Evaluation of a dementia prevention program to improve health and social care and promote human rights among older adults

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Abstract

Purpose – *This study aims to evaluate a human rights-informed dementia prevention program promoting better health and social care among older adults. In this study, the authors examined whether a dual-task training would improve cognition in healthy older adults.*

Design/methodology/approach – *Individuals attending the systematic health education program for older adults based in Japan were recruited for study inclusion, and divided into a dual-task training group (TG) and a control group (CG). The TG underwent 90 min of a weekly dual-task training for 12 weeks. Severity of dementia was measured using the Mini-Mental State Examination (MMSE) test. Brain function was assessed using a go/no-go task paradigm, during which cerebral blood flow was additionally measured using functional near-infrared spectroscopy to quantify oxyhemoglobin (oxy-Hb).*

Findings – *MMSE total score, number of errors in the go/no-go tasks and oxy-Hb values showed significant improvements in the TG.*

Research limitations/implications – *Owing to the small number of participants allocated to the CG, the results must be interpreted with caution. Replication and further validation based on large-scale, randomized-controlled trials is warranted.*

Practical implications – *This study highlights potential benefits of incorporating an early prevention training for dementia into a human rights-friendly health education program.*

Social implications – *This study suggests a potential means to reduce costs of social security and health care by introducing a human rights-informed dementia prevention program.*

Originality/value – *The results suggest that dual-task training may improve cognitive function in healthy older adults, thereby contributing to better health and improvement of social health care, based on a human rights-informed health education program for the prevention of dementia.*

Keywords *Social care, Cognitive, Prevention, Dementia, Public services, Older adults, Health care, Civil society, Dual task*

Paper type *Research paper*

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Introduction

The aging of the population is progressing worldwide. In the 21st century, many people are living longer lives. However, as a result, the number of people suffering from non-communicable diseases, including dementia, is increasing (World Health Organization, 2012). An aging population means that an increasing number of individuals reach the age at which a decline in cognitive function becomes more probable (Alzheimer's Disease International, 2015). Alzheimer's Disease International reported that in 2015, one person was diagnosed with dementia every 3 s worldwide, totaling approximately 46.8 million incident cases. This number is expected to nearly double every 20 years and is predicted to reach 131.5 million by 2050. Additionally, this increase in the incidence of dementia has been associated with numerous public health, social and economic problems (Ministry of Health, Labour and Welfare, 2015). Several studies have reported that cognitive functions, such as selective attention, memory function and executive function, decline with age (Ardila, 2000; O'Sullivan, 2000). Mild cognitive impairment (MCI) is a clinical signature of the prodromal phase of dementia (Petersen, 2011; Barnes, 2003).

Treatments for dementia include nonpharmacological approaches, pharmacological approaches or both. Non-pharmacological approaches include cognitive activities such as reading, exercise (e.g. walking) and socializing (e.g. family gatherings) (Groot, 2016; Jeff, 2016; Zoe, 2019).

Moreover, studies on the effects of multicomponent exercises and training in dual tasks have reported that they improve MCI (Suzuki, 2013; Doi, 2013). The effectiveness of this technique for stimulating brain function is supported by evidence that dual-task training works more effectively prefrontal cortex activation in younger people than in older people. This rationale suggests that it may be effective to do it as soon as possible in older adults (Holtzer, 2011).

Since 1998, a systematic health education program for the older adults developed at Shinshu University in Japan (HEPS) has implemented systematic and human rights-friendly health education programs targeting older adults in Japan, Thailand, Indonesia and the Philippines (Watanabe, 2015; Murata, 2015; Maruo, 2015; Aznar, 2017; Nakade, 2017; Fujimori, 2018; Fujimori, 2020; Maruo, 2020; Gede, 2021). HEPS has administered ongoing comprehensive social capital-oriented and human rights-friendly health education through these programs to foster empathy and cooperation with a regular goal of 7,000 steps per day. Systematic HEPS evaluates energy expenditure and tests brain function, physical fitness and blood parameters. HEPS also arranges educational seminars regarding exercise, nutrition and recreational activities such as hiking and cooking. The HEPC used the plan-do-check-act cycle (PDCA), which was developed, and obtained the International Organization for Standardization (ISO) 9001: 2008: QC14J0022 certification in 2014, and moved to self-declaration in 2021. The HEPS plans to develop and integrate a dementia improvement program into its existing health education program. Dementia has been reported to improve through increasing self-esteem, personal and social resources, providing clean space and mutual support and reducing adversity of stigma and social isolation (Sally, 2020). It has also been suggested that knowledge of dementia is particularly poor among racial and ethnic minority groups (Alzheimer disease and associated disorders, 2015). Therefore, the development of a program aiming at the improvement of symptoms of dementia and that also incorporates aspects related to hate incidents might be particularly valuable (Theo, 2012).

