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The Effects of Forest Walking on Physical and Mental Health Based on Exercise Prescription

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Abstract: This study aimed to verify the effects of prescribed personalized forest walking by considering individuals' characteristics. To prescribe individualized exercise programs, we developed an algorithm to calculate exercise intensity based on each participant's age, regular exercise, fatigue level, and chronic disease type, if any. To investigate the effects of forest walking on physical and mental health based on exercise prescription, we recruited 59 participants (average age: 39.1 ± 19.0 years old) aged 18 years or older. Physiological and psychological responses were compared before and after walking in the forest. Systolic blood pressure, diastolic blood pressure, percent body fat, negative affect, and emotional exhaustion significantly decreased, while the pulse rate significantly increased following the forest walking. Additionally, we investigated the effects of exercise relative to successfully maintaining one's target heart rate and found that these effects were even greater when success score of maintaining the target heart rate while walking improved. Comparison of the groups relative to successfully achieving the target heart rate indicated that the high-achievement group had significant reductions in systolic and diastolic blood pressure, body fat mass, percent body fat, negative affect, and emotional exhaustion, and a significant increase in pulse rate. However, the low-achievement group only showed a significant reduction in emotional exhaustion. This study showed that prescribed forest walking has a positive impact on human health and is expected to have a positive effect on the motivation to start and continue exercising.

Keywords: blood pressure; body composition; exercise; forest therapy; forest trails; health promotion; hiking; target heart rate; wearable device; well-being

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1. Introduction

Considering the recent expansion of sedentary lifestyles, with the risk of metabolic syndrome and obesity on the rise, the practice of walking is particularly important. Studies have shown that forest walking can not only promote physical health but also assist in stress relief. Ochiai et al. [1] reported that it increases positive mood and decreases negative mood. Park et al. [2] found that it reduces the level of cortisol, the stress hormone, and blood pressure while enhancing parasympathetic nervous system activity. Li et al. [3] indicated that forest walking decreases the levels of norepinephrine and dopamine, as well as blood pressure, while increasing anti-stress hormones. Song et al. [4] reported that a short 15 min forest walk increases parasympathetic nervous system activity compared to walking in urban areas, reducing sympathetic nervous system activity and heart rate. Horiuchi et al. [5] highlighted that, in the elderly, it contributes to blood pressure reduction and mood state improvement.

As the number of people visiting forests increases, the incidence of hiking accidents is also on the rise [6–8]. These accidents are mainly caused by human factors such as carelessness, poor judgment, and noncompliance with safety rules rather than external environmental factors such as avalanches and falling rocks [9–11].

Unlike external environmental factors, accidents caused by human factors can be reduced by raising individual safety awareness; therefore, various institutions present safety rules and provide related education. The Union Internationale des Associations d'Alpinisme (UIAA) has issued guidelines for safe hiking and uploaded videos related to climbing technique and skills [12]. In South Korea, hiking routes are classified into five levels based on their gradient and difficulty, allowing individuals to choose trails suitable for their capabilities [13]. In addition, educational programs and practical training for safe forest walking have been conducted [14]. However, despite studies showing that accident rates during hiking depend on characteristics such as age [7,15], sex [16], the presence of chronic illnesses [17,18], and regular exercise habits [19], information regarding forest walking tailored to individuals' health conditions and characteristics is insufficient.

In the field of sports medicine, research is being conducted to determine the intensity of exercise to maximize its effect while minimizing the risks and injuries that may occur during exercise. Previous studies have mainly been conducted to improve the skills of sports players [20] or to restore function during rehabilitation from injury or disease [21–23]. However, recently, research has also been conducted on exercise prescriptions for improving physical strength and health, as health problems have emerged due to individuals' sedentary lifestyles [24–26].

Applying exercise prescriptions that consider individuals' health status and characteristics to forest walking could reduce accident rates and enhance the effectiveness of exercise, ultimately benefiting hikers. In addition, forest walking based on exercise prescription can elicit interest, motivating individuals to initiate and sustain physical activity [27]. Therefore, this study aims to derive a safe and efficient method of forest walking based on the principles of exercise prescriptions. The objectives of this study are as follows: (1) To develop optimal personalized forest walking exercise prescriptions based on information such as the individual's age, regular exercise, and fatigue levels, as well as the presence and type of any chronic illnesses. (2) To verify the effects of participating in forest walking exercises three times a week as per the developed exercise prescriptions. (3) To compare the differences in these effects between the group that closely followed the exercise prescription and the group that did not.

