The effects of whole body vibration exercise intervention on electroencephalogram activation and cognitive function in women with senile dementia

Ki-Hong Kim1, Hyang-Beum Lee2,*

1Department of Special Physical Education, Yong In University, Yongin, Korea
2Department of Physical Education, Yong In University, Yongin, Korea

This study conducted the Korean version of Mini-Mental State Examination (MMSE-K) to women aged 65 or older residing in Gangwon-do Province and screened those who were suspicious to have mild dementia for receiving 23 points or lower in it. For eight weeks, this author tried to verify the effects of whole body vibration exercise intervention on electroencephalogram (EEG) activation and cognitive function in women with senile dementia. According to the results, both EEG activation and cognitive function indicated statistically significant difference in terms of the interactive effect between the measuring times and groups, and there was statistically significant improvement found after the whole body vibration exercise intervention. The results of this study are meaningful because they present the possibility of whole body vibration exercise intervention to be integrated into the plan to improve life quality in patients with senile dementia by stimulating their muscle spindles and sensory organs only with the amplitude and the number of vibrations with no burden of physical activity and enhancing their EEG activation and cognitive function through the responses of the neuromuscular system.

Keywords: Whole body vibration, Senile dementia, Electroencephalogram, Cognitive function, Women

INTRODUCTION

Dementia is one of the typical organic mental disorders resulted from reduced cognitive function accompanying many different cognitive as well as behavioral symptoms (Wesson et al., 2013). Among the diseases resulting in behavioral disorders in the aged, dementia is the most frequently found disease, and its prevalence rate is continuously increasing, and in 2027, the number of patients with it are expected to be over one million (Minister of Health & Welfare, 2011).

Dementia, one of the typical senile diseases, is a clinical syndrome caused by brain damage resulted from either disease or trauma. It can be largely divided into two kinds: Alzheimer disease, a degenerative brain disease, and vascular dementia resulted from cerebrovascular disease. Dementia can be diagnosed by single-photon emission computed tomography (SPECT), functional magnetic resonance imaging (fMRI), or brainwave analysis (EEG). Among these, brainwave analysis is used to observe the changes of brain functions directly and diagnose dementia and trace its progress with the indexes reflecting the development of it (Florence et al., 2004). So far, over 70 or so causes of dementia have been known, but 70% to 80% of them are irreversible and not exactly identified, so it is difficult to provide causative treatment for it (Korean Dementia Association, 2006); however, it is reported that if dementia is detected in an early stage and proper treatment is given, it can influence dementia positively in the aspects of enhancing cognitive as well as physical functions (Ayalon et al., 2006).

To treat senile dementia, both medication and nonmedication methods such as art, music, and exercise therapies are being employed harmoniously. Particularly, exercise therapies are known to...
activate brain metabolism, increase cerebral blood flow, stimulate
the secretion of neurotransmitters, and enhance abilities to live, so
it is reported that they can improve life quality in patients with
senile dementia positively (Flannery, 2002). Despite the impor-
tance of exercise therapy, patients with senile dementia tend to re-
fuse exercise itself due to their malfunctioning body, so it is lim-
ited to manage dementia by general exercise. It means that we need
to devise exercise methods that reflect the patients’ characteristics.
Among the types of exercise, whole body vibration exercise is
what one can practice with no burden of physical activity. Whole
body vibration exercise is done only through one’s weight on the
platform that produces mechanical vibrations. With a variety of
amplitudes and vibrations, it stimulates muscle spindles as well as
sensory organs and draws responses from the neuromuscular sys-
tem. In this way, it can enhance the user’s physical functions (Tor-
vinen et al., 2002). This author thinks that it can be integrated
into the intervention of exercise therapy effectively for patients
with senile dementia whose physical activity is limited.

Here, this study provided the 8-week intervention of whole
body vibration exercise to women with senile dementia and exam-
ined the effects of it on EEG activation and cognitive function.
The purpose of this study is to provide foundational material to
improve life quality in patients with senile dementia by develop-
ing an effective interventional exercise program.

MATERIALS AND METHODS

Study subjects
This study conducted the Korean version of Mini-Mental State
Examination-K (MMSE-K) to women aged 65 or older residing
in Gangwon-do Province and screened those who were suspicious
to have mild dementia for receiving 23 points or lower in it.
When selecting the subjects, this researcher excluded those par-
ticipating in any physical activity programs as it could influence
the result. Also, to prevent the spread of this experimental inter-
vention, the experimental group and control group were chosen
from two different places distant from each other. Before the ex-
periment, the participants and their guardians received explana-
tion about the purpose of this study, and those who had permis-
sion from their doctor were asked to write an agreement and then
joined in this research. Omitting one from the experimental
group that missed over two sessions for personal reasons and also
one from the control group that was willing to quit it in the mid-
dle, this author finally conducted analysis with data gained from
total 18 persons, 9 in the experimental group and 9 in the control
group. The physical characteristics of the subjects are shown in
Table 1.