The present study aimed to evaluate whether dual-task training improves cognition and inhibitory control in healthy older adults.

2. Methods

2.1 Study design

All participants in the control group (CG) and training group (TG) completed the Mini-Mental State Examination (MMSE) and go/no-go tasks and oxyhemoglobin (oxy-Hb) levels in the brain were measured using functional near-infrared spectroscopy (fNIRS) during the go/no-go task assessments before and after a 12-week intervention. MMSE scores, go/no-go task performance and oxy-Hb values during the go/no-go task were obtained at the School of Medicine Laboratory where the fNIRS device was installed, and dual-task training was conducted at the gymnasium of Shinshu University.

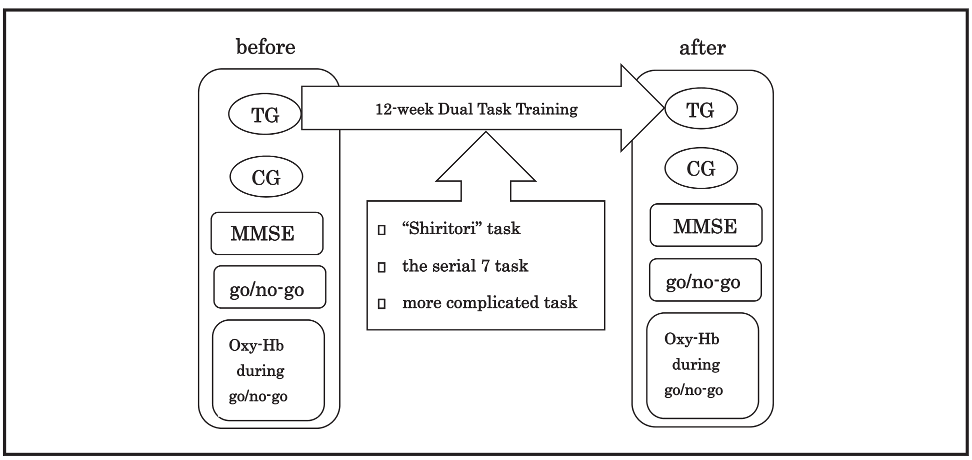
The 12-week dual-task training program went from June to September 2016. The participants assigned to the TG underwent 90 min of dual-task training weekly for 12 weeks. The dual-task training program followed a standardized format that included 10 min of stretching, 10 min of normal walking and 70 min of training in three dual-task activities. The three dual-task training activities included the following: ① playing Shiritori (a word game in Japan in which one player has to say a word starting with the last syllable of the word provided by the previous player) while walking, ② engaging in the serial seven subtraction task starting at 100 while walking and ③ counting numbers starting from the thumb with the right hand and from the little finger with the left hand at the same time while walking. With the transitions from task ① to ③, the tasks became more complicated and made it such that the participants would not become bored (Figure 1).

2.2 Participants

The CG and TG included voluntary participants who provided informed consent. The total study participants were 71 healthy, Japanese individuals. The CG was a combination of volunteers gathered through newspaper advertisements, and individuals planning to participate in HEPS the following year. The TG constituted voluntary HEPS participants at Shinshu University. The mean age of the nine participants in the CG was 71.1 ± 3.9 years; there were four males (mean age: 72.8 ± 2.5 years) and five females (mean age: 69.8 ± 4.5 years). The 62 in the monthly and weekly TG had a mean age of 66.5 ± 5.1 years (mean ± SD); there were 17 males (mean age: 68.9 ± 4.9 years) and 45 females (mean age: 65.5 ± 4.9 years). A small number of CG participants did not participate in the 12-week dual-task training, reported no benefit and participated only in the measurements. However, it may be difficult to make an accurate comparison because the CG comprised a smaller sample as compared to the TG. Therefore, this study may serve as a case study.