2. Materials and Methods

2.1. Participants

This study was approved by the Institutional Review Board of Kongju National University (approval no. KNU_IRB_2022-085). The study participants were adults aged 18 years and older who understood the research objectives. All participants provided written, informed consent. The exclusion criteria, as specified on the participant recruitment poster, were the following: being unable to communicate, receiving treatment at a hospital, having a history of heart or cerebrovascular disease, and being unable to walk due to joint pain. Participants were recruited via promotional articles related to participation in the experiment that were posted on the bulletin board of an online local community website. The experiment was conducted on 59 participants (Table 1). All study participants were residents of Yesan-gun. They all lived within an approximately 20–30 min driving distance from the experimental site.

Table 1. Participant information.

	Age (Years)	Height (cm)	Weight (kg)
Total (n = 59)	39.1 ± 19.0	165.6 ± 9.1	65.9 ± 13.6
Male (n = 26)	35.0 ± 20.4	173.5 ± 5.8	71.8 ± 10.7
Female (n = 33)	41.6 ± 17.7	159.6 ± 5.6	60.7 ± 13.7

Mean ± Standard deviation.

2.2. Experimental Site

The experiment was conducted from 5 October to 20 November 2022, and during this period, the daily average temperature was 12.1 ± 2.7 °C and the humidity was 75.0 ± 9.8%.

This study was conducted on a forest trail at a forest welfare facility located in Yesan-gun, South Korea. Forest welfare refers to economic, social, and emotional assistance designed to enhance people's well-being through government-provided, forest-based welfare services [28], which are provided by the Korean government through forest welfare facilities. The total area of the experimental site was 134 ha, and the dominant tree species were *Pinus densiflora* (53 ha, 40%) and oak (42 ha, 31%), including *Quercus variabilis* and *Quercus acutissima*. Detailed information on the forest trail, including distance, height, and slope, is provided in Table 2.

Table 2. Geographical information of the forest trail.

Distance (m)	Height (m)		Average Slope (°)	Composition of Slope (%)		
	Start	End		Uphill	Downhill	Flat
2715	90	171	2.5	55.8	40.2	4.0

2.3. Exercise Prescription

We aimed to calculate the appropriate exercise intensity for each individual to maximize the benefits of forest walking while minimizing the potential risks and injuries. Referring to the American College of Sports Medicine (ACSM) FITT-VP guidelines for health promotion and cardiovascular fitness [29], we developed an algorithm to calculate exercise intensity ranging from 30% to 60% based on individuals' health information, age, regular exercise, and perceived fatigue levels (Figure 1) [30]. Approximately 30%–60% represents a relative range of the maximum exercise intensity, which is associated with an individual's maximum heart rate [31].

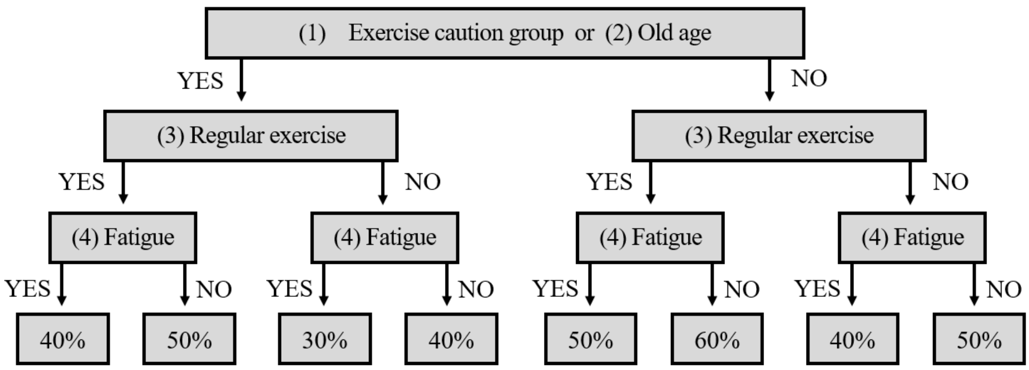

Figure 1. The algorithm was used to determine forest exercise prescriptions.

Those who answered "yes" to question (1) in Table 3 participated in the experiment after receiving confirmation from the doctor that they could proceed with the walking exercise. The experiment was conducted safely by setting the exercise intensity according to the steps listed in Figure 1.

Table 3. The algorithmic questions for exercise prescription.