Measured items & methods for measurement
In order to examine how 8-week whole body vibration exercise
intervention changes EEG activation and cognitive function in
women with senile dementia, this researcher employed brainwave
analysis (EEG) and MMSE-K. Before the experiment, the subjects
were aware of the requirements, exercise procedures, exercise
methods, and the measuring methods. After the 8-week whole
body vibration exercise intervention was provided, data gained
before the experiment and after the 8-week experiment were ana-
lyzed comparatively.

EEG activation was measured by using a brainwave measuring
instrument (LXE3208, LAXHA Inc., Daejeon, Korea). Electrodes
were attached to total 8 spots, Fp1, Fp2, F3, F4, T3, T4, P3, and
P4, grounded on the International 10/20 Electrode System. After
the reference electrode was applied to the right earlobe and the
ground electrode to the forehead, measurement was done in a mo-
nopolar way. Sampling frequency per second was set as 256 Hz,
and gain as 6,944 μV. Brainwaves were begun to be recorded when
no artifacts were detected for over 10 sec continuously (Fig. 1).

| Variable   | Exercise group (n=9) | Control group (n=9) |
|------------|---------------------|---------------------|
| Age (yr)   | 79.22 ± 4.02        | 81.44 ± 3.75        |
| Height (cm)| 156.48 ± 2.08       | 156.84 ± 2.81       |
| Weight (kg)| 57.03 ± 2.71        | 58.87 ± 2.72        |

Values are presented as mean ± standard deviation.

Fig. 1. The international electrode system.
Cognitive function was measured by MMSE-K. It was measured by a specialized investigator trained for MMSE-K through one-to-one interviews. MMSE-K consists of total five areas and 30 questions: 10 questions for orientation about time and space, 6 questions for memory regarding registration and remembrance, 5 questions for concentration and calculation in numeracy, and 7 questions for linguistic skills such as naming, 3-step ordering, copying, and repeating, and 2 questions for understanding and judgment. They got 1 point for a right answer and 0 for no answer. If the total score was over 24, they were regarded normal, 20 to 23 points as mild disorder, and under 19 points as severe disorder (Park and Kwon, 1989).

The whole body vibration exercise program

The intervention with the whole body vibration exercise program used in this study is grounded on the American College of Sports Medicine Exercise Guideline with Recommendations (American College of Sports Medicine, 2014). It recommends the aged to exercise 3 to 5 times a week for 30 to 40 min each time continuously for 8 to 12 weeks to see the effect. In consideration of the subjects’ physical characteristics, whole body vibration exercise was done 5 times a week for 8 weeks. As warm-up and warm-down exercise, whole body stretching was done mildly.

In the whole body vibration exercise program, a whole body vibration exerciser (VM-10, Korea) was used. The exercise involved 5 sets of the standing position, squat position, and sumo squat position lasting for 2 min, and between the positions, they took a rest for 1 min. This researcher decided on the intensity of whole body vibration exercise by reviewing a journal (Bruyere et al., 2005) and having an expert meeting. It began with the frequency of 20 Hz, and it increased gradually as 5 Hz every 2 weeks.

Data processing

This study adopted pretest-posttest control group design and employed a computer statistical program, IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA), to analyze the effects of whole body vibration exercise intervention. To examine the subjects’ physical characteristics, this author performed descriptive statistical analysis and calculated the mean and standard deviation. To look into the effects of whole body vibration exercise intervention on EEG activation and cognitive function in women with senile dementia in association with the whole body vibration exercise intervention, in Fp1, Box M = 5.319, F(3, 46,080.000) = 1.533, and P = 0.204, and in Fp2, Box M = 4.370, F(3, 46,080.000) = 1.259, and P = 0.287. In F3, Box M = 0.389, F(3, 46,080.000) = 0.112, and P = 0.953, and in F4, Box M = 5.437, F(3, 46,080.000) = 1.567, and P = 0.195. In T3, Box M = 2.757, F(3, 46,080.000) = 0.794, and P = 0.497, and in T4, Box M = 1.208, F(3, 46,080.000) = 0.348, and P = 0.791. Also, in P3, Box M = 5.669, F(3, 46,080.000) = 1.634, and P = 0.179, and lastly, in P4, Box M = 3.280, F(3, 46,080.000) = 0.945, and P = 0.418. The equivalence assumption

