

Six-Month Lower Limb Aerobic Exercise Improves Physical Function in Young-Old, Old-Old, and Oldest-Old Adults

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The effect of aerobic exercise on physical function and mental health in various adult age groups (young-old, 65-74; old-old, 75-84; oldest-old, ≥ 85 years) is unclear. The aim of this study was to investigate the effects of the Kohzuki Exercise Program (KEP) on physical function and mental health in these age groups. The KEP consisted of 40-min supervised sessions 3 times per week for 6 months as follows: 5 min of warm-up, 30 min of lower limb aerobic exercise, and 5 min of cool-down. A total of 50 participants (22 young-old, 20 old-old, and 8 oldest-old) who participated in the KEP completed at least 88% of the sessions. In statistical analysis, 3 (group: oldest-old, old-old, young-old) \times 2 (time: baseline and after 6 months) analyses of variance were used to determine if there were significant main and interaction effects. Significant interactions were probed using the post-hoc paired *t* test. The Short Physical Performance Battery (SPPB) score showed significant group \times time interactions after 6 months ($p = 0.031$). In the post-hoc test, oldest-old ($p < 0.001$), old-old ($p < 0.001$), and young-old ($p < 0.01$) groups had significantly better physical function after 6 months. However, none of the mental health measures showed group \times time interactions at 6-month. Our results suggest that a 6-month KEP led to improved physical function in oldest-old, old-old, and young-old adults. The KEP was effective for oldest-old adults in particular. The KEP exhibits good adherence, making it suitable for a wide age range in society.

Keywords: lower limb aerobic exercise; old-old; oldest-old; physical function; young-old

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Introduction

In gerontology, older adults are often subdivided into three categories: young-old (65-74 years old), old-old (75-84 years old), and oldest-old (≥ 85 years old) (Zizza et al. 2009; Comploj et al. 2015). Among older adults, physical function decreases 4% per year after the age of 65 years (Milanovic et al. 2013), and mobility disability is prevalent, affecting 24% of adults older than 75 years and 80% of adults over 85 years (Fried et al. 2004; Stenhausen et al. 2013). Moreover, as the number of individuals reaching the age of 75 has grown rapidly in recent years, decline in physical function predisposes old-old and oldest-old adults to loss of independence, poor quality of life, and hospitalization (Fried et al. 2000; Arai et al. 2010; La Grow et al. 2013). In older adults aged 75 years and over, prevention of disability in physical and mental function is a key objective for successful ageing (Orr et al. 2006).

Currently, aerobic exercise is widely recommended as

a part of the exercise prescription for older adults because of its positive effects on physical function and maintaining independence (Short et al. 2003; Ansai et al. 2016). Clinical studies have shown that individuals aged 65 to 84 years can benefit significantly from aerobic exercise, improving physical function parameters such as muscle mass, balance, and walking speed (Shigematsu et al. 2002; Short et al. 2003; Harber et al. 2009). In addition, a multi-component exercise including aerobic exercise has been reported to have a positive impact on balance, gait speed, walking distance, and mobility in older adults aged 65 years and over (Eggenberger et al. 2015) or aged 79 to 90 years (Rogers et al. 2003; Ansai et al. 2016). Progressive moderate- to high-intensity group programs including balance, jumping, and lower limb strength exercises can maintain or even improve the physical function of healthy older women aged 65 to 80 years (Korpelainen et al. 2006; Karinkanta et al. 2010). On the other hand, studies by Luukinen et al. (2006) and Serra-Rexach et al. (2011) in oldest-old adults

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demonstrated that muscle strength exercise did not improve physical function. All of the aforementioned exercise studies targeted adults aged 65 to 99 years, whereas studies investigating the effectiveness of aerobic exercise interventions specifically in old-old (75-84 years) and oldest-old (≥ 85 years) age groups are scarce.

To our knowledge, none of the aforementioned studies verified the age-specific effects of lower limb aerobic exercise. Moreover, effects of lower limb aerobic exercise on mental health for three age groups, including the oldest-old, have not been reported. Therefore, the purpose of this study was to investigate the effects of lower limb aerobic exercise (Kohzuki Exercise Program; KEP) on physical function and mental health in young-old, old-old, and oldest-old. The hypothesis was that the KEP would be effective at improving physical functional measures in old-old and oldest-old adults.