The participants were instructed to eat their usual meals and to finish eating approximately 4 h before the start of the experiment. The participants were also instructed to avoid drinking alcohol and caffeinated drinks on the day before the experiment. Smoking was not allowed on the day of the experiment. None of the participants had a history of neurological or major medical or physical disorders, and none was taking any medications at the time of the study. Participation in this study was voluntary, and the participants would not be adversely affected by non-participation. Even if they agreed to participate once, they could withdraw at any time. The participants agreed to participate in this research as volunteers after receiving a detailed explanation of this study. All participants were informed of the potential experimental risks, and written informed consent was obtained in accordance with the

Figure 1 Research flow chart



human participant's policy of Shinshu University. The protocol of this study was approved by the Ethics Committee for Shinshu University (approved number: UMIN000009309).

2.3 Mini-Mental State Examination

To assess cognitive function to understand the participants' characteristics and status, the MMSE was performed before and after the 12-week intervention. The MMSE is a 30-point questionnaire that is used extensively in clinical and research settings to measure cognitive impairment. Administration of the test takes between 5 and 10 min and examines functions including registration, attention and calculation, recall, language, ability to follow simple commands and orientation. MMSE scores of 24 points or more indicated normal cognition. Lower scores can indicate severe ($\leq$ 9 points), moderate (10–18 points) or mild (19–23 points) cognitive impairment (Folstein, 1975).

2.4 Go/no-go tasks

The go/no-go task (custom-made by Shinshu University Faculty of Engineering, Japan) (Masaki *et al*., 1971; Terasawa, 2014) was used to estimate the inhibitory decision process and comprised three experimental stages:

1. formation;
2. differentiation; and
3. reverse differentiation.

First, in the formation stage, participants were instructed to grasp the rubber ball in response to a red light that was randomly displayed. The formation stage comprised five trials. Second, during the differentiation stage, the participants were instructed to grasp the rubber ball in response to a red light but not a yellow light when a red or yellow light was randomly displayed. Third, during the reverse differentiation stage, the participants were instructed to grasp the rubber ball in response to yellow light but not a red light when a red or yellow light was randomly displayed. In each of the differentiation and reverse differentiation stages, the participants completed 20 trials. Red and yellow lights were equally randomly displayed ten times each. In this article, the term "miss" indicates an incorrect response when the participants did not grasp the rubber ball when they should have. Conversely, the term "mistake" means an incorrect response when the participants grasped the rubber ball when they were not supposed to. The participants' go/no-go task performance was assessed before and after the health education program.

The results before and after the 12-week session of MMSE and the go/no-go tasks were compared: the before and after values for each item and the total score on the MMSE and the mistakes, misses and reaction times for grasping the rubber ball in the go/no-go task.

2.5 Oxyhemoglobin values during the go/no-go task

Oxy-Hb levels in the brain were measured using fNIRS (OMM-3006, Shimadzu, Kyoto, Japan), while the participants performed the go and no-go tasks. During the go/no-go task, the sequence of the red and yellow lights was randomly generated by the program; the sequence always consisted of five red and five yellow lights. The test included a 40 s rest period, five go tasks, five no-go tasks and 40 s in the following sequence: a 40 s rest, followed by a series of ten 1-s tasks and a 40 s rest. The time between consecutive stimuli was set at 40 s to allow the brain blood flow to return to its baseline level. The experiment lasted for 7 min and 30 s, including rest periods. The participants wore a head cap that covered the entire head; it contained 15 optodes (corresponding to 22 channels) overlying each hemisphere, including C3/C4 of the international 10/20 system in the caudal portion (9×9-cm square area). Each channel comprised one emitter (red) and one detector (white) optode each, located 3 cm apart. The channel locations are shown in Figure 2. The sampling rate for each channel was approximately 8 Hz. The oxy-Hb concentration was focused, as this has been reported to be sensitive to neurohemodynamic interactions (Hoshi, 2001; Strangman, 2002). Changes in oxy-Hb concentrations were detected using three wavelengths (780, 805 and 830 nm) of near-infrared light with a pulse width of 5 ms. The change in oxy-Hb concentrations from the control baseline was estimated using a modified Beer–Lambert law (MBLL) (Cope, 1988). Based on the MBLL, signal changes in oxy-Hb and deoxyhemoglobin (deoxy-Hb were calculated) using known extinction coefficients (Cope, 1988). ΔSignal oxy-Hb and ΔSignal deoxy-Hb are denoted in arbitrary units of millimolar-millimeter (Maki, 1995). Additionally, changes in oxy-Hb concentration were used as an indicator of fluctuations in the regional cerebral blood volume, because an earlier near-infrared spectroscopy signal study using a perfused brain model proposed that oxy-Hb, rather than deoxy-Hb, was the most sensitive parameter (Hoshi, 2001).