| Spot  | Group | Pretest | Posttest | F     | P   | \( \eta^2 \) |
|-------|-------|---------|----------|-------|-----|------------|
| Fp1   | EG    | 0.032 ± 0.006 | 0.066 ± 0.006 | 24.252 | 0.001 | 0.603      |
|       | CG    | 0.032 ± 0.005 | 0.032 ± 0.004 | 220.055 | 0.001 | 0.932      |
|       | T4    | 225.042 | 0.001 | 0.934 |
| Fp2   | EG    | 0.035 ± 0.004 | 0.049 ± 0.006 | 8.398  | 0.010 | 0.344      |
|       | CG    | 0.037 ± 0.004 | 0.035 ± 0.003 | 49.866 | 0.001 | 0.757      |
|       | T3    | 85.664  | 0.001 | 0.843 |
| F3    | EG    | 0.048 ± 0.006 | 0.062 ± 0.005 | 7.513  | 0.014 | 0.320      |
|       | CG    | 0.049 ± 0.005 | 0.048 ± 0.005 | 178.382 | 0.001 | 0.918      |
|       | T3    | 189.888 | 0.001 | 0.922 |
| F4    | EG    | 0.076 ± 0.004 | 0.086 ± 0.003 | 5.132  | 0.038 | 0.243      |
|       | CG    | 0.078 ± 0.005 | 0.076 ± 0.005 | 44.316 | 0.001 | 0.735      |
|       | T3    | 98.800  | 0.001 | 0.861 |
| T3    | EG    | 0.279 ± 0.017 | 0.310 ± 0.020 | 4.624  | 0.047 | 0.224      |
|       | CG    | 0.275 ± 0.022 | 0.273 ± 0.022 | 251.834 | 0.001 | 0.940      |
|       | T3    | 308.765 | 0.001 | 0.951 |
| T4    | EG    | 0.376 ± 0.037 | 0.512 ± 0.038 | 20.242 | 0.001 | 0.559      |
|       | CG    | 0.369 ± 0.034 | 0.367 ± 0.035 | 3,203.720 | 0.001 | 0.995      |
|       | T3    | 3,397.190 | 0.001 | 0.995 |
| P3    | EG    | 0.358 ± 0.035 | 0.483 ± 0.030 | 25.518 | 0.001 | 0.615      |
|       | CG    | 0.353 ± 0.029 | 0.351 ± 0.029 | 1,605.043 | 0.001 | 0.990      |
|       | T3    | 1,868.650 | 0.001 | 0.991 |
| P4    | EG    | 0.470 ± 0.039 | 0.594 ± 0.041 | 16.653 | 0.001 | 0.513      |
|       | CG    | 0.463 ± 0.031 | 0.462 ± 0.031 | 6,466.749 | 0.001 | 0.998      |
|       | T3    | 6,560.554 | 0.001 | 0.998 |

Values are presented as mean ± standard deviation. EG, exercise group; CG, control group.
of variate and covariate matrices is satisfied, and according to the results of verifying Mauchly’s sphericity assumption, Huynh-Feldt’s $\varepsilon$ equals 1 in all the variables, so the sphericity assumption is satisfied.

The results of EEG activation in women with senile dementia after the whole body vibration exercise intervention are presented in Table 2. As shown in Table 2, $F_{p1}$, $F_{p2}$, $F_3$, $F_4$, $T_3$, $T_4$, $P_3$, and $P_4$ all indicated interactive effects in terms of EEG activation in women with senile dementia after the whole body vibration exercise intervention.

The changes of cognitive function according to the whole body vibration exercise intervention

According to the results of conducting a homogeneity test on the matrices of cognitive function’s variates and covariates in women with senile dementia in association with the whole body vibration exercise intervention, Box $M = 1.419, F(3, 46.080.000) = 0.409$, and $P = 0.747$, which means that the equivalence assumption of variate and covariate matrices is satisfied, and according to the results of verifying Mauchly’s sphericity assumption, Huynh-Feldt’s $\varepsilon$ equals 1, so the sphericity assumption is satisfied.

The results of cognitive function in women with senile dementia after the whole body vibration exercise intervention are presented in Table 3. As shown in Table 3, cognitive function indicated interactive effects in women with senile dementia after the whole body vibration exercise intervention.

DISCUSSION

This study provides scientific ground materials about the effects of whole body vibration exercise intervention in patients with senile dementia. In order to improve life quality in patients with senile dementia, this author has examined the effects of 8-week whole body vibration exercise intervention on EEG activation and cognitive function and also analyzed the findings with those in advanced research comparatively.

