Effects of Active Learning Education on Arterial Stiffness of Older Adults with Low Health Literacy: A Randomized Controlled Trial

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Aim: We examined the effects of active learning education on arterial stiffness and physical activity of community-dwelling older adults with low health literacy.

Methods: This study is a secondary analysis of randomized controlled trial of 60 participants aged 65 and older with low health literacy. The intervention group (n=30) participated in a weekly 90-minute active learning program session for 24 weeks, which addressed health promotion in older age. The control group (n=30) attended a 90-minute health education class in a didactic manner. The outcomes were measured at baseline and in week 24. The degree of arterial stiffness was assessed based on the cardio-ankle vascular index (CAVI) using the VS-1500 device (Fukuda Denshi Co., Ltd., Tokyo, Japan). The shortened version of the self-reported International Physical Activity Questionnaire was used to assess the amount of total physical activity determined by the metabolic equivalent hours per week. We used analysis by intention-to-treat, with multiple imputation for missing data.

Results: Seven participants (11.7%) dropped out prior to the post-intervention assessment. The multiple imputation analysis revealed that the intervention group showed significant improvement in CAVI [between-groups difference (95% confidence interval) -0.78 (-1.25 to -0.31), Cohen's d=0.82] and physical activity [32.5 (0.3 to 64.7), Cohen's d=0.57] as compared with the control group. The sensitivity analysis for the complete cases showed similar results.

Conclusion: Active learning health education may be effective in improving arterial stiffness and physical activity in older adults with low health literacy.

Key words: Physical activity, Cardiovascular, Preventative health care, Rehabilitation, Behavioral change

Introduction

Arterial stiffness is a major determinant of increased cardiovascular risk⁵. Pulse wave velocity (PWV) is considered the gold standard for a non-invasive measurement of arterial stiffness, but it has several limitations, including its sensitivity to the blood pressure level and the bias of distance determination⁶. Recently, the new cardio-ankle vascular index (CAVI) has been used by many research and clinical investigation centres to estimate arterial stiffness independently from blood pressure at the time of measurement⁷. Several studies have shown CAVI to be a valuable prognostic tool to predict cardiovascular events in different populations⁸-⁹. However, there is limited evidence to support the effects of therapeutic intervention on CAVI².

Health literacy is the ability to obtain, understand, appraise, and apply health information⁴. Low health literacy has been associated with greater healthcare services use⁹, poorer self-management of chronic diseases (e.g. diabetes)⁵, unhealthy lifestyles (e.g. physical inactivity)⁶, a higher mortality rate⁹, and a higher risk of arterial stiffness (CAVI ≥ 9.0) among community-dwelling older adults¹⁰. These findings suggest that older adults with low health literacy could
be at a higher risk of arterial stiffness and related cardiovascular events.

A randomized controlled trial (RCT) demonstrated that active learning education can effectively enhance one's physical activity, dietary habits, and physical function by improving one's health literacy\(^{14}\). We focused on active learning education, involving learners in higher-order thinking (e.g., evaluation, synthesis) and participation in activities (e.g., discussion, presentation, planning) rather than passive listening\(^{15}\), as an efficient alternative to training-based intervention. If active learning strategies can promote health literacy and physical activity, then it may also improve arterial stiffness. Therefore, in this study, we hypothesized that active learning education is associated with improvements in arterial stiffness. To test this hypothesis, we examined the effects of active learning education on CAVI and physical activity of community-dwelling older adults with low health literacy.

**Methods**

**Study Design**

This study is a secondary analysis of a single-blinded RCT, registered with the University Hospital Medical Information Network (UMIN) clinical trials registry (UMIN000023725). Participants were randomly allocated to the intervention group underwent 24-week active learning education (\(n=30\)), and the control group attended a didactic health education class (\(n=30\)). This study is different from the previous study in terms of the measures analysed. The previous study focused on the improvement of health literacy as primary outcome\(^{16}\), whereas the present study used arterial stiffness and self-reported physical activity as outcome measures. The local ethics committee (Toyama Prefectural University; approval no. H28-11) approved the study protocol. Outcome assessors were blinded to the group assignment.

