Comparison of brain nervous system activity and psychological changes before and after net-step exercise in Japanese adults of advanced age

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Abstract Objective: Exercise for people's health are important in aging society. The net-step exercise, which was developed in Hokkaido and spread all over Japan at the present time. This study was performed to investigate the physiological and psychological changes induced by net-step exercise in Japanese adults of advanced age.

Methods: We visited two net-step exercise classes and recruited 22 older adults. Brain waves and Two-Dimensional Mood Scale (TDMS) scores were measured before and after the net-step exercise in 22 adults of advanced age (mean age=75.5 years, SD=5.4 years) of both sexes.

Results: The distribution rate of alpha-2 waves was significantly higher after than before exercise (*P*=0.03). Brain waves except alpha-2 waves was no significant changes. Similarly, the vitality, stability, and pleasure scores in the TDMS were significantly higher after than before exercise (*P*=0.01). However, arousal level scores was not showed significant difference.

Conclusion: These results suggest that the participants felt relaxation, concentration, and a high-spirited feeling by engaging in this exercise.

Keywords : Net-step exercise, Brain nervous system activity, Psychological changes, Japanese older adults

Introduction

According to the 2018 Population Census of Japan, the percentage of people aged >65 years is 27.7% of the total population. The percentage continues to rise and is expected to reach an estimated 38.4% by 2065. Thus, the extension of a healthy life expectancy is important to ensure that older adults can live independently in a familiar community.

Physical activity, which is one method for extension of a healthy life expectancy in older people, is expected to reduce the decline in cognitive function[1)] and the risk of dementia[2)]. Physical activity is also a preventative factor against coronary heart disease[3)] and depression[4)]. Dual-task training reportedly improved motor functions in older individuals who participated in cognitive dual-task training[5)]. A dual-task exercise, which is called a net-step exercise, was developed as a health activity in community-dwelling adults of advanced age in Hokkaido, Japan in 2005[6)]. This exercise is considered to provide an opportunity for social participation in older adults[7)]. Net-step exercise, in the capacity of dual-task training, might have a positive effect on physical and mental health. A few studies have shown the relationship among cognitive function, depressive symptoms, and net-step exercise[8,9)]. However, no reports have identified an association between brain nervous activity as a physiological parameter and net-step exercise.

In the present study, we investigated the influence of net-step exercise on physiological and psychological changes in Japanese adults of advanced age.

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Materials and Methods

Participants

Recruitment was conducted through announcements from August to September 2015 in two net-step exercise houses in Sapporo, Japan. The study included 22 older adults (aged 71–81 years) of both sexes. The exclusion criterion was the presence of a cardiac pacemaker.

All participants received written information on the trial and provided signed informed consent.

Methods

Net-step exercise involves the use of nets with a length of 4 m, width of 1.5 m, and squares of 50 × 50 cm that form a grid of 24 squares (3 × 8)[6]. The participants slowly step over the net without setting their foot on the net using many different stepping patterns. The duration of the net-step exercise in the present study was about 1 hour, including a warm-up activity of 15 minutes. First, the participants watched the instructor's demonstration step. Two participants then formed a pair and took the same step while singing a nursery rhyme. The other participants watched with pleasure until their own turn.

The initial data obtained from the participants were sex, age, commencement time of net-step exercise, and frequency per week of net-step exercise. We subsequently measured the participants' physiological and psychological parameters before and after the net-step exercise.

With respect to physiological parameters, the participants underwent electroencephalography for 1 minute for examination of brain nervous activity after resting for 1 minute immediately following the net-step exercise. For electroencephalography measurement, participants rested on a chair with their eyes closed. Electroencephalography was performed using Brain Pro-Light FM-828 (Futek Electronics Co., Ltd., Yokohama, Kanagawa, Japan), which is a simplified and handheld high-power device. A sensor band was attached to the participant's forehead. The exploratory electrode was Fp2 according to the international 10/20 system. The sampling frequency was 1,024 Hz, and the filters used were 5 Hz, 8 Hz, 10 Hz, 12 Hz, and 20 Hz. Electroencephalograms were Fast Fourier Transform (FFT) -converted data. Frequency bands were divided into theta waves (4–7 Hz; sleep state), alpha-1 waves (8–9 Hz; relaxed state), alpha-2 waves (10–11 Hz; relaxed concentration state), alpha-3 waves (12–13 Hz; tense concentration state), and beta waves (14–30 Hz; anxiety and strain state). The distribution rate of each wave was calculated and used for analysis.