The changes of EEG activation

There are ways to diagnose dementia objectively, for example, SPECT, fMRI, or brainwave analysis (EEG). Among them, EEG is mainly used as it is easy, economical, and noninvasive. EEG has been used as one of the most examination tools to diagnose dementia since 1931 when Berger reported that patients with senile dementia indicate the low wave phenomenon in their brainwave. EEG activation shows the functional state of a brain as an electrical signal attributed to the activity of cerebral nerves. Since patients with dementia indicate lower EEG activation than normal elders, it is needed to devise interventions to elevate it (Mahendra, 2012). Therefore, considering the characteristics of patients with senile dementia tending to refuse exercise itself due to their physical functional disorders, this author came up with whole body vibration exercise intervention that could draw responses from the neuromuscular system through mechanical vibrations with no burden of physical activity and observed the changes of EEG activation.

According to the results of verifying the effects of the whole body vibration exercise intervention on EEG activation in women with senile dementia, statistically significant differences were found in $F_{p1}$, $F_{p2}$, $F_3$, $F_4$, $T_3$, $T_4$, $P_3$, and $P_4$ all in terms of interactive effects between the measuring times and groups. Significant improvement was observed after the whole body vibration exercise intervention. This means that the whole body vibration exercise intervention elevates EEG activation positively in women with senile dementia. The result of this study corresponds to the result of Crabbe and Dishman (2004) that has measured brainwaves before, during, and after the exercise in patients with senile dementia and found the alpha waves before and right after the walking exercise and found that the left frontal lobe’s alpha waves increase significantly after the walking exercise. These results support the findings of this study. The findings tell us that in patients with senile dementia having limitations in exercising due to their cognitive or behavioral disorders, whole body vibration exercise intervention will enhance EEG activation by stimulating their muscle spindles and sensory organs with the amplitudes and vibrations with no burden of physical activity and drawing responses from the neuromuscular system.

To sum up the above results, whole body vibration exercise intervention can be a safe and effective exercise method that can in-

### Table 3. The results of cognitive function after the whole body vibration exercise intervention

| Group | Pretest     | Posttest    | $F$  | $P$  | $\eta^2$ |
|-------|-------------|-------------|------|------|----------|
| EG    | 20.889 ± 1.27 | 23.556 ± 1.24 | 4.692 | 0.046 | 0.227    |
| CG    | 21.333 ± 1.12 | 20.889 ± 1.05 | 29.091 | 0.001 | 0.645    |
|       | G × T       |             | 57.018 | 0.001 | 0.781    |

Values are presented as mean ± standard deviation.
EG, exercise group; CG, control group.
crease EEG activation in women with senile dementia and delay and prevent functional decline in their brain. Therefore, the findings of this study are meaningful as they present the possibility of integrating whole body vibration exercise into the plan to improve the neuromuscular system safely and enhance life quality in patients with senile dementia indicating cognitive as well as behavioral disorders.

**The changes of cognitive function**

Dementia is a phenomenon of losing long-term memory in old age due to the damage of the cerebral cortex in charge of long-term memory and is accompanied with such symptoms as reduction in linguistic skills, space perception, and cognitive function. Among them, cognitive function is particularly more important because if one loses it, one may not be able to lead an ordinary life, obtain independency in life, or live a social life desirably (Wheatley, 2001). For them to secure independency in everyday life, it is demanded to devise interventions that can prevent reduction in cognitive function. In fact, exercise therapy is known as an effective method to prevent decline in cognitive function if it is practiced regularly in a long-term period (Vogel et al., 2009). Here in this study, whole body vibration exercise intervention was applied as anyone can participate in it safely as well as easily with no burden of physical activity, and then, this researcher observed how their cognitive function changed.

According to the results of verifying the effects of the whole body vibration exercise intervention on cognitive function in women with senile dementia, statistically significant differences were found in terms of interactive effects between the measuring times and groups. After the whole body vibration exercise intervention, significant improvement was observed. This implies that the whole body vibration exercise intervention enhances cognitive function positively in women with senile dementia. The findings correspond to the result of Rolland and Chevrollier (2001) that regular exercise prevents decline in cognitive function resulted from dementia positively, to the result of Kemoun et al. (2010) that a 15-week physical activity program provided to patients with dementia enhances the experimental group's cognitive function significantly, and also to the result of Schuit et al. (2001) that in patients with dementia, the increase of physical activity reduces the risk of reduction in cognitive function. They all support the findings of this study. The result seems to be attributed to the fact that the whole body vibration exercise intervention provided to women with senile dementia increases blood circulation safely with no physical burden and influences cognitive function positively through activated cerebrovascular circulation.

