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Original article

Cardiac and pulmonary benefits of forest walking versus city walking in elderly women: A randomised, controlled, open-label trial

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Abstract

Introduction: Interest increases in the role of the natural environment providing health benefits. This study compared forest and city walking on arterial stiffness and pulmonary function.

Methods: A single-centre, parallel, randomised, and controlled, open-label trial was conducted. Seventy women >60 years were recruited into the study. The forest-walking group walked around a forested area for 1 h. The city-walking group walked around an urban area for 1 h. Blood pressure, arterial stiffness (CAVI), and pulmonary function (FEV1, FEV6) were assessed before and 30 min after the walking activity.

Results: Of the 70 women randomly assigned to the forest walking ($n = 50$) or city walking ($n = 20$) groups. Eight participants were excluded from analysis due to early dropout leaving43 participants in the forest-walking group and 19 in the city-walking group. One hour of forest walking significantly improved CAVI ($p < 0.01$), FEV1 ($p < 0.01$) and FEV6 ($p < 0.01$). No significant change was observed in the city-walking group. There were significant differences in changes of CAVI ($p < 0.01$), FEV1 ($p = 0.02$), and FEV6 ($p = 0.04$), between the city-walking and the forest-walking groups. No significant side effects were reported.

Conclusion: Our results showed that forest walking improved arterial stiffness and pulmonary function in 61 elderly Korean women. Further large scale and long-term studies are needed to better understand the clinical significance of these findings. Clinical trial registered with www.cris.org (KCT0000631).

Keywords: Forest environment; Arterial stiffness; Pulmonary function; Phytoncides; Exercise; Walking

Introduction

There is growing interest in the role of environment in human health. Environmental stressors such as air pollution and crowding in urban areas substantially increases stress [1]. In contrast, the natural environment has positive health effects [2]. A forest environment is one of the most accessible ways to experience the natural environment. Forests have been considered human resting places for a long time because of their beautiful scenery, fresh air, and quiet atmosphere. In Korea, forest bathing and "taking in" the forest atmosphere are the most popular activities associated with forests [3]. Many studies have evaluated the effects of forest bathing on human health [4–9]. Walking in forests has been shown to reduce levels of stress hormones [4,5], sympathetic nerve activity [6,7], and anxiety [7]. In addition, green spaces, such as forests and urban parks, are considered to help people recover from mental stress through soft stimulation without additional mental effort [1]. A previous study demonstrated EEG changes in participants who moved closer to trees in the urban city (green space) [8]. The EEGs indicated reduced frustration and arousal with an increased meditative state. Recent studies show that forest environments also affect cardio-metabolic parameters. Walking in a forest significantly reduces blood pressure [6,4] and fasting glucose levels [9]. Although the precise mechanism(s) underlying these findings is unknown, the harmonies of each forest element are considered important. Among them, many have studied the beneficial roles of tree phytoncides (tea tree oils). Phytoncides regulate autonomic function [10] and have anti-oxidant properties [11] that affect the human body both through the olfactory pathway and the blood stream.

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Atherosclerosis is one of the most common diseases among the elderly and significantly increases the risk of cardiovascular disease and mortality [12,13]. Chronic activation of sympathetic tone [14], and increased oxidative stress [15,16], with aging, promote atherosclerosis. Pulmonary function decreases with age [17,18] and can lead to adverse outcomes and mortality in older populations [19,20]. Although various factors affect pulmonary function, chronic accumulation of oxidative stress [21,22] and autonomic dysfunction [23] are known to lead to a decline in pulmonary function.

Because forest environments have been associated with changes in the autonomic nerve system and have anti-oxidant and anti-inflammatory properties, forest environments may also affect arterial stiffness and pulmonary function; however, current studies have not evaluate these relationships, and contain little information about the effects of forests on the elderly. We, therefore, investigated the acute effects of forest walking on arterial stiffness and pulmonary function in Korean elderly women.