2.5 Statistical analyses

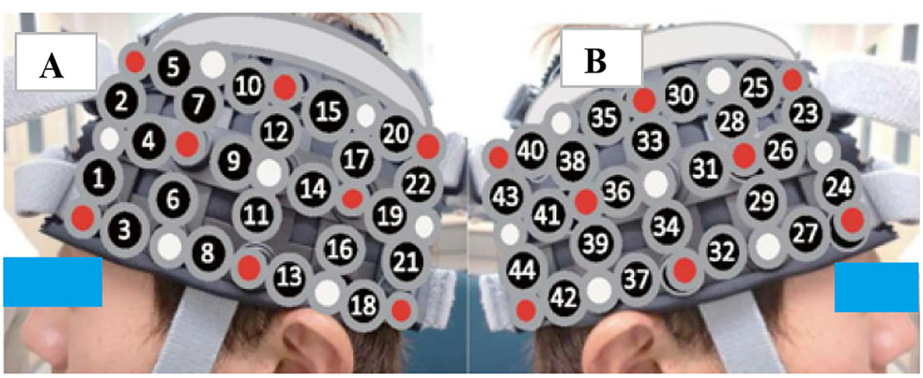
A 2×2 (pre- and post-test $\times$ TG and CG) two-way analysis of variance (ANOVA) with repeated measures were performed to evaluate significant differences in the MMSE scores, go/no-go task performance and brain blood flow during go/no-go tasks. In the case of significant interactions, three *post hoc* analyses were performed to interpret the pre- and post-test results within both groups. First, a paired *t*-test was used to assess significant changes in pre- and post-test results within the TG and CG. Second, one-way ANOVA was calculated to interpret the pre- and post-test results in both groups. Finally, *post hoc* tests were performed using the Tukey–Kramer correction. Bonferroni correction was not selected in this situation because of the unequal sample sizes between the TG and CG. The level of significance was set at $p < 0.05$. All statistical analyses were performed using the SPSS statistical package (SPSS Statistics Ver. 26).

3. Results

3.1 Mini-Mental State Examination

Table 1 shows the significant differences between the groups in terms of the two-way ANOVA interactions for the MMSE scores, go/no-go task performance and brain blood flow.

Figure 2 Location of near-infrared spectroscopy probes on the scalp



Note: Functional near-infrared spectroscopy data were obtained using a 44-channel spectrometer. Partcipants wore a head cap such that channels 1–22 were located over the left hemisphere (A) and channels 23–44 were located over the right hemisphere (B)