Question	Question Sentence
(1) Exercise caution group	If any of the following applies. 1) I have been advised to exercise caution by a doctor. 2) I have experienced discomfort due to fast and irregular heartbeats. 3) I have experienced chest pain during exercise. 4) I have experienced breathing difficulties for no reason. 5) I have experienced dizziness and fainting. 6) I have pain in my lower-extremity joints and feet.
(2) Old age	I am over 65 years old.
(3) Regular exercise	In the past three months, I have performed medium-intensity exercise at least three days a week for at least 30 min.
(4) Fatigue	My condition during last week was "bad" or "very bad".

2.4. Experimental Design

The experiment comprised pre-measurement, exercise prescription, forest walking, and post-measurement stages (Figure 2). Participants were restricted from consuming caffeine, meals, or cigarettes, all of which could affect the body's physiological responses, 2 h prior to the start of the experiment.

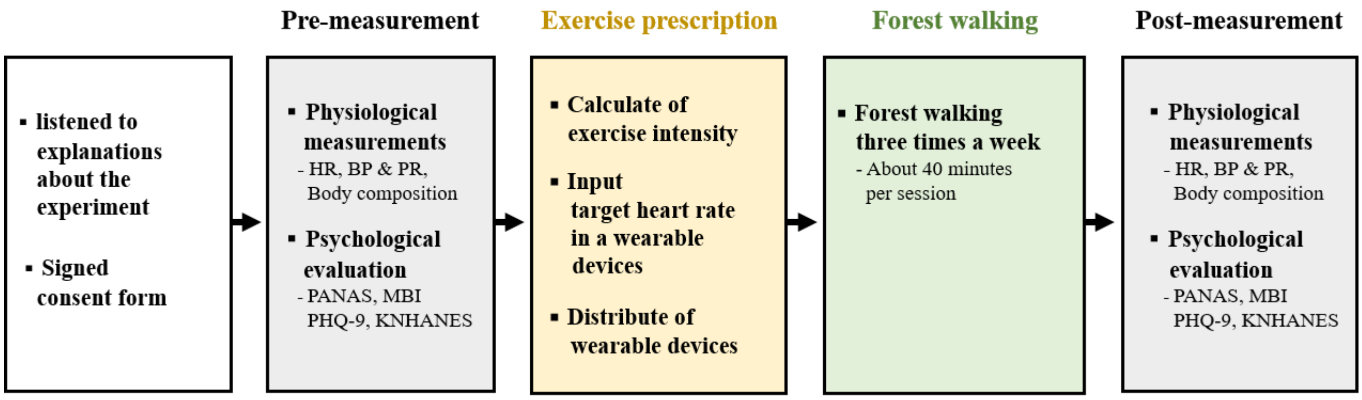

Figure 2. Experiment design. HR (heart rate), BP (blood pressure), PR (pulse rate), PANAS (positive and negative affect scale), MBI (maslach burnout inventory), PHQ-9 (patient health questionnaire-9), and KNHANES (korean national health and nutrition examination survey).

The pre-measurement procedure was as follows: The participants visited the laboratory, sat in a chair, listened to sufficient explanations about the background, purpose, and methods of this study, and signed a consent form for participation in the experiment. After resting for approximately 5 min while sitting in the chair, their resting heart rate, blood pressure, and body composition were measured. They then completed a pre-experiment questionnaire containing information necessary for the exercise prescription, such as age, regular exercise, and psychological evaluation.

The exercises were conducted using the following methods and sequences: The individual's maximum heart rate, indicating the heart rate at maximum exercise intensity for an individual, was calculated using the formula developed by Fox et al. [32]: "220 − (age)". Their target heart rate was calculated using Karvonen's [33] formula: "(maximum heart rate − resting heart rate) × exercise intensity + resting heart rate". Exercise intensity was assigned to participants using the procedure shown in Figure 1, based on the information provided in the pre-experiment questionnaire. The target heart rate range, which was entered into a wearable wristband device, was set at ±10 bpm around the target heart rate.

Subsequently, the participants were given the wearable device and instructed on how to wear and use it. Participants were instructed to walk within their designated target heart rate range during the forest walking exercise.

The participants visited the experimental site three times a week when they wanted to walk through the designated forest trail. When walking in the forest, if their heart rate was outside the preset target range, the wearable device vibrated so that the exercise could be performed smoothly.