Methods

Participants

We completed an unbalanced, randomised [2:1], open-label, parallel-group study involving people aged 60–80 years conducted in Korea. The study population was recruited by advertisement at the Senior Welfare Center in Mokpo City. Although we intended to recruit males and females, more than 95% of participants were female by the time approximately 50% of participants had been recruited. Therefore, we added the inclusion criteria that participants must be females aged 60–80 years. All subjects participated in the study voluntarily, and written informed consent was obtained from each participant. The study complied with the Declaration of Helsinki and the institutional review board of Yonsei University College of Medicine approved this study.

Participants with a history of chronic liver disease, chronic renal disease, coronary artery occlusive disease, cerebrovascular disease, dementia, and/or cancer were excluded. Women who had difficulties with walking because of disability or pain were also excluded as were participants with blood pressures higher than 160/100 mmHg. This resulted in 70 subjects who were then included into the study. Screening interviews were conducted at the public health center by a trained nurse.

Participants were randomly assigned to groups by computer-generated random selection of numbers. This simple randomisation procedure resulted in a 1:2 allocation into the forest versus city-walking group. Participants were asked to visit the public hospital of Mokpo city on either November 17th or 24th 2012 at 7:00 am and were not informed about their group assignment. Random allocation and assignment were performed by nurses working in the public hospital in Mokpo city. They assisted the study process as volunteers who were not involved in data analysis.

Study design

The forest-walking and the city-walking experiments were conducted separately (1 week apart) on different days. On Saturday, November 17, 2012, the forest-walking group visited the pyunback tree (*Chamaecyparis obtuse*) forest in Janghung, Mokpo City. The altitude of the forest was 150 m, and the surface was flat without inclines or declines. On Saturday, November 24, 2012 the city-walking group visited an urban area in Mokpo City. To control for variance, city walking took place at an altitude and on a surface similar to those in the forest setting. The altitude of the urban area was 50 m, and the surface was flat, paved, and lacked inclines or declines and lacked trees. On November 17, during the forest walking, the weather was clear, temperatures ranged from 13.3 to 20.1 °C, and humidity was 52.3%. The date for city-walking was selected based on a similar weather forecast. Walking in the city took place on November 24. The weather was also clear, the temperatures ranged from 14.4 to 19.4 °C, and humidity was 55.4%.

Participants walked at their usual pace for 1 h in the morning around the forest/urban area. Participants were educated about the walking protocol before the study began. Walking at a usual pace was defined as walking with normal breathing and without sweating, becoming over heated, or experiencing palpitations, and as if they were moving between the rooms in their house at a relaxed pace. Five assistants were placed in the walking area (within 10 km from the starting places) in case of an accident or a participant became lost. Assistants also monitored walking speed and distance. Participants were not permitted to go further than 10 km from the starting places. During the period of walking, we restricted entry of non-participants into the walking areas. Anthropometric, arterial stiffness, and pulmonary function measurements were obtained before and 30 min after walking activities. All of the measurements took place in a comfortable and quiet room, and each measurement was performed by one well-trained family medicine doctor. Because each test required about 5 min for completion, we divided participants into three groups to reduce the time and to standardize the time point for the forest- and city-walking groups. To control for the effects of caffeine and alcohol, the participants were not allowed to consume beverages that contained caffeine or alcohol during the experiments.

Measurements

All subjects completed a questionnaire about lifestyle, including smoking, alcohol consumption, and exercise. Smoking was defined as current cigarette smoking, and alcohol consumption was defined as either drinking alcohol more frequently than once per week or drinking 70 g or more of alcohol per week. Regular exercise was defined as physical exercise performed three times per week for either 30 min or more. The hypertension group ($n = 21$) was defined as subjects who used anti-hypertensive medicine; the diabetes group ($n = 9$) was defined as subjects who used either insulin or oral hypoglycemic medicine; and the dyslipidemia group ($n = 5$) was defined as subjects who used a lipid-lowering agent. Blood pressure was measured in the subjects' right arms in sitting positions after a 10-min resting period using a mercury sphygmomanometer (Baumanometer®, W.A. Baum Co., Copiague, NY, USA). Blood pressure was measured twice for each subject, with 5-min intervals. We recorded average values for the analysis. The inter-assay coefficient of variation (CV) for blood pressure was 7.2%. It was calculated from two repeated measurements of blood pressure obtained at more than 1-week intervals in 20 elderly women. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Each subject was standing when the waist circumference was measured midway between the lowest ribs and the iliac crest [24].