Table 1 Result of *t*-test and two-way ANOVA for MMSE, go/no-Go tasks and fNIRS

			Paired t-*test*				*Two way ANOVA*			*One way ANOVA*	*Tukey-Kramer*	
Measurement items	*TG/pre*	*TG/post*	*p-value*	*CG/pre*	*CG/post*	*p-value*	*Pre/post*	*TG/CG*	*interaction*	*TG Pre/TG Post/ CG Pre/CG Post*	*TG Pre/Post*	*CG Pre/Post*
MMSE												
Q1	4.8 ± 0.4	5.0 ± 0.0	0.001	4.8 ± 0.4	4.1 ± 0.6	0.01	NS	0.001	0.001	0.001	0.01	0.01
Q4	3.5 ± 2.0	4.7 ± 1.1	0.001	4.7 ± 0.7	3.7 ± 1.9	NS	0.01	NS	0.01	0.001	0.01	NS
Total	27.8 ± 2.2	29.5 ± 1.2	0.001	29.0 ± 0.7	27.4 ± 1.9	NS	0.001	NS	0.001	0.001	0.01	NS
Go/no-go tasks												
Error	1.7 ± 1.4	0.8 ± 0.9	0.001	1.0 ± 2.2	1.6 ± 1.4	NS	0.01	NS	0.05	0.05	0.01	NS
fNIRS (mol/L cm)												
During go task												
5ch	−0.274 ± 1.949	1.413 ± 2.139	0.001	0.753 ± 2.233	−0.461 ± 3.858	NS	NS	NS	0.01	0.01	0.05	NS
18ch	−0.619 ± 2.828	2.592 ± 3.856	0.001	2.156 ± 2.216	1.380 ± 4.093	NS	0.01	NS	0.01	0.001	0.01	NS
During no-go task												
2ch	0.259 ± 2.372	−0.234 ± 2.418	NS	−1.916 ± 2.777	−0.083 ± 2.385	NS	NS	0.0443	0.05	0.05	NS	NS
17ch	0.622 ± 4.190	−0.562 ± 3.555	NS	−1.306 ± 2.963	0.389 ± 2.446	NS	NS	NS	0.05	NS	NS	NS
39ch	0.120 ± 4.682	−1.192 ± 4.073	NS	−2.374 ± 2.345	−0.161 ± 2.470	0.05	NS	NS	0.05	NS	NS	NS
42ch	−0.273 ± 5.427	−3.033 ± 4.711	0.05	−1.336 ± 3.332	0.140 ± 2.925	NS	NS	NS	0.05	0.05	0.05	NS
Total ch	0.160 ± 0.430	−0.765 ± 0.881	0.001	−0.894 ± 0.825	−0.702 ± 1.200	NS	0.001	0.001	0.001	0.001	0.01	NS

Notes: Mean and standard division scores for paired *t*-test (pre × post), *p*-value of interaction for two-way ANOVA (pre/post × TG/CG), *p*-value of inter-group variation for one-way ANOVA (pre/post, TG/CG) and *p*-value of compare groups for Tukey–Kramer (TG: pre/post, CG: pre/post) of each question in MMSE, go/no-go tasks and fNIRS

The test items that showed a significant difference in MMSE scores were the test items with a maximum of 5 points for both Q1 and Q4. Q1 is a test of orientation of time: What is the (year) (season) (date) (day) (month)? Q4 is a test of attention and calculation ability, and seven was subtracted from 100 five times.

Two-way ANOVA showed a significant difference in the interaction for the MMSE Q1 scores (df = 1; F = 30.20; $p < 0.001$). *Post hoc* analysis using Tukey's test to evaluate pre- and post-test differences between the groups on MMSE Q1 scores showed a significant difference (TG/pre vs post: 4.8 ± 0.4 vs 5.0 ± 0.0, respectively; $p < 0.001$; CG/pre vs post: 4.8 ± 0.4 vs 4.1 ± 0.6; $p < 0.01$). A significant difference in interaction was found for Q4 scores (df = 1; F = 7.20; $p < 0.01$). *Post hoc* analysis using Tukey's test to evaluate the pre- and post-test changes on MMSE Q4 scores between the groups revealed a significant difference (TG/pre vs post: 3.5 ± 2.0 vs 4.7 ± 1.1; $p < 0.001$). A significant difference was also found in the interaction for the total MMSE scores (df = 1; F = 14.21; $p < 0.001$). The *post hoc* analysis to evaluate pre- and post-test changes revealed a significant difference in the between-group difference in total MMSE scores (TG/pre vs post: 27.8 ± 2.2 vs 29.5 ± 1.2; $p < 0.001$).

3.2 Go/no-go tasks

There were no differences in response times in the go/no-go tasks. However, there were significant differences in the interaction in terms of errors (df = 1; F = 3.98; $p < 0.05$). *Post hoc* analysis using Tukey's test showed significant differences between pre- and post-test changes in the errors in the go/no-go tasks (TG/pre vs post: 1.7 ± 1.4 vs 0.8 ± 0.9, respectively; $p < 0.001$). Conversely, the number of errors in the go/no-go task of the CG increased although no significant difference was observed.