Methods

This prospective, intervention trial was conducted among 50 community-dwelling older adults from December 2014 to May 2015. Ethical approval was obtained from the Tohoku University Graduate School of Medicine Ethics Committee. The protocol of this study was registered in the University Hospital Medical Network Clinical Trials Registry (UMIN000023953).

Participants were recruited through an advertisement and poster in a community senior center. The eligibility criteria for inclusion were older adults aged 65-74 years, 75-84 years, or ≥ 85 years (Zizza et al. 2009; Comploj et al. 2015), who were healthy, community-dwelling, and able to ambulate independently indoors and outdoors. Exclusion criteria were as follows: recent injuries, neurological or cognitive disorders, cardiopulmonary diseases, or previous regular sports or martial arts training.

Intervention

All participants participated in the KEP. The KEP consisted of 40-min supervised exercise sessions 3 times per week for 6 months, as follows: 5 min of warm-up and stretching, 30 min of lower limb aerobic exercise using a TERASUERUGO® (Showa denki Co., Ltd., Osaka, Japan), and 5 min of cool-down and relaxation. Intensity of exercise was targeted at a heart rate of 40-60% of maximum and Borg scale of 11 ("fairly light") to 13 ("somewhat hard") (Kim et al. 2016).

Primary outcome

The primary outcome measure was physical function, which was evaluated using the Short Physical Performance Battery (SPPB) (Guralnik et al. 1994). The SPPB is a brief performance battery specifically developed for older adults, including frail adults and those with disabilities, chronic diseases, or stroke, to assess balance, gait speed, and lower body strength (Guralnik et al. 1994; Taylor-Piliae et al. 2014). The SPPB is a questionnaire with 5 items and 3 tests score: balance (side-by-side stand, a semi-tandem stand, and a tandem stand), gait speed (4 m walking speed), and lower body strength (time to stand up from a chair 5 times). Each of the 3 tests have scores ranging from 0 to 4. SPPB total score (0: poor performance to 12: best performance) is calculated by adding the 3 tests (Guralnik et al. 1994). Taylor-Piliae et al. (2014) reported that the minimal clinically important difference in total score is considered to be an increase of 1

point between baseline and follow-up.

Secondary outcome

Secondary outcome measures were related to mental health. Mental health outcome was assessed with a questionnaire administered to the participants, using The Short Form 12 Health Survey (SF-12) (Ware et al. 1996). The SF-12 is a selected, brief version of the SF-36 that assesses physical and mental composite summary (PCS and MCS, respectively) in eight domains: physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). The SF-12 score ranges from 0 to 100, with higher scores indicating better quality of life (QoL). General cognitive function was evaluated using the Korean version of the Mini-Mental State Examination (MMSE) (Hux et al. 1998). MMSE scores range from 0 to 30, with higher scores indicating greater cognitive function. Depression was evaluated using the Short Form-15 Geriatric Depression Scale (GDS) (Sheikh et al. 1991). GDS scores range from 0 to 15, with higher scores indicating severe depression. Sleep quality was estimated using the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989). PSQI scores range from 0 to 21, with higher scores indicating poor quality of sleep. All measures were administered at baseline and after 6 months.

Statistical analysis

Variables are expressed as means and standard deviations. All primary and secondary outcomes were compared between the three age groups. Baseline characteristics of participants in the three age groups were compared using analysis of variance (ANOVA) for continuous variables and the chi-square test for categorical variables. Multiple comparisons were performed only when the between-group difference was significant for categorical variables. In order to examine differences over time between groups, 3 (group: oldest-old, old-old, young-old) \times 2 (time: baseline and after 6 months) analyses of variance were used to determine if there were significant main and interaction effects. Significant interactions were probed using the post hoc paired t test. For all analyses, a p-value < 0.05 was required for significance. All data were analyzed using Statistical Package for the Social Sciences (SPSS) version 20 (IBM Corp., Chicago, IL, USA).

Results

A total of 50 participants were enrolled in this study. Baseline characteristics of participants are summarized in Table 1. All 50 participants who took part in the KEP completed at least 88% of the sessions over the 6-month period. The average age of all participants was 76.7 ± 6.0 years. Eight participants were included in the oldest-old group, 20 participants were included in the old-old group, and 22 participants were included in the young-old group. The SPPB in the oldest-old group was lower than that in the old-old and young-old group ($p < 0.01$). The PSQI in the oldest-old and old-old groups was higher than that in the young-old group ($p < 0.05$).