Measurement of pulmonary function

Pulmonary function was measured with a portable, Vitalograph, Copd-6 meter. One well-trained family medical doctor performed all spirometric tests in a standardized manner to reduce variability. In a sitting position, participants took a deep breath and inserted the mouthpiece into their mouths while holding their breath. The subjects blew vigorously and continuously for 6 s. After 6 s, the device alarm beeped to inform the participants that they could stop blowing. During the exercise, we recorded forced expiratory volume in 1 s (FEV1) and forced expiratory volume in 6 s (FEV6). The maneuver was performed three times for each subject and we selected the best values in each case. The inter-assay CV values of pulmonary function (FEV1, FEV6) provided by the manufacturer were less than 3%.

Measurement of CAVI

Cardio-ankle vascular index (CAVI) is a measure of arterial stiffness of the artery from the heart to the ankles. As arteriosclerosis progresses, the CAVI value becomes higher. Lowered extensibility of the aorta causes onset of heart disease and is a factor determining prognosis. CAVI was measured with a VaSera VS-1000 instrument (Fukuda Denshi Co. Ltd., Tokyo, Japan), using previously described methods [25]. Subjects were examined in their supine position after 10 min of bed rest. Electrocardiogram electrodes were placed on both wrists and a phonocardiogram was placed on the right sternum border of the second intercostal space. Cuffs were applied around both upper arms and ankles to detect brachial and ankle pulse waves. Pulse wave velocity was measured by dividing pulse wave length by the time needed for the pulse wave to propagate from the aorta, through the femoral artery, to the tibal artery of the ankle. CAVI was calculated as:

$$\mathrm{CAVI} = a\left[\frac{2\rho}{\Delta P} \times \ln\left(\frac{P_s}{P_d}\right) PWV2\right] + b,$$

where P_s, systolic pressure, P_d, diastolic pressure, $\Delta P = P_s - P_d$, p = blood density, and a and b were constant. We recorded mean values of right and left CAVI. The inter-coefficient of variance (CV) value of CAVI was 1.9%. The inter-assay CV value of CAVI calculated from two repeated measurements obtained at more than 1-week intervals in 20 elderly women was 3.9%.

Statistical analysis

We evaluated our study sample size with a two-sample inequality *t*-test, using PASS v2008 (NCSS statistical software, Kaysville, UT, USA). Our intended study sample provided a power of 80% for a one-sided $\alpha = 5\%$, assuming an average CAVI change of 0.5 [standard deviation (SD) = 0.6] between the forest- and city-walking groups. The calculated sample size was 54, with 1:2 ratio between the city- and forest-walking groups. The expected dropout rate was 20%.

Data are presented as means ± SDs. A Kolmogrov–Smirnov goodness of fit test was performed to determine normality. To test for significant differences from the baseline, we used a paired *t*-test, for normally distributed data (systolic BP and diastolic BP), and a Wilcoxon paired rank test, for non-normal data (CAVI, FEV1 and FEV6). The differences of mean changes between the two groups were compared with a Student's *t*-test, for normally distributed data (systolic BP and diastolic BP), and a Mann-Whitney *U* test for non-normal data (CAVI, FEV1 and FEV6).

We performed all statistical analyses using the Statistical Package for the Social Sciences, v18.0, of SPSS (Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

