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Effects of Exercise Intensity Differences in Forest Therapy Programs on Immunoglobulin A and Dehydroepiandrosterone Levels in Older Adults

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Abstract: The purpose of this study was to examine the effects of exercise intensity and the duration of an exercise-based forest therapy program on physiological changes in older adults. The forest therapy program consisted of 20 sessions over 10 weeks. Forty-one older adults aged 65 years and older were divided into no treatment (daily activity group) and experimental (forest therapy) groups. The experimental group was further divided into the medium-intensity forest exercise group and the high-intensity forest exercise group to analyze physiological changes according to exercise intensity and duration. The physiological changes were analyzed by collecting saliva and measuring changes in the levels of immunoglobulin A and dehydroepiandrosterone, a hormone used to predict aging. Changes within the daily activity group and the forest therapy group after their respective exercises were analyzed using paired t-tests. Saliva testing was performed before and in weeks 5 and 10 of the program and analyzed using a repeated measures analysis of variance to assess the effects of the forest therapy on the medium-intensity forest exercise group and the high-intensity forest exercise group based on the duration of exercise. As a result of the study, a significant increase in immunoglobulin A was observed in the medium-intensity forest exercise group. The daily activity group and the high-intensity forest exercise group showed an increase, but there was very little change and no significance. Changes in dehydroepiandrosterone decreased in the daily activity group and significantly increased in the moderate-intensity forest exercise group at 5 and 10 weeks, showing that regular moderate-intensity forest exercise has an effect on dehydroepiandrosterone. The high-intensity forest exercise group improved over time, but no significant level of change was observed. This study shows that forest exercise has a beneficial effect on immunoglobulin A and dehydroepiandrosterone levels in older adults.

Keywords: forest walking; older adults; exercise intensity; exercise duration; immunoglobulin A; dehydroepiandrosterone

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1. Introduction

Advancements in the medical system have significantly increased the life expectancy of older adults. However, with our expertise and resources, we can work towards reducing these numbers and improving them. However, in Korea, 84.1% of older adults have a chronic disease, and 54.9% have two or more chronic diseases [1]. According to the Korean Ministry of Health and Welfare, the number of people with severe chronic diseases has decreased compared to that in 2017, while the number of older adults with chronic diseases has increased, which can be interpreted as a result of the growing aging population. The increase in the number of older adults with chronic diseases is predicted to lead to an increase in national healthcare expenditure and social burden [2,3]. Preventive alternatives

are needed to improve the health and immunity of older adults, who are the mainstay of an aging society, to achieve the societal goal that each individual should be able to enjoy lifelong health in accordance with the vision of the Korean National Health Plan.

The purpose of forest therapy activities is to prevent diseases and strengthen immunity, and these activities have attracted public attention due to the growing interest in nature-friendly therapy. Sixty-four percent of Korea's total land area is covered by forests, making forest exercise a popular activity accessible to everyone. The forest stimulation caused by the irregular heights of the forest trails [4,5] requires topographical mobility, which stimulates the muscles in the body in various ways. The sense of balance and physical function improve more in older adults walking on a bumpy forest path than in those walking on a flat surface [6]. In middle-aged women who walk in the woods rather than on a flat surface, a brain-derived neurotrophic factor, a biomarker of cognitive function, and the muscle growth hormone insulin-like growth factor-1 (IGF-1) change significantly [7]. The topography of the forest provides a special healing factor that creates forest stimulation. The irregularity of the uphill slope of the mountain forest improves not only aerobic exercise but also the anaerobic capacity, in contrast to exercise on a flat ground [8]. The uphill slope of the mountain forest generates muscle resistance, increases the range of motion of the joints, and has a great effect on muscle contraction and elasticity. There is an improvement in body flexibility and balance strength in elderly people [9]. This therapeutic effect occurs as a result of walking on forested terrain. It is expected that forest exercise will improve health and play a preventive role against disease. Exercise acts as an exogenous stimulus stress in situations where there is a discrepancy between environmental factors and one's own performance ability [10]. The body gains the effect of improving homeostasis, anti-aging function, and immune function by increasing cell dynamics due to the exercise load stimulation generated by the slope of the forest [11]. However, overtraining can have adverse effects; therefore, it is of paramount importance to regulate exercise intensity according to individual physical ability. In some cases, elite athletes exercise at intensities that exceed their limits in order to improve their performance [12]. Overexertion can lead to a state of fatigue, and the subsequent decline in immune function can increase susceptibility to viral infections [13]. In addition, overtraining can disrupt hormonal balance and induce oxidative stress, and has been reported to cause cell membrane damage in male and female rats [14]. Therefore, the adjustment of the exercise intensity according to the individual physical capacity is an important factor in maintaining a healthy life through exercise. Regarding exercise intensity, several studies have examined the effects of exercise on elite athletes and healthy individuals [15]. However, because older adults have age-related declines in physical function, it is challenging to apply the same exercise intensity as the general population or elite athletes. In addition, studies of effective exercise intensity in older adults are lacking.