To sum up the above results, whole body vibration exercise intervention allows patients with senile dementia to participate in regular exercise with no feeling of refusal. It enhances the functional plasticity of the cerebral cortex, increases connectivity between the dendrites of neurons, and improves the functions of the central nervous system efficiently (Chodzko-Zajko and Moore, 1994). Since it does improve brain functions in this way, it can be regarded as a proper exercise type for patients with senile dementia. Accordingly, we can conclude that whole body vibration exercise intervention that anyone can be applied to safely with no burden can be used to improve brain functions, obtain independency in everyday life, and elevate life quality desirably.

**CONFLICT OF INTEREST**

No potential conflict of interest relevant to this article was reported.

**REFERENCES**

American College of Sports Medicine. ACSM’s guidelines for exercise testing and prescription. 9th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2014.

Ayalon L, Gum AM, Feliciano L, Areán PA. Effectiveness of nonpharmacological interventions for the management of neuropsychiatric symptoms in patients with dementia: a systematic review. Arch Intern Med 2006;166:2182-2188.

Bruyere O, Wuidart MA, Di Palma E, Gourlay M, Ethgen O, Richy F, Reginster JY. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. Arch Phys Med Rehabil 2005;86:303-307.

Chodzko-Zajko WJ, Moore KA. Physical fitness and cognitive functioning in aging. Exerc Sport Sci Rev 1994;22:195-220.

Crabbe JB, Dishman RK. Brain electrophysiological activity during and after exercise: a quantitative synthesis. Psychophysiology 2004;41:563-574.

Flannery RB Jr. Treating learned helplessness in the elderly dementia patient: preliminary inquiry. Am J Alzheimer Dis Other Demen 2002;17:345-349.

Florence G, Guerit JM, Gueguen B. Electroencephalography (EEG) and somatosensory evoked potentials (SEP) to prevent cerebral ischaemia in the operating room. Neurophysiol Clin 2004;34:17-32.

Kemoun G, Thibaud M, Roumagne N, Carotte P, Albinet C, Toussaint L, Paccalin M, Dugué B. Effects of a physical training programme on cognitive function and walking efficiency in elderly persons with de-
Whole body vibration exercise intervention on EEG activation and cognitive function

Kim KH and Lee HB

Korean Dementia Association. Dementia. Seoul (Korea): Academiya; 2006.

Mahendra B. Dementia: a survey of the syndrome of dementia. London: Springer Science & Business Media; 2012.

Minister of Health & Welfare. 2011 Survey of living conditions and welfare needs of the elderly. Sejong (Korea): Minister of Health & Welfare; 2011.

Park JH, Kwon YC. Development of the test for the elderly - Korean Version of Mini-Mental State Examination (MMSE-K). J Korean Neuropsychiatr Assoc 1989;28:125-135.

Praamstra P, Boutsen L, Humphreys GW. Frontoparietal control of spatial attention and motor intention in human EEG. J Neurophysiol 2005;94:764-774.

Rolland F, Chevrollier JP. Depression, anti-thyroid antibodies and Hashimoto encephalopathy. Encephale 2001;27:137-142.

Schuit AJ, Feskens EJ, Launer LJ, Kromhout D. Physical activity and cognitive decline, the role of the apolipoprotein e4 allele. Med Sci Sports Exerc 2001;33:772-777.

Torvinen S, Kannus P, Sievänen H, Järvinen TA, Pasanen M, Kontulainen S, Järvinen TL, Järvinen M, Oja P, Vuori I. Effect of four-month vertical whole body vibration on performance and balance. Med Sci Sports Exerc 2002;34:1523-1528.

Vogel T, Brechat PH, Lepêtre PM, Kaltenbach G, Berthel M, Lonsdorfer J. Health benefits of physical activity in older patients: a review. Int J Clin Pract 2009;63:303-320.

Vogt T, Schneider S, Brümmer V, Strüder HK. Frontal EEG asymmetry: the effects of sustained walking in the elderly. Neurosci Lett 2010;485:134-137.

Wesson J, Clemson L, Brodaty H, Lord S, Taylor M, Gitlin L, Close J. A feasibility study and pilot randomised trial of a tailored prevention program to reduce falls in older people with mild dementia. BMC Geriatr 2013;13:89.

Wheatley CJ. Evaluation and treatment of cognitive dysfunction. In: Pendleton HM, Schultz-Krohn W, Pedretti LW, Early MB. Occupational therapy: practice skills for physical dysfunction. 5th ed. St. Louis (MO): Mosby; 2001. p. 456-491.