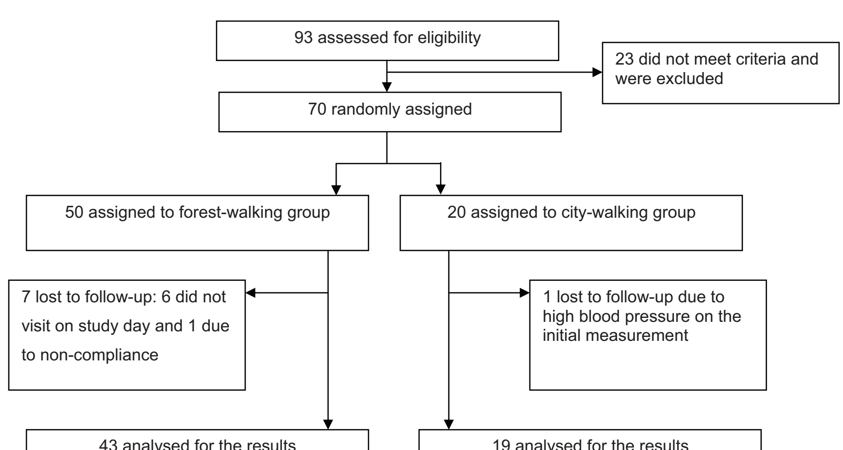

Fig. 1. Flowchart of study design and subject participation.

Table 1
Basic baseline characteristics.

Variables	City-walking group	Forest-walking group	p-Value
Subjects, n	19	43	
Age (years)	71.11 ± 5.80	70.19 ± 4.66	NS
BMI (kg/m^2)	23.18 ± 2.70	24.32 ± 4.75	NS
Waist circumferences (cm)	83.44 ± 7.99	85.12 ± 7.57	NS
Blood pressure (mmHg)			
Systolic	127.78 ± 15.14	122.30 ± 14.01	NS
Diastolic	81.83 ± 11.67	76.51 ± 11.16	NS
CAVI[a]	8.59 ± 0.98	8.32 ± 1.22	NS
Pulmonary function			
FEV1[a] (L)	1.71 ± 0.39	1.54 ± 0.49	NS
FEV6[a] (L)	2.16 ± 0.51	2.03 ± 0.59	NS
Alcohol (n, %)	2 (10.5)	10 (23.3)	NS
Regular exercise (n, %)	6 (31.6)	19 (44.2)	NS
Hypertension (n, %)	8 (38.1)	13 (30.2)	NS
Diabetes (n, %)	3 (15.8)	6 (14.0)	NS
Dyslipidemia (n, %)	1 (5.3)	4 (9.3)	NS

Data are expressed as mean ± SD or numbers (percentages). A Kolmogrov–Smirnov goodness of fit test was performed to determine normality.

[a] Values were non-normally distributed.

NS: not significant. Smoking was defined as current cigarette smoking. Alcohol consumption was defined as either drinking alcohol more frequently than once per week or drinking 70 g or more of alcohol per week. Regular exercise was defined as physical exercise performed three times per week for 30 min or more. The hypertensive group was defined as subjects who used anti-hypertensive medicine. The diabetes group was defined as subjects who used insulin or oral hypoglycemic medicine. The dyslipidemia group was defined as subjects who used a lipid-lowering agent. BMI, body mass index; CAVI, coronary-ankle vascular index; FEV1, forced expiratory volume for 1 s; FEV6, Forced expiratory volume for 6 s.

Results

Of 50 people in the forest-walking group, six withdrew because they could not reach? The study place on time, and one discontinued during the study because of non-compliance. Of 20 subjects in the city-walking group, one was excluded because of initial high blood pressure (systolic blood pressure >200 mm Hg; participant moved to the public health center in Mokpo for assistance). We obtained final data for 43 participants in the forest-walking group and 19 participants in the city-walking group (Fig. 1).

Table 3
Mean changes in the clinical variables, during the study period for city-walking and forest-walking groups.

Variables	City-walking group	Forest-walking group	p
Blood pressure (mmHg)			
Systolic	−0.78 ± 11.52	−8.16 ± 12.57	0.03
Diastolic	−0.78 ± 5.96	−7.35 ± 8.20	<0.01
CAVI	−0.11 ± 0.51	−0.42 ± 0.72	<0.01
Pulmonary function			
FEV1 (L)	0.01 ± 0.18	0.19 ± 0.26	0.02
FEV6 (L)	0.04 ± 0.20	0.22 ± 0.36	0.04

Data are expressed as mean ± SD. p-Values were calculated with a Student's t-test, for normally distributed data (systolic BP and diastolic BP), and a Mann-Whitney U test, for non-normal data (CAVI, FEV1 and FEV6).