The inevitable process of physiological decline during life is called aging [16]. Although the decline in physiological function can be affected by age, the relative difference can be determined by an individual's internal and external factors [17]. Internal factors cause a difference in the limitations of an individual's genetically inherent ability to produce cells, or lifespan. External factors include influences related to the activities of daily living, including diet, alcohol consumption, and exercise. Exercising regularly according to the body's physical capacity and consuming the necessary nutrients are crucial for achieving optimal cellular competence and reaching a healthy old age [18].

In Korea, 48.8% of older adults reported using forest trails within walking distance of their homes for exercise [19], and older adult women who walked in forests had better results in muscle strength and flexibility than those who walked on a treadmill for the same period [20]. In addition, one study reported that forest walking lowered blood glucose levels more than walking on a flat ground in older adults with non-insulin-dependent diabetes [21]. This form of forest exercise was more effective in increasing superoxide dismutase (SOD) for removing blood lipids and free oxygen related to cardiovascular disease than indoor exercise, and melatonin related to antioxidants and the immunity of

physiological functions [22]. Middle-aged men's 12-week forest walking exercise showed the physiological stabilization of blood pressure and nervous system function, a reduction in lipid peroxides and increase in antioxidants, and psychological stability in terms of emotional state and recovery from depression [23]. The forest walking movement can play a role in reducing the costs of healthcare systems, while increasing the well-being of participants [24]. Exercising in the forest can increase the number of nerve cells, protecting the nerves, and help to recover from brain diseases [25]. Walking in natural or urban green spaces reduces ghrelin, which stimulates appetite, and cortisol, a stress hormone [26]. It has been reported that people are more likely to be physically active in green spaces and may engage in longer or more intense activities in natural environments [27,28]. Walking in the forest has beneficial effects on the body components, including reducing blood pressure and heart rate and improving cardiopulmonary and neurochemical parameters [29]. Walking in a forest environment, as opposed to walking in cities, reduces atherosclerosis and improves lung function in elderly women in Korea [30]. These urban forests can be used at no cost, demonstrating their efficiency in terms of cost and achieving exercise effects. Although there are many benefits to exercising in the forest, some concerns about this form of exercise need to be addressed.

In the woods, the exercise load is generated by the slope, and it has been reported that overexertion on uphill slopes causes metabolic damage, whereas transient muscle damage may occur on downhill slopes [31]. Elite athletes may accept the adverse effects of exercise to improve their performance; however, when exercising for health, an individual's physical capacity should be considered. In particular, it remains unclear how much exercise load is necessary to minimize metabolic damage in older adults exercising in a downhill forest. Therefore, the aim of this study was to investigate improvements in physiological functions in older adults as a function of different exercise intensities while participating in a forest therapy program focused on forest exercises.

An immune hormone, immunoglobulin A (IgA), and an aging-related hormone, dehydroepiandrosterone (DHEA), which are used to analyze physiological changes, were measured as salivary variables. Meanwhile, cardiovascular indicators, such as HRV, blood pressure, heart rate, and cortisol, were used as biomarkers to reveal the benefits of the forest treatment. IgA and DHEA are less commonly used biomarkers in forest therapy research. However, as an active forest therapy activity, forest walking exercise is important to reveal the benefits of forest therapy by evaluating its impact on more diverse biomarkers. The use of saliva is preferred in various studies because it can be safely and easily collected in a non-invasive manner without requiring special skills.

The main role of IgA as a primary antibody in the immune defense system is to bind to invading microbes and microbial toxins and trap them in a layer of mucus, thereby preventing access to the mucosa or disrupting the attachment of toxins to receptors on mucosal cells [32]. IgA is the most abundant immunoglobulin among the antibodies secreted by the mucosa [33]. Intense exercise entails weakening immune functions by reducing immunoglobulins; so, strategic exercise management is necessary to prevent exercise-induced immunosuppression [34]. Adults secrete about 2 g of IgA daily, and IgA deficiency is more likely to cause respiratory infections [35]. Older adults are considered a high-risk group for infectious diseases because they are susceptible to them due to a decrease in mucosal immune defenses [36].

DHEA, a steroid hormone secreted by the adrenal cortex, declines with age and is considered a marker of aging [37]. In cases of age-related DHEA decline, increases in DHEA levels can be induced by regular physical activity [38], suggesting that exercise is an important factor in DHEA changes.

2. Materials and Methods

2.1. Participants and Study Protocol

The participants for the study were recruited through advertisements in local newspapers and notices posted at local community centers and senior clubs. Fifty-seven participants

were recruited, of which forty-one met the specified criteria and were ultimately selected for the experiment. The inclusion criteria were as follows: aged over 65 years; no diagnosis of dementia; ability to perform 3 h of outdoor activity; ability to communicate and complete the self-report questionnaire; and ability to understand the purpose of the study and voluntarily sign the informed consent form.