Psychological parameters were measured using the Two-Dimensional Mood Scale (TDMS)[10]. The TDMS is composed of eight questionnaire items, and the mood assessment scale consists of the vitality level, stability level, pleasure level, and arousal level. The eight questionnaire items represent the four quadrants of a two-dimensional coordinate plane. The four categories are (1) high arousal-pleasure, (2) low arousal-displeasure, (3) low arousal-pleasure, and (4) high arousal-displeasure. The TDMS score is determined using a 6-point Likert scale. Four mood scale scores were calculated using the four above-mentioned categories[10] : vitality level score = (1) − (2), stability level score = (3) − (4), pleasure level score = [(1) + (3)] – [(4) − (2)], and arousal level score = [(1) + (4)] – [(3) − (2)]. Higher scores indicated a more positive psychological state.

Statistical analysis

The Wilcoxon signed-rank test was performed to assess the before and after exercise differences in the distribution rate of each brain wave and the four scale scores of the TDMS. The level of statistical significance was set at a P of <0.05. The analyses were performed with a commercially available statistical software package (Dr. SPSS II for Windows; SPSS Japan Inc., Tokyo, Japan).

Ethical considerations

This study was approved by the ethics committee of the Hokkaido Chitose College of Rehabilitation University.

Results

The mean age of the 22 participants (21 women, 1 man) was 75.5 years (range, 71–81 years). The mean participation period of the net-step exercise was 8.2 months (range, 2.0–14.4 months), and 82% of the participants engaged in the exercise one or two times per week.

Changes in the distribution rate of the five brain waves before and after net-step exercise are shown in Table 1. The median distribution rate of the alpha-2 waves significantly increased from 11.7% before exercise to 12.5% after exercise (P=0.03). In contrast, the distribution rate of the other four brain waves (theta waves, alpha-1 waves, alpha-3 waves, and beta waves) showed no significant change.

Table 2 shows the changes in the TDMS scores before and after net-step exercise. Significant increases were noted in the median vitality level scores (before and after exercise scores, 4.0 and 6.5; P=0.02), stability level scores (before and after exercise scores, 4.5 and 8.0; P =0.03), and pleasure level scores (before and after exercise scores, 8.0 and 14.0; P=0.01), suggesting a positive psychological effect of net-step exercise. However, the arousal level scores were not significantly different before and after exercise.

Table 1 Changes in distribution rate of brain waves on before and after the net-step exercise

Brain waves	Median level (%) [25-75 percentile]		P^*
	Before net-step exercise	After net-step exercise	
Beta	28.2 [20.5-35.6]	25.6 [20.8-35.6]	0.99
Alpha-3	19.0 [17.0-25.1]	17.4 [15.4-23.1]	0.08
Alpha-2	11.7 [6.8-17.8]	12.5 [8.9-19.0]	0.03
Alpha-1	15.3 [9.5-23.3]	14.6 [11.1-21.4]	0.69
Theta	21.2 [15.6-30.4]	18.8 [13.1-28.8]	0.45

*Wilcoxon rank sum test

Table 2 Changes in Two-Dimensional Mood Scale (TDMS) scores on before and after the net-step exercise

TDMS levels	Median levels (scores) [25-75 percentile]		P^*
	Before net-step exercise	After net-step exercise	
Vitality	4.0 [1.5-6.0]	6.5 [2.5-8.0]	0.02
Stability	4.5 [3.0-7.3]	8.0 [5.0-9.3]	0.03
Pleasure	8.0 [7.0-12.0]	14.0 [10.5-16.3]	0.01
Arousal	-1.0 [-4.0-2.0]	-1.0 [-5.0-1.3]	0.93

*Wilcoxon rank sum test

Discussion

The net-step exercise has three characteristic features[6]. (1) This exercise requires two people to walk carefully and rhythmically. The participants waiting for their turn remain seated in chairs around the net. (2) The participants must remember the step pattern based on the instructor's demonstration. (3) The instructor and waiting participants watch and encourage the participants and do not mention any mistakes that were made during the net-step exercise. This suggests that the participants must concentrate during the net-step exercise and that they are relaxed because of the friendly atmosphere.