Baseline characteristics of study participants are described in Table 1. There were no significant differences between city- and forest-walking groups in age, BMI, waist circumference, baseline blood pressure, baseline CAVI, and baseline pulmonary function. The frequency of alcohol intake, regular exercise, hypertension, diabetes, and dyslipidemia were also similar in both groups.

Table 2 shows the clinical variables, at baseline and after intervention. In the city-walking group, no significant changes in blood pressure, CAVI, and pulmonary function occurred after the walking activity. Walking in the forest, however, significantly decreased systolic blood pressure, diastolic blood pressure, and CAVI, and it significantly increased FEV1 and FEV6 ($p < 0.01$).

Table 3 and Fig. 2 show the changes in clinical variables between the city- and forest-walking groups during the study period. Significant differences in changes in systolic blood pressure ($p = 0.03$), diastolic blood pressure ($p < 0.01$), CAVI ($p < 0.01$), FEV1 ($p = 0.02$), and FEV6 ($p = 0.04$) between the city- and forest-walking groups occurred. No significant side effects or harmful events were reported during the intervention in either group.

Discussion

In this randomized, controlled study, we found that forest walking significantly improved arterial stiffness as measured by

Table 2
Clinical variables at baseline, and after intervention, for city-walking and forest-walking groups.

Variables	City-walking group (n = 19)			p	Forest-walking group (n = 43)			p
	Baseline	After city walking	Mean differences		Baseline	After forest walking	Mean differences	
Blood pressure (mmHg)								
Systolic	127.78 ± 15.14	129.78 ± 14.53	2.00 ± 17.51	NS	122.30 ± 14.01	112.05 ± 16.77	−10.26 ± 13.11	<0.01
Diastolic	81.83 ± 11.67	83.11 ± 8.94	1.28 ± 8.55	NS	76.51 ± 11.16	66.58 ± 13.70	−9.93 ± 11.15	<0.01
CAVI	8.59 ± 0.98	8.70 ± 0.86	0.11 ± 0.51	NS	8.32 ± 1.22	7.90 ± 1.09	−0.42 ± 0.72	<0.01
Pulmonary function								
FEV1 (L)	1.71 ± 0.39	1.72 ± 0.41	0.01 ± 0.04	NS	1.54 ± 0.49	1.73 ± 0.42	0.19 ± 0.26	<0.01
FEV6 (L)	2.16 ± 0.51	2.19 ± 0.55	0.04 ± 0.20	NS	2.03 ± 0.59	2.26 ± 0.51	0.22 ± 0.36	<0.01

Data are expressed as mean ± SD. p-Values were calculated with paired t-tests, for normally distributed data (systolic BP and diastolic BP), and Wilcoxon paired rank tests, for non-normal data (CAVI, FEV1 and FEV6). NS: not significant. CAVI, coronary-ankle vascular index; FEV1, forced expiratory volume for 1 s; FEV6, forced expiratory volume for 6 s.