Primary outcome

The results of SPPB for physical function are shown in Table 2 and Fig. 1. After 6 months of KEP, all groups had

Table 1. Baseline characteristics of participants.

Variable	Total Mean (SD) (n = 50)	Oldest-old group Mean (SD) (n = 8)	Old-old group Mean (SD) (n = 20)	Young-old group Mean (SD) (n = 22)	Group Difference ^c
Characteristic					
Age (years)	76.7 (6.0)	86.2 (1.5)	78.8 (2.4)	71.2 (2.6)	< 0.01
Female (%)	44 (88.0)	7 (87.5)	17 (85.0)	20 (90.9)	n.s
Weight (kg)	58.5 (8.2)	54.1 (7.6)	58.6 (7.3)	60.4 (8.8)	n.s
Height (cm)	153.9 (6.3)	151.2 (8.4)	153.9 (6.0)	155.2 (5.6)	n.s
BMI (kg/m ²)	24.6 (2.9)	23.7 (3.5)	24.7 (3.0)	25.0 (2.7)	n.s
Physical function					
SPPB (0-12) ^a	8.66 (1.84)	6.27 (0.82)	9.00 (1.60)	9.22 (1.60)	< 0.01
Mental health					
MMSE (0-30) ^a	26.21 (2.86)	24.13 (3.87)	26.10 (2.81)	26.91 (2.43)	n.s
GDS (0-15) ^b	2.56 (2.90)	3.75 (2.25)	2.40 (2.60)	2.27 (3.34)	n.s
PSQI (0-21) ^b	7.12 (3.87)	7.50 (3.46)	8.45 (3.97)	5.77 (3.63)	< 0.05

Values are n (%) or mean (SD, Standard Deviation).

BMI, Body Mass Index; PSQI, Pittsburgh Sleep Quality Index; GDS, Geriatric Depression Scale; MMSE, Mini-Mental Status Examination; n.s., not significant.

^aHigher score indicates better functioning.

^bLower score indicates better functioning.

^cANOVA for continuous or chi-square for categorical variables, as appropriate.

Table2. Baseline and changes in physical function.

	Oldest-old group Mean (SD) (n = 8)		Old-old group Mean (SD) (n = 20)		Young-old group Mean (SD) (n = 22)		Group Effect ^b	Time Effect ^b	Group × Time Interaction ^b
	Baseline	6-month	Baseline	6-month	Baseline	6-month			
SPPB Total Score (0-12) ^a	6.27 (0.82)	9.88 (1.11)***	9.00 (1.60)	10.15 (1.50)***	9.22 (1.63)	11.59 (0.80)**	< 0.0001	< 0.0001	< 0.05
Balance Score (0-4) ^a	1.88 (0.64)	3.25 (0.71)	2.80 (0.77)	3.85 (0.37)	2.91 (0.81)	3.86 (0.47)	< 0.0001	< 0.0001	n.s.
Gait speed Score (0-4) ^a	2.25 (0.71)	3.00 (0.53)	3.00 (0.65)	3.40 (0.50)	3.09 (0.68)	3.73 (0.46)	< 0.0001	< 0.0001	n.s.
Chair stand Score (0-4) ^a	2.13 (0.64)	3.43 (0.52)**	3.20 (0.83)	3.80 (0.41)**	3.23 (0.75)	3.95 (0.21)*	< 0.0001	< 0.0001	< 0.05

n.s., not significant.

^aHigher score indicates better functioning.

^bTwo-way repeated measures ANOVA; p-value.