After the last forest walk, participants returned to the laboratory for post-measurements within 24 h, at the same time as for the pre-measurements. The precautions (no eating, smoking, or consuming caffeine for 2 h prior to measurements) and time, indicators, and post-measurement procedure were the same as those in the pre-measurement stage.

2.5. Physiological Measurements

2.5.1. Heart Rate

Heart rate refers to the number of heartbeats in one minute [34]. In this study, a heart rate sensor (H10, Polar, Kempele, Finland) and smartwatch (Pacer Pro, Polar, Finland) were used to measure and calculate participants' heart rate by recording electrocardiogram (ECG) data. The resting heart rate was measured while seated with eyes closed for five minutes, and the average value was used.

2.5.2. Blood Pressure

Systolic blood pressure (SBP) represents the pressure exerted on the blood vessels when the heart contracts, while diastolic blood pressure (DBP) represents the pressure exerted on the blood vessels when the heart is relaxed. In this study, an oscillometric method (BPBIO330n; Inbody, Seoul, Korea) was used to measure blood pressure. Two measurements were obtained from the right upper arm of each participant. If the difference in systolic blood pressure between the first and second measurements was equal to or exceeded 10 mmHg or the difference in diastolic blood pressure was equal to or exceeded 6 mmHg, an additional measurement was taken, and the average of the second and third measurements was used.

The pulse rate, which is the number of times the arterial wall vibrates per minute owing to contractions of the heart, was also measured [35].

2.5.3. Body Composition

In this study, body composition was measured using a bioelectrical impedance analysis (BIA) device (Inbody270, Inbody, Seoul, Korea), which assesses differences in electrical conductivity based on tissue biological characteristics. BIA can be measured easily and conveniently by estimating the body composition ratio [36], and it also shows high reliability and validity as an evaluation index of objective body components [37]; therefore, it is actively used for diagnosing obesity. In this study, weight, skeletal muscle mass, body fat mass, body mass index (BMI), and percent body fat were used as variables.

2.6. Psychological Measurements

2.6.1. Positive and Negative Affect Scale (PANAS)

In this study, we used the Positive and Negative Affect Scale (PANAS) questionnaire developed by Watson et al. [38] and translated into Korean by Lee et al. [39]. The questionnaire has a two-subscale design consisting of 10 items each for positive affect and 10 items for negative affect, which were rated using a 5-point Likert scale. The maximum and minimum scores for both positive and negative affect are 40 and, respectively, 0 points. In the study by Park and Lee [40], the Cronbach's α values for the subfactors of positive and negative affect were reported as 0.80 and 0.86, respectively. In our study, these values were found to be 0.69 and, correspondingly, 0.61.

2.6.2. Maslach Burnout Inventory (MBI)

This study used the Maslach Burnout Inventory (MBI) questionnaire developed by Maslach and Jackson [41] and translated into Korean by Shin et al. [42]. The questionnaire has a three-subscale design consisting of personal accomplishment, emotional exhaustion, and depersonalization. In this study, only one subscale—emotional exhaustion—was used. Items were rated on a 5-point Likert scale, with higher scores indicating more severe emotional exhaustion. The maximum and minimum scores for emotional exhaustion are 20 and, respectively, 0 points. In the study by Shin et al. [42], the Cronbach's α value was reported as 0.9. In our study, this value was calculated as 0.58.

2.6.3. Patient Health Questionnaire-9 (PHQ-9)

The Patient Health Questionnaire-9 (PHQ-9) questionnaire developed by Spitzer et al. [43] and translated into Korean by Park et al. [44] was used in this study. This is a self-reported questionnaire designed to diagnose major depressive disorder. It consists of nine items rated on a 4-point Likert scale. A total score of 5 or higher suggests the possibility of depression; if the score is 10 or higher, professional counseling is recommended. The maximum and minimum scores for emotional exhaustion are 27 and, respectively, 0 points. In the study by Park et al. [44], the Cronbach's α values were reported as 0.81. In our study, these values were found to be 0.59.

2.6.4. The Korean National Health and Nutrition Examination Survey (KNHANES)

The Korean National Health and Nutrition Examination Survey (KNHANES) questionnaire, developed by Lee et al. [45], was used in this study. It consists of 20 items structured into three subscales: fatigue, depression, and anger. Higher scores indicate higher stress levels. The maximum and minimum scores for emotional exhaustion are 45 and, respectively, 0 points. In the study by Choi et al. [46], the Cronbach's α value was reported as 0.79. In our study, this value was found to be 0.57.