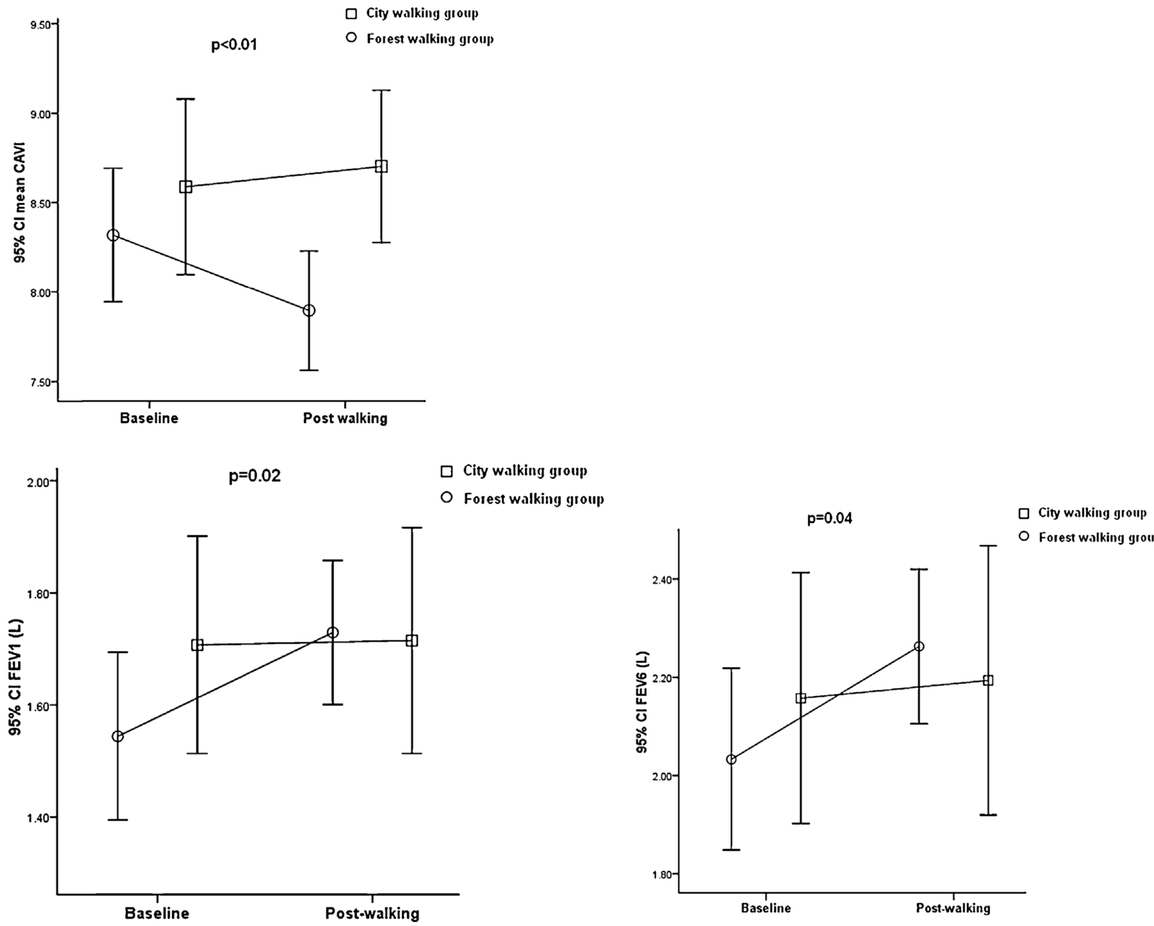

Fig. 2. Mean changes in arterial stiffness (CAVI) and pulmonary function (FEV1, FEV6) for forest walking versus city walking at baseline and after walking *p*-values represent the significance of between-group differences in variable changes from baseline to post-walking. Error bar = 95% confidence interval (CI).

CAVI and pulmonary function. These changes were not significant in the city-walking group.

Forest environments have many positive effects on human health, reducing stress levels and enhancing relaxation. Walking in forests is known to increase human immune function, reduce stress hormone levels, and regulate autonomic function [6,7,4,26]. Although many studies identify the health benefits of forest environments, none have tested for changes in arterial stiffness and pulmonary function. To the best of our knowledge, this is the first study that has evaluated the effect of forest environments on the elderly.

In our study, both systolic and diastolic blood pressure decreased significantly after forest walking, but did not change after city walking. This is consistent with previous studies: Park et al. [26] reported a blood pressure lowering effect after 20 min of forest walking in young male students; and Li et al. [4] showed similar results in healthy, middle-aged, males. In contrast to these studies, we enrolled subjects >60-years-old, for which the prevalence of hypertension was much higher. We believe studying the effects of forest walking on blood pressure in the elderly, who have a higher prevalence of hypertension and other cardiovascular risk factors, is important.