*Post hoc paired t test (vs baseline); *p < 0.05, **p < 0.01, ***p < 0.001

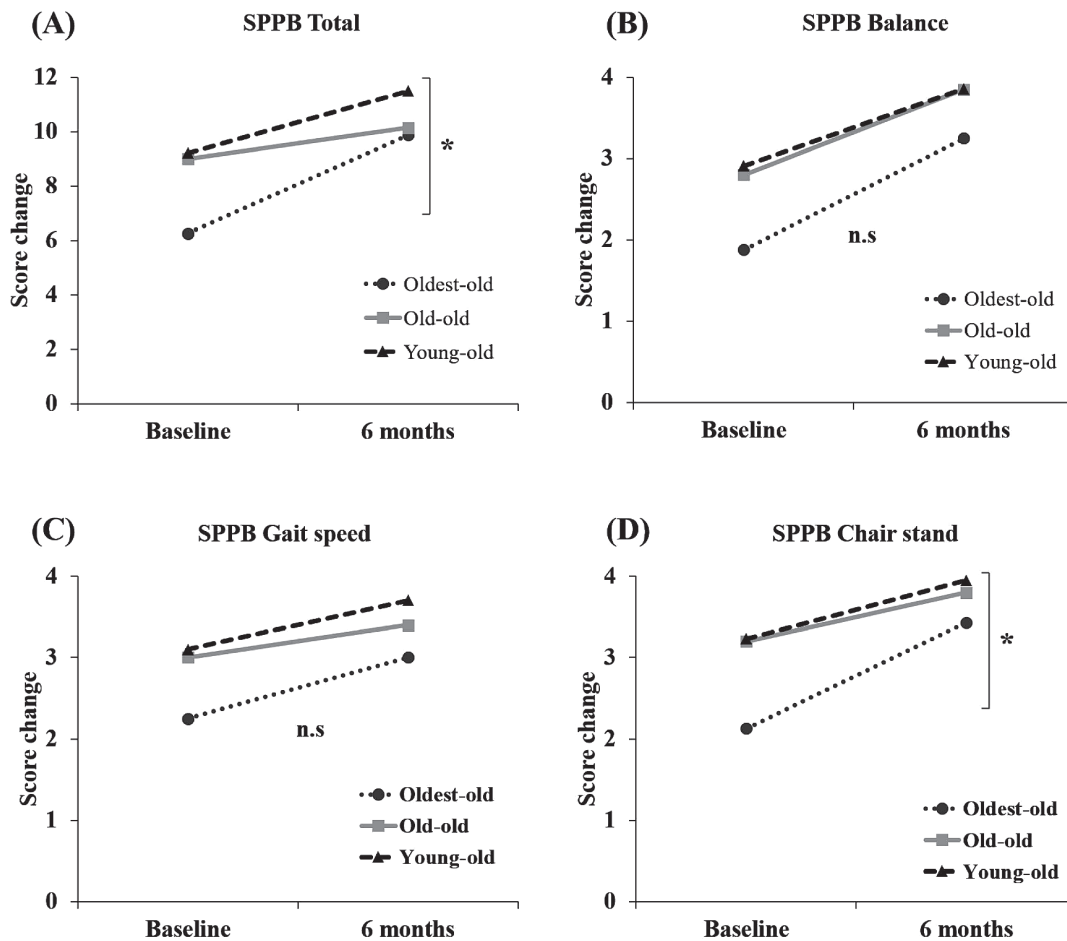


Fig. 1. Physical function outcomes between groups and time interaction.

Mean score change from baseline for (A) SPPB Total, (B) SPPB Balance, (C) SPPB Gait speed, (D) SPPB Chair stand to 6 months. A different symbol is used for each group: oldest-old (Circle), old-old (Square) and young-old (Triangle). Each point represents a mean value. * $p < 0.05$ was Group (oldest-old, old-old, young-old) \times Time (baseline and after 6 months) Interaction. n.s., not significant.

substantial improvements in SPPB total score ($F = 84.268$, $p < 0.0001$). There was a significant group by time interaction for SPPB total score ($F = 3.737$, $p = 0.031$). The post hoc test indicated that oldest-old ($t = -12.095$, $p < 0.001$), old-old ($t = -6.962$, $p < 0.001$), and young-old ($t = -6.973$, $p < 0.01$) groups had significantly better physical function over time. In the 3 SPPB tests, the chair stand score showed significant within group by time interaction ($F = 2.705$, $p = 0.035$). There was no significant within group by time interaction for SPPB balance and gait speed scores. However, there were significant within-time effects for SPPB balance ($F = 45.310$, $p < 0.0001$), SPPB gait speed ($F = 15.221$, $p < 0.0001$), and SPPB chair stand ($F = 4.044$, $p < 0.0001$) scores over the 6 months of the KEP. Moreover, we verified a clinically relevant increase in the SPPB scores between baseline and after 6 months in the oldest-old, old-old, and young-old groups.