**Participants**

Eligible participants included older adults who obtained a maximum score of 33 out of 50, an indicative of low health literacy, on the shortened version of the European Health Literacy Survey Questionnaire\(^{17}\). Individuals meeting the following criteria were excluded: (a) with disability that can affect the execution of basic and instrumental activities of daily living; (b) diagnosed with dementia; (c) with severe cardiac, pulmonary, or musculoskeletal diseases that can limit physical activity; or (d) participating in other research studies. Participants provided signed informed consent before participating in this study, in accordance with the Declaration of Helsinki in 1975.

**Intervention**

Intervention participants underwent a weekly 90-minute active learning program for 24 weeks. The themes of the program focused on the role of exercise, diet/nutrition, and cognitive activity in health promotion among older adults\(^{14}\). This program aimed to promote behavior changes in daily life and self-management in accordance with an individual's health status. Therefore, this weekly class was regarded as an opportunity that older adults can use to learn about and plan strategies to lead a healthy lifestyle. Participants were given a homework for each topic, in which they were instructed to search the assigned topic through books, on the internet, or using any other media. In the subsequent class, participants raised and discussed ideas. An overview of the group work results was provided to the entire class. Using their shared ideas and knowledge, participants planned a behavioral change and implemented healthy behaviors in daily life based on such plans. Additionally, the extent to which the participants were leading a healthy lifestyle was regularly reviewed as a part of the group work. Group work was conducted with small groups of 4 to 5 participants. They self-monitored their physical activity using an accelerometer, then recorded the data on a notebook.

For 24 weeks, control participants attended a 90-minute health education class, which was taught using the didactic teaching method. Although the themes of the program were similar to those in the intervention group, active learning strategies were not used. Control participants received brochures about leading a healthy lifestyle in older adulthood, which delineated the importance of physical activity (e.g., walking, strength training), a balanced diet, and appropriate medical consultation.

**Measurements**

**Arterial Stiffness Measurement**

CAVI was determined using a VS-1500 vascular screening system (Fukuda Denshi Co., Ltd., Tokyo, Japan). CAVI is an indicator of arteriosclerosis that reflects vascular stiffness, which is measured by the pulse wave velocity between the heart and the ankle; the Bramwell-Hill equation is used, based on the stiffness parameter \(\beta\) theory\(^{18}\). The electrocardiogram, phonocardiogram, and pressures and waveforms of brachial and ankle arteries were measured in the supine position. CAVI was calculated automatically for right and left side and its mean values on both sides were used in the analysis. As peripheral artery
disease can affect the accuracy of CAVI, we also ensured and confirmed that none of the participants had this disease, as evidenced by their ankle-brachial indices (ABI) of less than 0.9.

**Physical Activity**

The shortened version of the self-reported International Physical Activity Questionnaire (IPAQ)\(^{(19)}\) was used to assess physical activity. Participants were asked about the frequency (days/week) and duration (minutes/day) of their physical activities in three levels (walking, moderate- and vigorous-intensity activities). Moderate-intensity activities were defined as those that cause a person to breathe somewhat more heavily than normal, and vigorous activities were defined as those that cause a person to breathe more heavily than normal. They were weighted by their energy requirements as metabolic equivalents (MET), with one MET equating to around one kcal/kg/hour, which approximately corresponds to sitting quietly (3.3 for walking, 4.0 for moderate physical activity, and 8.0 for vigorous physical activity). Therefore, the IPAQ scores were a combined measure of the amount and intensity of physical activity (computed by multiplying the MET score by hours performed within a week) in terms of MET-hour per week (MET-h/week)\(^{(20)}\). Total physical activity, as an outcome measure, was calculated by the sum of the three levels of activity.