3.3 Oxyhemoglobin values during go/no-go tasks

Two-way ANOVA revealed significant differences in the interaction between channels in oxy-Hb levels measured by near-infrared spectroscopy. In the analysis of each channel of oxy-Hb during the go trials, two-way ANOVA showed a significant difference in the interaction in Channel 5 (df = 1; F = 8.57; $p < 0.01$). *Post hoc* analysis of the pre- and post-test changes using Tukey's test showed significant between-group differences (TG/pre vs post: -0.274 ± 1.949 vs 1.413 ± 2.139; $p < 0.001$). A significant difference in the interaction was observed in Channel 18 (df = 1; F = 8.63; $p < 0.01$). Evaluation of the pre- and post-test changes using *post hoc* analysis using Tukey's test showed a significant difference (TG/pre vs post: -0.619 ± 2.828 vs 2.592 ± 3.856; $p < 0.001$).

A significant difference for the interaction was also noted in Channel 42 (df = 1; F = 5.27; $p < 0.05$); *post hoc* analysis showed a significant difference (TG/pre vs post: -0.273 ± 5.427 vs -3.033 ± 4.711; $p < 0.001$). In addition, a significant difference in the interaction was observed for total channels (df = 1; F = 35.64; $p < 0.001$). *Post hoc* analysis of the pre- and post-test changes showed a significant difference between groups (TG/pre vs post: 0.160 ± 0.430 vs -0.765 ± 0.881; $p < 0.001$).

4. Discussion

To confirm the effects of dual-task training, MMSE scores were compared between the TG and CG. Regarding Q1, which assessed orientation in time, the MMSE scores in the TG significantly improved, whereas the MMSE scores in the CG were significantly lower on the post-test than on the pretest. These data suggested that dual-task training was effective in the TG, while the MMSE score in the CG decreased due to aging or other factors. Furthermore, regarding Q4, which was a test of attention and calculation ability, the total MMSE scores in the TG were significantly improved, i.e. dual-task training was effective. There are multiple reports of improvement in cognitive function by dual-task training, and the possibility of effects of dual-task training is not low (Senem *et al.*, 2020; Abeer, 2019; Mikel, 2019; Hars, 2014).

To confirm the effects of dual-task training, the performance in go/no-go tasks was assessed to evaluate executive function and inhibitory function. Go/no-go tasks have been used for 20 years as an assessment of brain function in HEPS (Watanabe, 2015; Murata, 2015; Maruo, 2015; Aznar, 2017; Nakade, 2017; Fujimori, 2018; Fujimori, 2020; Maruo, 2020; Gede, 2021). Previous studies have reported that in the act of grasping the rubber ball in the go trials, which assesses executive function, individuals with dementia miss and fail to grasp the rubber ball (Murata, 2015; Terasawa, 2014). However, in this study, no misses in the go/no-go tasks were observed in any of the participants. The TG showed a significantly decreased number of mistakes in the assessment of inhibitory function, which involved not grasping the rubber ball in the no-go trials. Additionally, similar to the report by Falbo *et al.* (Falbo, 2016), dual-task training has been shown to improve inhibitory function. In addition, the TG with an average age of 67 showed significant improvement in both MMSE and go/no-go tasks, while the CG with that of 71 showed a decline in both test performances. From this, as reported by Holtzer *et al.*, the training may be more effective on the younger brain (Holtzer, 2011). In a previous study, participants tended to respond quickly to go/no-go tasks, resulting in low accuracy and misses before the HEPS. However, if participants walk more than 6,000 steps a day, the reaction times in the go/no-go tasks are reduced, and mistakes and misses are also reduced. Then, in the next stage, it was reported that the reaction times in the go/no-go tasks became significantly faster, the mistakes significantly decreased and the misses also tended to decrease (Watanabe, 2015; Murata, 2015; Nakade, 2017; Fujimori, 2018; Fujimori, 2020).