2.7. Data Analysis

The Statistical Package for the Social Sciences (SPSS) (version 27.0) was used for statistical analysis, and the significance level was set at $p < 0.05$. Regarding the physiological measurements, one individual was excluded from the body composition analysis due to missing data. In the psychological measurement, two people were excluded from PHQ-9, one from MBI, and one from the subscale of negative affect in PANAS as the participants had missed questions.

The following three analyses were conducted: (1) To investigate the effect of participating in prescribed forest walking three times a week, participants' pre- and post-measurement values were compared; (2) to confirm the difference in effect according to the degree of achievement of remaining within the target heart rate range, the pre- and post-measurement values were compared by dividing the scores of the high- and low-achievement groups based on the median value of the target heart rate range achievement rate; (3) changes (post-measurement − pre-measurement) were calculated, and the scores were compared between the groups.

For analyses (1) and (2), as the data were paired, the physiological responses from populations exhibiting normal distribution were analyzed using the paired *t*-test, while psychological responses from populations not exhibiting normal distribution were analyzed using the Wilcoxon signed-rank test. For analysis (3), as the data were independent, the physiological responses from populations exhibiting normal distribution were analyzed using the independent samples *t*-test, while psychological responses from populations not exhibiting normal distribution were analyzed using the Mann–Whitney U test.

3. Results

3.1. Comparison of Pre- and Post-Measurements for All Participants

When comparing the pre- and post-measurements for all participants, systolic blood pressure, diastolic blood pressure, and percent body fat significantly decreased, and the pulse rate significantly increased (Table 4). In addition, negative affect and emotional exhaustion scores significantly decreased (Table 5). No significant differences were found in the other indicators.

Table 4. Comparison of physiological responses between pre- and post-measurements for all participants.

		n	Pre-Test M (SE)	Post-Test M (SE)	Changes (Post − Pre) M (SE)	*t*	*p*	
Blood pressure	Systolic blood pressure (mmHg)	59	119.2 (2.3)	115.1 (2.1)	−4.1 (0.2)	3.289	0.001	**
	Diastolic blood pressure(mmHg)	59	72.5 (1.7)	69.2 (1.5)	−3.3 (0.1)	3.248	0.001	**
	Pulse rate (bpm)	59	76.4 (1.4)	80.2 (1.6)	3.9 (0.2)	−2.789	0.004	**
Muscle fat analysis	Weight (kg)	58	65.1 (1.8)	65.3 (1.8)	0.2 (0.2)	−1.181	0.121	
	Skeletal muscle mass (kg)	58	26.0 (0.9)	26.3 (0.9)	0.3 (0.2)	−1.338	0.093	
	Body fat mass (kg)	58	18.1 (1.0)	17.7 (1.0)	−0.4 (0.2)	1.662	0.051	
Obesity analysis	Body mass index (kg/m^2)	58	23.6 (0.5)	23.7 (0.5)	0.0 (0.0)	−0.828	0.206	
	Percent body fat (%)	58	27.8 (1.1)	27.0 (1.1)	−0.7 (0.4)	1.723	0.045	*

* $p < 0.05$, ** $p < 0.01$ by paired *t*-test. M: mean, SE: standard error.

Table 5. Comparison of psychological responses between pre- and post-measurements for all participants.

		n	Pre-Test M (SE)	Post-Test M (SE)	Changes (Post − Pre) M (SE)	*z*	*p*	
Positive affect and negative affect scale	Positive affect	56	21.1 (1.0)	20.8 (1.2)	−0.3 (0.8)	−0.222	0.412	
	Negative affect	55	5.2 (0.6)	4.0 (0.5)	−1.2 (0.8)	−2.135	0.016	*
Patient health questionnaire-9		57	2.6 (0.4)	2.2 (0.3)	−0.4 (0.3)	−1.036	0.150	
Korean national health and nutrition examination Survey		59	4.9 (0.7)	3.9 (0.5)	−0.9 (0.5)	−1.639	0.051	
Maslach burnout inventory	Emotional exhaustion	58	4.9 (0.5)	3.9 (0.4)	−0.9 (0.3)	−2.784	0.003	**

* $p < 0.05$, ** $p < 0.01$ by Wilcoxon signed-rank test. M: mean, SE: standard error.