**Demographic and Clinical Characteristics**

Participants’ age, sex, educational level, living circumstance, and body mass index were recorded. Their medical conditions (e.g., presence of chronic diseases, the total number of prescribed medications, and smoking status) were assessed. We used the Mini-Mental State Examination (MMSE)\(^{(21)}\) and Timed Up & Go Test (TUG)\(^{(22)}\) to assess global cognitive function and physical performance. Frailty status was determined according to Fried criteria\(^{(23)}\).

**Statistical Analysis**

The normality of the measured variables was assessed using visual inspection of the data frequency distribution and the Shapiro-Wilk test. Continuous variables are presented as mean ± SD and were compared between the intervention and control groups using independent sample \(t\) tests. Non-normally distributed data are presented as median (IQR) and were compared using the Mann-Whitney test. Categorical variables are expressed as \(n\) (%) and were compared using chi-square tests. We compared changes in CAVI and physical activity at 24 weeks from the baseline by group, using independent samples \(t\) tests. Following the intention-to-treat approach, multiple imputation for missing data on the study outcomes was conducted (based on 20 replications), assuming missing at random. We performed a complete case analysis on participants who underwent post-intervention assessment to test sensitivity. All analyses were conducted using SPSS version 25 (IBM Corp., Chicago). Cohen’s \(d\) values were calculated as measures of effect size.

**Results**

Fig. 1 presents the trial profile. Thirty participants were allocated to each of the intervention (age = 74.0 ± 4.9; sex = 33.3% male) and control (age = 73.9 ± 4.4; sex = 33.3% male) group. Table 1 shows baseline demographic characteristics and health-related variables. Seven participants (11.7%) dropped out prior to the post-intervention assessment (intervention group: 2 had medical problems and 2 refused to continue; control group: 1 had medical problems and 2 refused to continue). The median attendance rate in the weekly class of the active learning program was 91.7% (IQR = 87.5–96.9). During the study period, 3 adverse events (i.e., 2 hospitalizations in the intervention group and 1 hip fracture in the control group) were reported, but none of them were attributable to participation in the intervention program.

The primary imputed analysis showed a significantly greater improvement in CAVI [between-groups difference (95% confidence interval) = -0.78 (-1.25 to -0.31), \(d=0.82\)] and total physical activity [32.5 (0.3 to 64.7), \(d=0.57\)] in intervention group than in control group (Table 2). Results of the complete case analysis showed a significantly greater improvement in CAVI [-0.70 (-1.19 to -0.21), \(d=0.83\)] and total physical activity [34.6 (1.2 to 67.9), \(d=0.51\)] in intervention group than in control group, which did not differ qualitatively from those in the intention-to-treat data-set.

**Discussion**

Findings of the RCT showed that a 24-week active learning education improves CAVI and self-reported physical activity among older adults with low health literacy. Some pharmacological (i.e. lipid-lowering and anti-diabetic drugs) and non-pharmacological (i.e. smoking cessation and weight reduction) treatments have been reported to be associated with an improvement in CAVI of patient population\(^{(2, 24-26)}\). This RCT is the first to demonstrate the effectiveness of educational intervention on improving CAVI of older adults with low health literacy. The low attrition rate (≤ 15%)\(^{(27)}\) and low risk of adverse events for active
learning education support the applicability to older individuals with low health literacy.

We suppose that increased physical activity mainly contributed to the decrease in CAVI. A longitudinal study showed that adopting a physically active lifestyle is associated with a lower risk of arterial stiffness in older adults. Another study reported that healthy older adults, who underwent an exercise program, including Tai Chi sessions thrice a week, experienced a significant improvement in CAVI after six months of intervention; however, the effects were not maintained after decreasing the frequency to twice a week. Our active learning education aimed to promote not only exercise in the class but also physical activity in daily life, which may contribute to sustainable behavioral changes and improvements in CAVI. Prolonged effects on physical activity improvement were found at 24-week follow-up assessments after intervention cessation.

Our active learning program provided the participants the opportunity for improving their abilities of self-management through learning process, including exploration of health promotion, sharing information with other group members, and application for preventive health-care in daily life. The collaborative learning style, which is one of the key elements of active learning, may have also enhanced social interaction and boosted the individuals' motivation to increase regular physical activities even among participants with low health literacy, who are less likely to engage in physical activity.