In Channels 5 and 18 of the oxy-Hb during the go task of the go/no-go tasks, the TG had significantly higher oxy-Hb levels than the CG. However, in Channel 42 and the total channels during the no-go task, the TG had significantly lower oxy-Hb levels than the CG. At this time, because the MMSE scores and the number of mistakes in no-go trials improved, oxy-Hb levels decreased. It has been reported that this is because oxy-Hb levels decrease when the tasks are simple, and oxy-Hb levels increase when the tasks become difficult (Sagari, 2020). Additionally, there have been reports that when tasks become easier, oxy-Hb levels decrease (Ikegami *et al.*, 2008). Improved MMSE scores and a decrease in the number of mistakes in no-go trials show improved cognitive function based on inhibitory control. In this task, if the participants can perform the go task accurately, i.e. they can grasp the rubber ball accurately, this could indicate enhanced executive function and an increase in the oxy-Hb level. On the other hand, no-go tasks are stationary tasks that do not require movement. However, the participants still consumed much energy in the beginning to suppress the grasping movement until they became accustomed to the task. Thus, if the no-go task can be performed accurately, this suppression function can be strengthened, and the oxy-Hb level can be lowered without accurately grasping the rubber ball in a stationary state. This indicates that the number of misses and mistakes in the go/no-go tasks has improved in previous studies (Fujimori, 2018; Maruo, 2020).

The small number of CG in this study may not apply in every situation and the relevant considerations need to be revisited.

5. Limitations

In this study, the participants were initially roughly divided equally into two groups, namely, the TG and the CG. However, considerable attrition from the CG created an imbalance between the groups. Future research should address this issue. The fNIRS device was mounted around the frontal lobe; therefore, the oxy-Hb status throughout the brain is unknown. Furthermore, after dual-task training, the TG showed a significant increase in oxy-Hb during go performance; however, there was a simultaneous and significant decrease in oxy-Hb in the no-go task. Future research will comprise an increased number of participants.

fNIRS channels that cover the entire brain will be investigated and compared with the results of functional magnetic resonance imaging (fMRI) to further investigate this phenomenon.

6. Conclusions

The aging of the population is progressing worldwide. An aging population means that an increasing number of individuals reach the age at which a decline in cognitive function becomes more probable. Therefore, when cognitive function declines, it may increase the risk of developing dementia. For that reason, social support services for people with dementia aligned with human rights values is a necessity. Cognitive impairment in the middle-aged and aged population often imposes a large burden on health-care systems unless new options of prevention and improvement are identified. Given the growing old adults population in most countries, healthy lifestyles may decrease the rate of age-related cognitive changes and help delay the onset of cognitive symptoms in the setting of age-associated disease. If this becomes possible, an economic spillover effect can be expected by reducing social security costs.

The purpose of this study was to evaluate whether dual-task training improves cognition and inhibitory control in healthy older adults, and thus contributes to social care for human rights.

This paper evaluated the scope of using dual-task training in cognition improvement and inhibitory control in healthy older adults. Using a 12-week dual-task program infers that the intervention has significantly improved the cognitive ability and inhibitory control indicators, i.e. MMSE scores, go/no-go task performance and oxy-Hb values among the members of the treatment group.

This finding may be considered important contribution in evidence creating literature of the dual-task and multi-task training on cognitive improvement and inhibitory control. It has direct implication to public health and social care policies.

Abbreviation list

TG: dual-task training group, CG: control group, MMSE: Mini-Mental State Examination, oxy-Hb: oxyhemoglobin, MCI: mild cognitive impairment, HEPS: a systematic health education program for the older adults developed at Shinshu University in Japan, PDCA: the plan-do-check-act cycle, ISO: the International Organization for Standardization, WHO: World Health Organization, fNIRS: functional near-infrared spectroscopy, MBLL: modified Beer–Lambert law, deoxy-Hb: deoxyhemoglobin, ANOVA: analysis of variance, fMRI: functional magnetic resonance imaging.

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Authors' contributions

KK[a]), KT and FS planned the experiment and collected the data. NW, TN, KA, HT, HA, KK[a]) and YA performed the data analysis. KK a), MO and SJM composed the article. All authors read and approved the final manuscript.

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Further reading

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