3.2. Comparison between High-Achievement and Low-Achievement Groups

The achievement rate of walking within the target HR range was calculated to compare the difference in the effect according to the degree of achievement. Among the 59 participants, the lowest and highest achievement rates were 12.94% and 95.98%, respectively, confirming that the achievement rate differed by individual. Based on the median value of 59.66%, those with an achievement rate of 59.66% or more were classified as high-achievement ($n = 30$), while those with an achievement rate less than 59.66% were classified as low-achievement ($n = 29$). A group comparison was then conducted.

The homogeneity of the demographic variables (gender, chronic disease, drinking, and smoking) between the high- and low-achievement groups was confirmed (Table 6). No differences were found for any of the indicators, indicating homogeneity among the groups.

Table 6. The results of an intergroup homogeneity test.

		Low-Achievement Group (n = 29)	High-Achievement Group (n = 30)	p
Gender	Male	11	15	0.351
	Female	18	15	
Chronic disease status	Not applicable	23	26	0.348
	High blood pressure	5	2	
	Hyperlipidemia	1	0	
	Osteoarthritis	0	1	
	Cancer	0	1	
Alcohol consumption status	Applicable	18	25	0.660
	Not applicable	11	5	
Smoking status	Applicable	4	4	0.959
	Not applicable	25	26	

by Chi-square test.

The physiological and psychological measurement results of the two groups are presented in Tables 7 and 8, respectively. When comparing the pre-test measurements between the two groups, no significant differences were found in any of the indicators, confirming the homogeneity of the two groups.

When comparing the pre- and post-measurement results within each group, the high-achievement group showed significant decreases in systolic blood pressure, diastolic blood pressure, body fat mass, percent body fat, and negative affect and emotional exhaustion scores, while pulse rate significantly increased. In contrast, in the low-achievement group, only the emotional exhaustion score significantly decreased. When comparing the changes (post − pre) between the groups, we found that the reduction in negative affect score and diastolic blood pressure and increase in positive affect score and pulse rate were significantly higher in the high-achievement group than in the low-achievement group.

Table 7. Comparison of physiological responses between the pre- and post-measurements of the two groups.

	Low-Achievement Group						High-Achievement Group						Group Comparison (Changes)	
	n	**Pre-Test M (SE)**	**Post-Test M (SE)**	**Changes (Post − Pre) M (SE)**	***t***	***p***	***n***	**Pre-Test M (SE)**	**Post-Test M (SE)**	**Changes (Post − Pre) M (SE)**	***t***	***p***	***t***	***p***
Systolic blood pressure (mmHg)	29	122.0 (3.6)	119.1 (3.2)	−2.9 (1.9)	1.550	0.066	30	116.5 (2.8)	111.3 (2.6)	−5.2 (1.5)	3.413	0.001 **	−0.945	0.174
Diastolic blood pressure (mmHg)	29	72.2 (2.5)	70.6 (2.3)	−1.6 (1.5)	1.055	0.150	30	72.8 (2.2)	67.8 (2.0)	−5.0 (1.4)	3.651	0.001 **	−1.703	0.047 +
Pulse rate (bpm)	29	78.0 (2.2)	77.9 (2.1)	−0.1 (1.7)	0.080	0.469	30	74.7 (1.8)	82.5 (2.3)	7.8 (1.9)	−4.012	0.000 **	3.035	0.002 ++
Weight (kg)	29	66.1 (2.8)	66.2 (2.8)	0.1 (0.1)	−0.914	0.184	29	64.1 (2.2)	64.3 (2.2)	0.3 (0.3)	−0.879	0.194	−0.436	0.332
Skeletal muscle mass (kg)	29	26.6 (1.5)	26.7 (1.5)	0.1 (0.1)	−0.814	0.211	29	25.4 (1.0)	25.9 (1.0)	0.5 (0.4)	−1.147	0.131	−0.860	0.197
Body fat mass (kg)	29	18.0 (1.3)	18.0 (1.3)	0.0 (0.3)	0.123	0.451	29	18.2 (1.4)	17.4 (1.5)	−0.7 (0.4)	1.925	0.032 *	1.547	0.064
Body mass index (kg/m^2)	29	24.0 (0.8)	24.0 (0.7)	0.0 (0.1)	−0.878	0.194	29	23.3 (0.8)	23.4 (0.8)	0.0 (0.1)	−0.371	0.357	0.224	0.412
Percent body fat (%)	29	27.4 (1.5)	27.3 (1.6)	−0.1 (0.4)	0.328	0.373	29	28.1 (1.5)	26.7 (1.5)	−1.4 (0.8)	1.786	0.043 *	1.440	0.078

M: mean, SE: standard error. Grey color indicates the results of comparing the groups. * $p < 0.05$, ** $p < 0.01$ (comparing of pre-test and post-test) as determined by paired *t*-test. $^{+}$ $p < 0.05$, $^{++}$ $p < 0.01$ (comparing two groups) as determined by independent samples *t*-test.