Compared with training-based intervention, active learning education has advantages, including its effectiveness, habituation of physical activity in daily life, and affordability. Active learning education does not need any of the training machines (i.e., bench step, treadmill, and cycle ergometer) and vigorous-intensity exercises (>60% heart rate reserve) that were used in the training programs in previous studies that aimed to decrease arterial stiffness in older adults. A meta-analysis that included those studies reported that arterial stiffness measured by PWV was decreased.
### Table 1. Baseline demographic and study outcomes by group

| Characteristic                          | Intervention group (n = 30) | Control group (n = 30) | p   |
|----------------------------------------|----------------------------|-----------------------|-----|
| Age, years                             | 74.0 ± 4.9                 | 73.9 ± 4.4            | 0.93<sup>a</sup> |
| Sex, male                              | 10 (33.3)                  | 10 (33.3)             | 1.00<sup>b</sup> |
| Education, years                       | 12.0 (9.0–13.3)            | 12.0 (11.3–13.3)      | 0.61<sup>c</sup> |
| Living alone                           | 6 (20.0)                   | 5 (16.7)              | 0.74<sup>b</sup> |
| Body mass index, kg/m<sup>2</sup>      | 22.7 ± 2.5                 | 22.7 ± 3.6            | 0.97<sup>a</sup> |
| Mini-Mental State Examination, point (range 0–30) | 28.5 (26.0–30.0)          | 28.0 (26.0–29.0)      | 0.63<sup>c</sup> |
| Smoking                                |                            |                       |     |
| Current                                | 2 (6.7)                    | 0 (0)                 |     |
| Former                                 | 7 (23.3)                   | 4 (13.3)              |     |
| Never                                  | 21 (70.0)                  | 26 (86.7)             |     |
| Frailty status                         |                            |                       | 0.36<sup>b</sup> |
| Robust                                 | 14 (46.7)                  | 15 (50.0)             |     |
| Pre-frailty                            | 14 (46.7)                  | 15 (50.0)             |     |
| Frailty                                | 2 (6.6)                    | 0 (0)                 |     |
| Timed Up & Go test (kg)                | 7.2 (6.7–7.7)              | 7.2 (6.6–7.9)         | 0.95<sup>c</sup> |
| Chronic conditions: n (%)              |                            |                       |     |
| Hypertension                           | 12 (40.0)                  | 15 (50.0)             | 0.51<sup>b</sup> |
| Diabetes mellitus                      | 3 (10.0)                   | 2 (6.6)               | 1.00<sup>b</sup> |
| Hyperlipidemia                         | 8 (26.7)                   | 6 (20.0)              | 0.54<sup>b</sup> |
| Heart disease                          | 3 (10.0)                   | 4 (13.3)              | 1.00<sup>b</sup> |
| Osteoporosis                           | 3 (10.0)                   | 7 (23.3)              | 0.17<sup>b</sup> |
| Number of medications used             | 1.0 (0–3.0)                | 2.0 (1.0–3.0)         | 0.25<sup>c</sup> |
| Arterial stiffness                     |                            |                       |     |
| CAVI                                   | 9.5 ± 1.1                  | 9.1 ± 1.3             | 0.14<sup>a</sup> |
| Increased arterial stiffness (CAVI > 9.0) | 21 (70.0)                | 19 (63.3)             | 0.58<sup>b</sup> |
| Physical activity                      |                            |                       |     |
| Total physical activity (MET-h/week)   | 31.8 (7.6–73.5)            | 41.7 (14.7–80.9)      | 0.39<sup>c</sup> |

Note. Values represent mean ± SD or median (IQR) or n (%). Abbreviations: CAVI = cardio-ankle vascular index; MET = metabolic equivalent.

<sup>a</sup>Calculated using the independent samples t test.

<sup>b</sup>Calculated using the chi-square test.

<sup>c</sup>Calculated using the Mann-Whitney test.

