05 ± 1.29	1.96 ± 1.27	0.653			
Static - EO sway velocity (cm/s)						
30CLPE	1.62 ± 0.37	1.43 ± 0.39	0.561			
60CLPE	1.45 ± 0.25	1.13 ± 0.23††	< 0.001	0.005	< 0.001	0.27
Control	1.61 ± 0.52	1.60 ± 0.54	0.051			
Static - EC sway area (mm^2)						
30CLPE	4.59 ± 2.37	2.89 ± 1.52	0.005			
60CLPE	4.12 ± 3.67	1.76 ± 0.74	< 0.001	0.105	0.028	0.14
Control	2.95 ± 2.58	2.82 ± 2.39	0.639			
Static - EC sway velocity (cm/s)						
30CLPE	2.39 ± 1.15	2.00 ± 0.70	0.001			
60CLPE	2.10 ± 1.01	1.68 ± 0.64	< 0.001	0.399	0.012	0.17
Control	2.15 ± 0.67	1.95 ± 0.73	0.957			
Dynamic - FRT (Ant) (cm)						
30CLPE	33.71 ± 4.92	37.78 ± 4.99	< 0.001			
60CLPE	33.50 ± 5.14	38.44 ± 4.83	< 0.001	0.581	0.002	0.22
Control	36.39 ± 9.29	36.20 ± 8.68	0.702			
Velocity (cm/s)						
30CLPE	105.18 ± 17.74	115.87 ± 17.26	0.001			
60CLPE	105.17 ± 15.13	116.86 ± 17.98	< 0.001	0.630	0.044	0.14
Control	108.52 ± 19.56	110.00 ± 20.78	0.169			
Cadence (steps/min)						
30CLPE	115.70 ± 10.65	112.74 ± 15.36	0.169			
60CLPE	110.98 ± 9.94	116.91 ± 10.94	0.007	0.646	0.013	0.16
Control	114.51 ± 10.97	113.86 ± 13.46	0.133			
Step length (cm)						
30CLPE	56.16 ± 7.22	61.10 ± 6.72	0.001			
60CLPE	56.86 ± 5.86	62.94 ± 5.60	< 0.001	0.551	0.012	0.17
Control	58.82 ± 10.30	58.93 ± 7.37	0.179			

Data expressed mean ± standard deviation.
EO, eye open; EC, eye closed; FRT, functional reach test; Ant, anterior; 30CLPE, 30-minute Cognitively-Loaded Physical Exercise group; 60CLPE, 60-minute Cognitively-Loaded Physical Exercise group; η^2_p, partial eta squared; †Significant difference compared to the control group, † = $p < 0.05$, †† = $p < 0.01$.

3.3 Balance & Gait

References

[1] Petersen RC, Lopez O, Armstrong MJ, Getchius TSD, Ganguli M, Gloss D, et al. Practice guideline update summary: Mild cognitive impairment: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. Neurology. 2018;90:126-135.

[2] Li JQ, Tan L, Wang HF, Tan MS, Tan L, Xu W, et al. Risk factors for predicting progression from mild cognitive impairment to Alzheimer's disease: a systematic review and meta-analysis of cohort studies. J Neurol Neurosurg Psychiatry. 2016;87:476-484.

[3] Lopez OL. Mild cognitive impairment. Continuum (Minneap Minn). 2013;19:411-424.

[4] Prestia A, Caroli A, van der Flier WM, Ossenkoppele R, Van Berckel B, Barkhof F, et al. Prediction of dementia in MCI patients based on core diagnostic markers for Alzheimer disease. Neurology. 2013;80:1048-1056.

[5] Langa KM, Levine DA. The diagnosis and management of mild cognitive impairment: a clinical review. JAMA. 2014;312:2551-2561.

[6] Duara R, Loewenstein DA, Greig-Custo MT, Raj A, Barker W, Potter E, et al. Diagnosis and staging of mild cognitive

impairment, using a modification of the clinical dementia rating scale: the mCDR. Int J Geriatr Psychiatry. 2010;25:282-289.

[7] Fink HA, Jutkowitz E, McCarten JR, Hemmy LS, Butler M, Davila H, et al. Pharmacologic Interventions to Prevent Cognitive Decline, Mild Cognitive Impairment, and Clinical Alzheimer-Type Dementia: A Systematic Review. Ann Intern Med. 2018;168:39-51.

[8] Butler M, Nelson VA, Davila H, Ratner E, Fink HA, Hemmy LS, et al. Over-the-Counter Supplement Interventions to Prevent Cognitive Decline, Mild Cognitive Impairment, and Clinical Alzheimer-Type Dementia: A Systematic Review. Ann Intern Med. 2018;168:52-62.

[9] Forbes D, Forbes SC, Blake CM, Thiessen EJ, Forbes S. Exercise programs for people with dementia. Cochrane Database Syst Rev. 2015;2015:CD006489.

[10] Regier NG, Hodgson NA, Gitlin LN. Characteristics of Activities for Persons With Dementia at the Mild, Moderate, and Severe Stages. Gerontologist. 2017;57:987-997.

[11] Sallis JF, Bull F, Guthold R, Heath GW, Inoue S, Kelly P, et al. Progress in physical activity over the Olympic quadrennium. Lancet. 2016;388:1325-1336.

[12] Penna LG, Pinheiro JP, Ramalho SHR, Ribeiro CF. Effects of aerobic physical exercise on neuroplasticity after stroke: systematic review. Arq Neuropsiquiatr. 2021;79:832-843.

[13] Huang X, Li B, Yu F, Zhou J, Wan Q, Chang H. Path analysis from physical activity to quality of life among dementia patients: A dual-path mediating model. J Adv Nurs. 2020;76:546-554.