Table 8. Comparison of psychological responses between the pre- and post-measurements of the two groups.

		Low-Achievement Group						High-Achievement Group						Group Comparison (Changes)	
		n	**Pre-Test M (SE)**	**Post-Test M (SE)**	**Changes (Post − Pre) M (SE)**	***z***	***p***	***n***	**Pre-Test M (SE)**	**Post-Test M (SE)**	**Changes (Post − Pre) M (SE)**	***z***	***p***	***z***	***p***
Positive affect and negative affect scale	Positive affect	27	21.8 (1.3)	20.3 (1.7)	−1.6 (1.3)	−1.240	0.108	29	20.4 (1.6)	21.3 (1.6)	0.9 (0.9)	−1.016	0.155	−1.651	0.049 +
	Negative affect	28	4.1 (0.7)	4.0 (0.7)	−0.1 (0.7)	−0.043	0.483	27	6.4 (0.9)	4.0 (0.8)	−2.4 (0.7)	−2.822	0.002 **	−2.055	0.020 +
Patient health questionnaire-9		27	2.7 (0.6)	2.6 (0.5)	−0.1 (0.5)	−0.146	0.442	30	2.4 (0.5)	1.9 (0.4)	−0.5 (0.3)	−1.486	0.069	−1.183	0.118
Korean national health and nutrition examination survey		29	4.2 (0.6)	3.6 (0.7)	−0.6 (0.5)	−0.995	0.160	30	5.5 (1.1)	4.2 (0.8)	−1.3 (0.8)	−1.295	0.098	−0.130	0.448
Maslach burnout inventory	Emotional exhaustion	28	4.9 (0.7)	3.9 (0.6)	−1.0 (0.5)	−2.056	0.020 *	30	4.9 (0.7)	4.0 (0.6)	−0.9 (0.4)	−1.971	0.024 *	−0.040	0.484

M: mean, SE: standard error. Grey color indicates the results of comparing the groups. * $p < 0.05$, ** $p < 0.01$ (comparing of pre-test and post-test) as determined by Wilcoxon signed-rank test. + $p < 0.05$ (comparing two groups) as determined by Mann–Whitney U test.

4. Discussion

This study was conducted to verify the effects of personalized forest walking prescriptions that consider individual characteristics. Physiological responses were measured using blood pressure, pulse rate, and body composition analyses, and psychological responses were evaluated using PANAS, PHQ-9, KNHANES, and MBI.

Blood pressure analysis revealed that systolic and diastolic blood pressure were significantly decreased following the forest walking exercise. This is consistent with previous studies that indicate that forest walking reduces blood pressure [1–3,5,47]. Furthermore, research has shown that walking in forests not only lowers the blood pressure of individuals with high blood pressure but also increases the blood pressure of individuals with low blood pressure to normal levels [48]. Walking in forests may be beneficial for those seeking to efficiently enhance and maintain their cardiovascular health. The results of the pulse rate analysis showed that the post-measurement pulse rate increased significantly compared to the pre-measurement pulse rate. A number of studies [49–52] have reported that exercise lowers blood pressure and heart rate simultaneously by reducing sympathetic nerve activity; however, these results contrast with the findings of our study. However, some studies have shown that exercise reduces blood pressure and increases heart and pulse rates. Jeon et al. [53] examined the effects of exercise on blood pressure and heart rate by measuring these parameters at rest and 20 min post-exercise periods. The results showed that blood pressure post-exercise significantly decreased compared to resting blood pressure, but heart rate significantly increased. They reported that the drop in blood pressure after exercise was caused by relaxation of resistance vessels, such as arterioles, rather than a decrease in cardiac output. Kim et al. [54] performed a step test for 8 min in a forest and compared blood pressure and pulse rate at rest, immediately after exercise, 5 min after exercise, and 10 min after exercise. Compared to the resting period, blood pressure had decreased 10 min after exercise, while the pulse rate had increased. However, there are few studies related to blood pressure reduction and pulse rate elevation, which makes it difficult to generalize the results. Furthermore, studies that simultaneously investigate blood pressure and pulse rate are lacking. Future research should accumulate sufficient data to investigate this issue in further detail.