### Table 2. Within- and between-groups differences in outcome measures among older adults between baseline and week 24

|                      | Changes between baseline and week 24 |
|----------------------|-------------------------------------|
|                      | Intervention group                  | Control group                  | Between-group |
|                      | Within-group differences (95 % CI)  | Within-group differences (95 % CI) | Between-groups differences (95 % CI) | p   | Effect size (Cohen’s d) |
| Multiple imputation analysis |                          |                                   |             |     |                         |
| CAVI<sup>§</sup>        | -0.44 (-0.77 to -0.10)             | 0.34 (-0.003 to 0.69)           | -0.78 (-1.25 to -0.31) | 0.001 | 0.82                     |
| Total physical activity (MET-h/week)<sup>§</sup> | 34.8 (11.9 to 57.7)               | 2.3 (-20.0 to 24.7)            | 32.5 (0.3 to 64.7)     | 0.048 | 0.57                     |
| Complete case analysis  |                          |                                   |             |     |                         |
| CAVI<sup>§</sup>        | -0.42 (-0.76 to -0.08)             | 0.28 (-0.07 to 0.64)           | -0.70 (-1.19 to -0.21) | 0.006 | 0.83                     |
| Total physical activity (MET-h/week)<sup>§</sup> | 34.8 (10.9 to 58.6)               | 0.2 (-23.2 to 23.6)            | 34.6 (1.2 to 67.9)     | 0.043 | 0.51                     |

Notes. * A negative difference between the means of the two groups indicates that improvements are greater in the intervention group than in the control group.

<sup>§</sup> A positive difference between the means of the two groups indicates that improvements are greater in the intervention group than in the control group.

Abbreviations: CAVI = cardio-ankle vascular index; MET = metabolic equivalent.
in aerobic trained groups as compared with controls, and the standardized mean difference was 0.44 in the older age subgroup (mean age ≥ 52.5 y) 34. According to the Cohen guidelines 35), this effect is considered small to medium. Meanwhile, our education program showed a large effect size (Cohen's $d=0.82$) without both special equipment and exercise prescription by professionals. It was much larger even when compared with the effects size of the exercise intervention study that used CAVI as the outcome (Cohen's $d=0.26$) 29. Although our program is based on education and supposed to require lower physical burden than training-based intervention, the characteristics to promote self-reliant efforts in daily life other than the weekly classes may contribute to the larger effect sizes. According to the above-mentioned advantages, active learning education can be considered as the suitable intervention to improve arterial stiffness and physical activity in terms of both effectiveness and feasibility in the community.

CAVI has been used in clinical settings and recognized as a strong predictor of cardiovascular events 36). Otsuka and colleagues 5 investigated changes in CAVI after management of atherosclerotic risk factors and whether these changes influenced the incidence of future cardiovascular events in patients with coronary artery disease (mean age 65 years). The results showed that the subjects with improvement in CAVI 6 months later had a lower risk of cardiovascular events during follow-up (2.9 years) than those without improvement. Taniguchi and colleagues 37) identified four trajectory patterns with advancing age for brachial-ankle PWV among community-dwelling older adults and demonstrated that individuals with very high PWV had a higher risk of all-cause mortality. Thus, it seems to be important for lowering the risk of the negative consequences to improve arterial stiffness, which progressively increases with aging, through therapeutic interventions, including the promotion of healthy lifestyles.

This study was limited by a small sample size and its failure to conduct follow-up assessments. A follow-up study must determine whether the beneficial effects of active learning education on arterial stiffness can be maintained beyond intervention cessation. Additionally, the mechanism of improvement in arterial stiffness has not been completely clarified. Not only expected mediating factors (e.g. healthy lifestyles), but also some unexpected confounding factors might affect the effects of active learning education.

**Conclusion**

We demonstrated the beneficial effects of active learning education on arterial stiffness, based on improvements in CAVI and the self-reported physical activity of older adults with low health literacy. According to its advantages, including the large effect size and affordability, active learning education in a community-based prevention program may favorably contribute to the improvements of arterial stiffness and physical activity.

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**Conflict of Interest**

None.

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