Secondary outcome

Table 3 shows the performance of groups at each outcome on the mental health evaluations. There was no sig-

nificant within group by time interaction for SF-12 (PCS and MCS), MMSE, GDS, and PSQI. However, there were significant improvements in time effects for the SF-12 (PCS, $F = 3.954$, $p = 0.024$), MMSE ($F = 5.033$, $p = 0.003$), GDS ($F = 8.620$, $p = 0.002$), and PSQI ($F = 46.022$, $p < 0.0001$) scores over the 6 months of the KEP. All groups had significant improvements in perceived mental health after 6 months of KEP ($p < 0.05$).

Discussion

The purpose of this study was to analyze the effect of 6-month aerobic exercise on physical function and mental health in young-old, old-old, and oldest-old. This study demonstrates that the 6-month KEP was associated with significant improvement in physical function based on the SPPB total score and chair stand score in oldest-old, old-old, and young-old groups. Moreover, the oldest-old group showed a significant increase in SPPB total score compared with the old-old and young-old groups. On the other hand, no significant differences between time and groups were identified for all of the mental health outcomes. However,

Table 3. Baseline and changes in mental health.

	Oldest-old group Mean (SD) (n = 8)		Old-old group Mean (SD) (n = 20)		Young-old group Mean (SD) (n = 22)		Group Effect ^c	Time Effect ^c	Group × Time Interaction ^c
	Baseline	6-month	Baseline	6-month	Baseline	6-month			
SF-12 (0-100) ^a									
PCS	29.04 (8.48)	35.52 (7.62)	40.79 (15.83)	44.11 (11.05)	47.10 (15.08)	45.58 (10.17)	< 0.05	< 0.05	n.s.
MCS	61.09 (10.13)	59.22 (4.81)	60.74 (8.69)	60.33 (9.83)	60.16 (8.53)	63.88 (6.28)	n.s.	n.s.	n.s.
PF	41.66 (13.36)	46.88 (20.83)	63.75 (30.86)	68.75 (21.27)	77.27 (26.62)	77.27 (24.29)	< 0.01	n.s.	n.s.
RP	66.66 (23.14)	86.11 (22.90)	75.02 (30.34)	98.75(5.59)	84.95 (23.64)	94.32 (15.30)	< 0.01	< 0.0001	< 0.05
BP	77.78 (8.33)	97.22 (8.33)	76.25 (18.98)	97.50 (7.69)	80.68 (15.30)	95.45 (9.87)	n.s.	< 0.001	n.s.
GH	62.22 (22.83)	64.44 (19.11)	74.50 (16.46)	71.50 (23.29)	78.86 (19.08)	75.92 (17.16)	< 0.05	n.s.	n.s.
VT	69.44 (20.83)	72.22 (15.02)	72.53 (19.70)	83.75 (18.63)	79.55 (21.32)	92.05 (11.92)	< 0.05	< 0.05	n.s.
SF	77.77 (8.33)	97.22 (8.33)	83.50 (21.61)	95.07 (13.08)	81.82 (19.18)	98.86 (5.33)	n.s.	< 0.01	n.s.
RE	77.78 (36.32)	96.88 (5.44)	83.75 (28.42)	99.01 (10.43)	92.05 (17.91)	95.45 (14.71)	n.s.	< 0.01	n.s.
MH	66.67 (21.65)	69.44 (16.67)	75.01 (19.02)	81.88 (12.48)	77.28 (16.65)	88.64 (11.51)	n.s.	< 0.05	n.s.
MMSE (0-30) ^a	24.13 (3.87)	25.13 (2.47)	26.10 (2.81)	26.90 (2.51)	26.91 (2.43)	27.95 (2.06)	< 0.05	< 0.01	n.s.
GDS (0-15) ^b	3.75 (2.25)	1.88 (2.17)	2.40 (2.60)	0.75 (0.97)	2.27 (3.34)	1.23 (1.27)	n.s.	< 0.01	n.s.
PSQI (0-21) ^b	7.50 (3.46)	5.25 (2.52)	8.45 (3.97)	4.40 (2.50)	5.77 (3.63)	3.23 (2.00)	n.s.	< 0.001	n.s.

SF-12, 12-Item Short-Form Health Survey; PCS, Physical Component Score; MCS, Mental Component Score; PF, Physical Functioning; RP, Role Physical; BP, Bodily Pain; GH, General Health; VT, Vitality; SF, Social Functioning; RE, Role Emotional; MH, Mental Health. PSQI, Pittsburgh Sleep Quality Index; GDS, Geriatric Depression Scale; MMSE, Mini-Mental Status Examination; n.s., not significant.