Body composition analysis showed that the percent body fat decreased after the intervention. This is similar to the results of previous studies showing that steady exercise reduces body fat [55–58]. Previous studies have also reported that continuous aerobic exercise not only reduces body fat but also increases muscle strength [59,60]. However, in this study, a significant difference was observed only in percent body fat. In previous studies, an exercise period of at least a month was set, and in this study, forest walking was conducted three times a week. It is possible that the inconsistencies between these results may be caused by differences in the duration of exercise.

Following the psychological response analysis, we found that negative affect and emotional exhaustion scores significantly decreased after the intervention. This is consistent with previous studies showing that walking in a forest aids in psychological relaxation [4,61–65]. Forest walking not only reduces depression [63] and negative effects such as confusion, anger, depression, and anxiety [4,65], but it also helps to improve mood [64]. This intervention is believed to be helpful for people who want to reduce their stress.

In this study, the participants were divided into high- and low-achievement groups based on their achievement of maintaining their target heart rate during the prescribed exercise. Regarding physiological responses, systolic and diastolic blood pressure significantly decreased, and pulse rate significantly increased after the intervention in the high-achievement group, but no significant differences were found in the low-achievement group. Psychological response measurements revealed that negative affect and emotional exhaustion scores significantly decreased in the high-achievement group. However, in the low-achievement group, only the emotional exhaustion score significantly decreased. When comparing the changes between the groups, we found that the reduction in negative affect score and diastolic blood pressure and increase in positive affect score and pulse rate were significantly higher in the high-achievement group than in the low-achievement group. This suggests that forest walking aids in physiological and psychological relaxation, but effectiveness is dependent on the achievement of the exercise prescription. Therefore, exercise prescriptions should be administered to individuals.

Forest walking based on exercise prescription can promote individuals' intrinsic motivation to engage in exercise. An increase in intrinsic motivation aids in maintaining the willingness to sustain exercise and has a positive impact on goal-setting and achievement [66]. These intrinsic motivations can increase further if they support an individual's "autonomy", "competence", and "relevance" [67]. Therefore, future research should contemplate methods of forest walking that can further enhance intrinsic motivation.

Recently, as the amount of time individuals spend being sedentary has increased worldwide, the time spent on physical activity has decreased [68,69], the risk of various diseases has increased, and the importance of exercise is increasing. Insufficient physical activity is associated with a 6%–10% increase in the risk of major non-communicable diseases such as coronary artery disease, heart disease, type 2 diabetes, breast cancer, and colorectal cancer [70]. For adults who spend more than 7 h a day sitting, each additional hour of sedentary time increases the probability of disease-related mortality by 5% [71]. It is estimated that 9.4% of the 57 million deaths worldwide are due to physical inactivity, emphasizing the risk of diseases caused by reduced physical activity [72]. This study is significant in that it presents a safe and efficient forest walking method that considers individual health conditions and is expected to be used as a guideline for forest walking exercises in the future.

Our study has several limitations. First, owing to difficulties in participant recruitment caused by the COVID-19 pandemic, this study was unable to establish a control group in which no exercise prescription was applied. In future studies, it will be necessary to compare the experimental and control groups. Second, although we observed differences in the effects of exercise based on the target heart rate range and achievement rate, the specific factors leading to decreased achievement rates were not identified. Future research should focus on analyzing the factors that contribute to low achievement rates and exploring methods to improve these rates. Third, this study was conducted only for a week. The more continuous and repetitive the exercise, the higher its efficiency [73]. Future studies should focus on the effects of forest walking with a long-term exercise prescription of more than one month. Fourth, prior research has reported that human responses may vary depending on the concentration of monoterpenes in the forest atmosphere during walking [74,75]. In our study, participants engaged in forest walking on different days, which may result in varying monoterpene concentrations. These fluctuations may influence the physiological responses of the participants differently. Therefore, future studies should incorporate measurements of air quality and monoterpene concentration to analyze this aspect more comprehensively.

5. Conclusions

In this study, prescribed forest walking physiologically reduced systolic and diastolic blood pressure, percent body fat, increased pulse rate, and psychologically reduced negative affect and emotional exhaustion scores. These effects were even greater when the success scores for walking and maintaining the target heart rate while walking improved. In conclusion, forest walking based on exercise prescriptions has a positive impact on human health.

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