[14] Mollinedo Cardalda I, López A, Cancela Carral JM. The effects of different types of physical exercise on physical and cognitive function in frail institutionalized older adults with mild to moderate cognitive impairment. A randomized controlled trial. Arch Gerontol Geriatr. 2019;83:223-230.

[15] Langoni CDS, Resende TL, Barcellos AB, Cecchele B, da Rosa JN, Knob MS, et al. The effect of group exercises on balance, mobility, and depressive symptoms in older adults with mild cognitive impairment: a randomized controlled trial. Clin Rehabil. 2019;33:439-449.

[16] Demurtas J, Schoene D, Torbahn G, Marengoni A, Grande G, Zou L, et al. Physical Activity and Exercise in Mild Cognitive Impairment and Dementia: An Umbrella Review of Intervention and Observational Studies. J Am Med Dir Assoc. 2020;21:1415-1422.

[17] Huang X, Zhao X, Li B, Cai Y, Zhang S, Wan Q, et al. Comparative efficacy of various exercise interventions on cognitive function in patients with mild cognitive impairment or dementia: a systematic review and network meta-analysis. Journal of sport and health science, 2022;11:212-223.

[18] Bolandzadeh N, Tam R, Handy TC, Nagamatsu LS, Hsu CL, Davis JC, et al. Resistance Training and White Matter Lesion Progression in Older Women: Exploratory Analysis of a 12-Month Randomized Controlled Trial. J Am Geriatr Soc. 2015;63:2052-2060.

[19] Gajewski PD, Falkenstein M. Physical activity and neurocognitive functioning in aging - a condensed updated review. Eur Rev Aging Phys Act. 2016;13:1.

[20] Yeh TT, Chang KC, Wang JJ, Lin WC, Wu CY. Neuroplastic Changes Associated With Hybrid Exercise-Cognitive Training in Stroke Survivors With Mild Cognitive Decline: A Randomized Controlled Trial. Neurorehabil Neural Repair. 2023;37:662-673.

[21] Ali N, Tian H, Thabane L, Ma J, Wu H, Zhong Q, et al. The Effects of Dual-Task Training on Cognitive and Physical Functions in Older Adults with Cognitive Impairment; A Systematic Review and Meta-Analysis. J Prev Alzheimers Dis. 2022;9:359-370.

[22] Kuo HT, Yeh NC, Yang YR, Hsu WC, Liao YY, Wang RY. Effects of different dual task training on dual task walking and responding brain activation in older adults with mild cognitive impairment. Sci Rep 2022;12:8490.

[23] Chen YL, Tseng CH, Lin HT, Wu PY, Chao HC. Dual-task multicomponent exercise-cognitive intervention improved cognitive function and functional fitness in older adults. Aging Clin Exp Res 2023;35:1855–1863.

[24] Yao L, Fang H, Leng W, Li J, Chang J. Effect of aerobic exercise on mental health in older adults: A meta-analysis of randomized controlled trials. Front Psychiatry 2021;12:748257.

[25] Yu DJ, Yu AP, Bernal JDK, Fong DY, Chan DKC, Cheng CP, et al. Effects of exercise intensity and frequency on improving cognitive performance in middle-aged and older adults with mild cognitive impairment: A pilot randomized controlled trial on the minimum physical activity recommendation from WHO. Front Physiol 2022;13:1021428.

[26] Barha CK, Galea LA, Nagamatsu LS, Erickson KI, Liu-Ambrose T. Personalising exercise recommendations for

brain health: considerations and future directions. Br J Sports Med 2017;51:636–639.

[27] Zhang W, Liu H, Zhang T. Immediate and short-term effects of single-task and motor-cognitive dual-task on executive function. PLoS One 2023;18:e0290171.

[28] Ciesielska N, Sokołowski R, Mazur E, Podhorecka M, Polak-Szabela A, Kędziora-Kornatowska K. Is the Montreal Cognitive Assessment (MoCA) test better suited than the Mini-Mental State Examination (MMSE) in mild cognitive impairment (MCI) detection among people aged over 60? Meta-analysis. Psychiatr Pol 2016;50:1039–1052.

[29] Jia X, Wang Z, Huang F, Su C, Du W, Jiang H, et al. A comparison of the Mini-Mental State Examination (MMSE) with the Montreal Cognitive Assessment (MoCA) for mild cognitive impairment screening in Chinese middle-aged and older population: a cross-sectional study. BMC Psychiatry. 2021;21:485.

[30] Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav Res Methods 2009;41:1149–1160.

[31] Cohen J. Statistical Power Analysis for the Behavioral Sciences. Cambridge, MA, USA: Academic Press, 2013.

[32] Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005;53:695-699.

[33] De Smet L, Fabry G. Grip force reduction in patients with tennis elbow: influence of elbow position. J Hand Ther 1997;10:229–231.

[34] Lindstrom-Hazel D, Kratt A, Bix L. Interrater reliability of students using hand and pinch dynamometers. Am J Occup Ther 2009;63:193–197.

[35] Hesseberg K, Bentzen H, Bergland A. Reliability of the senior fitness test in community-dwelling older people with cognitive impairment. Physiother Res Int 2015;20:37–44.

[36] Ferreira S, Raimundo A, Marmeleira J. Test-retest reliability of the functional reach test and the hand grip strength test in older adults using nursing home services. Ir J Med Sci 2021;190:1625–1632.

[37] Swanenburg J, de Bruin ED, Favero K, Uebelhart D, Mulder T. The reliability of postural balance measures in single and dual tasking in elderly fallers and non-fallers. BMC Musculoskelet Disord 2008;9:162.

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