In this study, the distribution rate of alpha-2 waves was significantly higher after than before the net-step exercise. This supports the effects of all three of the above-mentioned characteristic features of the net-step exercise and indicates that the participants felt more relaxed and that tension was relieved after the net-step exercise.

No studies have measured brain waves as an effect of the net-step exercise. Research has shown that alpha waves are significantly elevated by yoga. One study showed that alpha waves were significantly affected by yoga in 18- to 37-years-old university students. The students continued performing yoga three times a day for 21 days. The alpha waves were 57.85% higher after than before yoga[11]. Another study showed that alpha brain waves were significantly higher (about 1.2 times) after than before yoga exercise in women with premenstrual syndrome[12]. Each yoga session was 50 minutes long and consisted of 5 minutes of breathing exercises, 35 minutes of yoga pose practice, and 10 minutes of relaxation. These studies suggest that the elevation of alpha brain waves is a relaxation effect provided by yoga. In contrast, the rate of increase in alpha waves was about 1.1 times smaller with the net-step exercise than with yoga. We consider that this difference was caused by the combined relaxation and concentration effects of the measured alpha-2 waves in our study.

Although alpha-1 and alpha-3 waves decreased after the net-step exercise, the decrease was not significant. Alpha-1 waves reflect relaxation with low-grade awakening owing to approaching theta waves, and alpha-3 waves induce a lower stress state owing to approaching beta waves. Participants obtained relaxation with high-grade awakening according to a significant elevation in alpha-2 waves after the net-step exercise. Therefore, this could have led to the reduction in the alpha-1 and alpha-3 waves being insignificant.

The present study showed significant increases in the vitality, stability, and pleasure level scores after net-step exercise. The characteristics of the net-step exercise suggest that the participants' concentration increases and that they are relaxed because of the friendly atmosphere. In a previous study, physical activity such as walking, jogging, and net-step exercise were associated with decreased depression[8,13,14]. Increases in the vitality, stability, and pleasure level scores lead to improvements in depressive symptoms and higher vitality, stability, and pleasure. The features of the net-step exercise suggest that the participants gain improved concentration, relaxation, and a heightened mood by exercise. This in turn suggests that they will feel fresh and more relaxed after net-step exercise as a psychological effect.

The high vitality level score indicates an energetic and lively status. An increased stability level score, indicates relaxation and calmness, and an increased pleasure level score indicates comfort and feeling energetic[10]. There are no studies on the effects of net-step exercise and brain waves on TDMS scores. However, it is known that increasing alpha brain waves enhances relaxation, concentration, and provides calming effect. Therefore, we speculate that the rise in vitality, stability, and pleasure level scores is associated with the status of increasing alpha brain waves.

This study has several limitations. First, our sample size was small, which resulted in a reduced statistical power. Second, the participants of this study were restricted to urban areas; thus, the results may not represent other adults of advanced age. Third, some of the question items in the TDMS are probably difficult for older adults to understand. Therefore, it is possible that the participants could not accurately answer the questions. Finally, this was a cross-sectional study, and the assessments were only performed before and after participation in the net-step exercise. In addition, we did not consider detailed data such as the amount of exercise performed or the time spent watching the other participants. Further research will be required to compare a net-step exercise group and a control group for an accurate assessment.

In conclusion, this study showed that the net-step exercise induces both physiological and psychological changes characterized by a significantly increased alpha-2 brain waves distribution rate and higher vitality, stability, and pleasure level scores. Our results suggest that the physiological and psychological effects of the net-step exercise might increase relaxation and concentration for Japanese adults of advanced age.

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Self-Declaration of Conflicts of Interest

The authors have no conflicts of interest to declare.

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