^aHigher score indicates better functioning.

^bLower score indicates better functioning.

^cTwo-way repeated measures ANOVA; p-value.

mental health scores from the SF-12 (PCS), MMSE, GDS, and PSQI improved after 6 months of KEP compared to baseline. To our knowledge, this is the first study to evalu-

ate the effect of the KEP intervention by age group.

Short et al. (2003) reported that aerobic exercise (45 min, 3 times per week for 16 weeks) was associated with

improvements in muscle mass. Shigematsu et al. (2002) reported that dance-based aerobic exercise (60 min, 3 times per week for 12 weeks) was effective at improving walking speed in older adults aged 65 years and over. These studies did not analyze results according to age subgroups, and did not report effects on mental health. Our results showed that 6 months of KEP aerobic exercise improved physical function in three age groups. In the oldest-old group, a significant difference was found in terms of physical function between baseline and after 6 months of KEP, and this group showed more improvement than the old-old and young-old groups. Moreover, KEP benefited mental health based on SF-12 (PCS), MMSE, GDS, and PSQI.

In adults aged over 75 years, several studies found that resistance exercise (60 min, 2 times per week for 14 weeks) and balance exercise (60 min, 1 time per week for 48 weeks) significantly decreased results on the 6MWT, TUG, and chair rising tests (Kalapotharakos et al. 2010; El-Khoury et al. 2015). Our results show that the effect of KEP on physical function is consistent with that of previous studies in oldest-old and old-old adults, and suggest that 6 months of lower limb aerobic exercise (45 min, 3 times per week) effectively increases physical function in these adults. Moreover, we found that community-dwelling oldest-old and old-old groups who underwent KEP showed similar improvements in physical function compared with the young-old group.

In oldest-old adults, short-term, light- to moderate-intensity exercise (50 min, 3 times per week for 8 weeks) and home-based walking training (5 times per week) was not effective for improving physical function as examined by leg press, gait speed, and balance (Luukinen et al. 2006; Serra-Rexach et al. 2011). In comparison to the results of these two studies (Luukinen et al. 2006; Serra-Rexach et al. 2011), the current investigation showed significant improvement in physical function between pre- and post-test results in oldest-old adults. Moreover, relative to two studies on short-term, light- to moderate-intensity exercise (50 min, 3 times per week for 8 weeks) and home-based walking training (5 times per week), the KEP exercise protocol (40 min, 3 times per week for 6 months) appears to be more readily achievable for oldest-old adults. Results showed that the frequency and duration of the intervention sessions in this investigation represent a training regimen that can be maintained by the oldest-old adults. Additionally, during the intervention period, no participant experienced fractures or joint or muscle pain due to the KEP. Thus, the KEP may provide a good model for lower limb exercise programs for oldest-old adults. Although this investigation could not clarify the effect of KEP because we did not include a control group, a statistically significant main effect of time was found in terms of physical function between the three groups. Therefore, the KEP may have the potential to enhance physical function.

The present study has several limitations. First, this study did not include a non-exercise group or control group.

Therefore, the results are potentially a result of nonspecific effects due to the placebo effect or simply the presence of an intervention. Second, the sample size was small. Finally, the effect of the KEP on mental health was weak. Previous study suggested that a long-term intervention period might be one of the determinants to obtain improvement in QoL (El-Khoury et al. 2015). Therefore, further studies are necessary to investigate the effect of long-term KEP intervention over a period greater than 6 months, and should include a control group and a larger sample.

In conclusion, our results suggest that a 6-month KEP (lower limb aerobic exercise program) led to improved physical function in oldest-old, old-old, and young-old adults. Moreover, the KEP may enhance mental health in oldest-old, old-old, and young-old adults. The KEP is feasible to implement and exhibits good adherence, making it suitable for older adults. The KEP protocol (40 min, 3 times per week for 6 months) may provide a good model for lower limb exercise programs for oldest-old adults in particular. Further studies are necessary to investigate the effect of long-term KEP intervention over a period greater than 6 months, and should include a control group and a larger sample.

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Conflict of Interest

Dr. Kohzuki has received a research grant from SHOWA-DENKI CO., Ltd. Other authors (Cho, Han, Sung, Lee, Kim and Ogawa) declare no conflict of interest.

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