The precise mechanisms that underlie the effects of forest walking on arterial stiffness and pulmonary function remain unclear. We hypothesise the following. Firstly, forest environments have anti-oxidant and anti-inflammatory properties, such as those of phytoncide substances [10–12] produced by the trees [11]. An *in vivo* study showed a phytoncide solution to have a protective effect against reactive oxygen species, on human dermal fibroblasts [27]. The Pyunbak forest where we conducted the forest-walking study has a large number of *C. obtuse* trees that occupies more than 65 ha. *C. obtuse* has various phytoncides, including α-pinene, β-pinene, tricyclene, camphene, and limonene [28]. Given that oxidative stress contributes to the development of atherosclerosis by disrupting redox balance in the arterial wall, altering the vascular cell adhesion molecule, and increasing vascular smooth muscle cell growth [16]; an antioxidant can have an anti-atherogenic effect [15]. In a previous study, a one-day experience in a forest significantly increased serum adiponectin levels [4]. Adiponectin is an adipocytokine that has anti-inflammatory and anti-atherogenic properties [29]; therefore, the anti-oxidant and anti-inflammatory properties of forest environments may influence arterial stiffness. Oxidative stress and inflammation are also related to a decline in lung function; oxidative stress stimulates mucus production in epithelial cells and lung parenchymal inflammation, thereby limiting the airway by narrowing its lumen of airway [30,31]. Anti-oxidant and anti-inflammatory properties of forest environments may therefore have a protective effect on both vascular and pulmonary function.

Secondly, changes may occur in the autonomic nervous system. Forest walking significantly reduces urine adrenaline and noradrenaline levels, which reflect sympathetic nerve activity [4]. Similarly, forest walking decreases the average low frequency/high frequency ratio of heart rate variability, which is associated with sympathetic nerve activity and increases the average power of the high frequency components associated with parasympathetic nerve activity [7,26]. The autonomic nervous system has an important role in the regulation of the human organ system, including cardiovascular and pulmonary systems [32]; the sympathetic nervous system increases the tone of vascular smooth muscle; and the parasympathetic nervous system has the opposite role [33]. Impaired vaso-dilation is one of many factors that worsens arterial stiffness [34]. The autonomic nervous system also affects the bronchial smooth muscle cells. The parasympathetic nervous system relaxes bronchial smooth muscle, which has a positive effect on pulmonary function [35]. Forest environments may have positive effects on arterial stiffness and pulmonary function by increasing parasympathetic nervous system activity and by decreasing sympathetic nervous system activity.

Finally, air pollution in the city may also explain our results. Air pollution has various negative effects on human health, including effects on pulmonary and cardiovascular functions. Inhaled diesel exhaust and ozone gases increase cellular inflammation and oxidative stress in the respiratory system and amplify allergic reactions [36], which can compromise pulmonary function [37] and cause adverse effects on asthma [38]. Air pollution also has adverse effects on cardiovascular function through various mechanisms, including activation of the sympathetic nervous system, increased systemic inflammation, endothelial dysfunction, and direct harmful effects on the cardiovascular system [39]. Acute exposure to high concentrations of air pollutants is related with high blood pressure and atherosclerosis [40]. Furthermore, trees have aerodynamic effects on air pollution by sequestering carbon monoxide and reducing the concentration of air pollution [41,42]. Therefore, it is possible to hypothesise that forest walking may have benefits on cardiopulmonary functions by reducing the harmful effects of air pollution.

This study has several limitations. Firstly, we did not perform biochemical laboratory tests for either metabolic parameters or stress-related hormones. Secondly, we only evaluated the immediate effects of forest walking, suggesting the need for long-term studies to evaluate whether there are long term effects or benefits. Thirdly, we only enrolled elderly females; therefore, we cannot generalize our results to the entire population. Fourthly, forest and city walking took place on different days due to limited resources. Furthermore, the measurements and walking activities for both groups were not performed at the same time point because of differences in the study population and measurement times. Because we investigated the acute effects of forest walking, differences in the time points may affect the results of the study. Fifthly, we did not monitor blood pressure, heart rate, and walking speed during the interventions. Instead, we provided about 30 min of education before the study to teach participants about the correct walking pace. In addition, five assistants monitored the walking pace of participants during the interventions. However, variations in these factors among participants might affect the results. Finally, non-equal randomisation of the study groups (70:20) may bias the results of the study.

In conclusion, walking in a forest environment, in contrast to walking in a city, reduces arterial stiffness and increases pulmonary function in Korean elderly women. Our collective findings suggest that forest environments may promote better health and prevent cardiopulmonary diseases in older populations. Further large-sized and long-term studies are needed to better understand the clinical significance of our findings.

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Conflict of interest

None.

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