The participants were divided into a daily activity group (DAG, n = 17), medium-intensity forest exercise group (MFEG, n = 12), and high-intensity forest exercise group (HFEG, n = 12), according to the individual exercise intensity. The mean ages of the participants were DAG = 78.89, MFEG = 76.84, and HFEG = 73.75 years. There was a difference between groups (p = 0.010) and between DAG and HFEG in the mean age. Regarding gender, 4 females and 13 males were recruited for DAG, 4 females and 9 males for MFEG, and 6 females and 6 males for HFEG. The mean height values of the groups were DAG = 151.86, MFEG = 154.54, and HFEG = 160.85, and there was a difference between DAG and HFEG (p = 0.038). The body weight values were DAG = 57.55, MFEG = 59.09, and HFEG = 64.94, and there was no difference between groups. BMI values, which indicate obesity, were DAG = 25.34, MFEG = 24.83, and HFEG = 24.89, and there was no difference between groups. Table 1 shows the physical development indicators of the participants.

Table 1. Physical development indicators of the participants.

Group	Age	Sex		Height (cm)	Weight (kg)	BMI
		Male	Female			
DAG (n = 17)	78.89 (3.89)	4	13	151.86 (8.98)	57.55 (7.60)	25.34 (3.83)
MFEG (n = 12)	76.84 (4.06)	4	9	154.54 (9.01)	59.09 (8.36)	24.83 (3.11)
HFEG (n = 12)	73.75 (5.51)	6	6	160.85 (8.74)	64.74 (8.93)	24.89 (3.24)
F	F = 5.21			F = 3.55	F = 2.49	F = 0.124
p	p = 0.010 *			p = 0.038 *	p = 0.096	p = 0.883
Post hoc	HFEG < DAG			DAG < HFEG		

$p < 0.05$ *. Abbreviations: DAG, daily activity group; MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group; BMI, body mass index.

2.2. Program

The forest exercise program included breathing exercises, walking exercises, strength exercises, and cognitive strengthening programs in the forest from September to November. It was conducted twice a week for 10 weeks, from 10:00 a.m. to 12:00 p.m., lasting from 120 to 130 min. From sessions 1 to 5, the participants learned breathing exercises, and a forest healing instructor led an easy forest walk to help participants to adjust to walking in the forest. From sessions 6 to 10, the participants were instructed to walk at a faster pace. From sessions 11 to 20, the participants chose a forest walking path according to their physical strength and performed a walking exercise for 40 min. Muscular exercises (band) were performed once from sessions 1 to 5, repeated twice from sessions 6 to 10, and repeated 3 times from sessions 11 to 20. The exercise-based forest therapy program is shown in Table 2.

Table 2. Program activities for the experiment.

Theme	Activity	Duration (m)
Orientation	Check the participant's physical condition	10
Breathing training	(a) Standing, (b) Touching the fingertips, (c) Turning the shoulders (large movement), (d) Turning the shoulders (small movement), (e) Tapping the heart, (f) Tapping the five intestines, (g) Tapping the waist, (h) Breathing deeply, (j) Stimulating the cervical spine, (k) Stimulating the jaw line, (l) Stimulating the ear wheels, (m) Stimulating the facial muscles, (n) Pressing the eye, (o) Shaking the brain, and (p) Tapping the brain	40

Table 2. *Cont.*

Theme	Activity	Duration (m)
Forest walking	Rate of Perceived Exertion 1–5, Light activity 6–10, Moderately active 11–20, Vigorously active	40
Muscular exercises (Band)	Shoulders, Waist, Sides, Back, Arms, and Chest 1–5, 1 time 6–10, repeated 2 times 11–20, repeated 3 times	20
Program for cognitive enhancement	Aromatherapy foot/hand massage, dance with nature, nature painting, listening to nature sounds, nature memory card game, and tree leaf and fruit comparison	20

2.2.1. Breathing Training

Breathing exercises included breathing training with a combination of gymnastics and stretching that consisted of 16 movements. The breathing exercises were non-movement exercises that stimulated the muscles and joints of the body, which facilitated the observation of individual physical sensations after breathing training. Each movement was performed in three sets, and it took 40 min to complete all movements (Figure 1).



Figure 1. Breathing training.

2.2.2. Forest Walking Exercise

The program was conducted in an urban forest in Cheongju City, a forest area with hilly and flat trails (Figure 2). The forest exercise group wore Polar430 (Polar Electro Oy, Kempele, Finland) devices during the exercise, and the mean exercise distance walked and elevation reached by each group were measured and are presented in Table 3.



(**a**) Medium-intensity forest exercise area. (**b**) High-intensity forest exercise area.

Figure 2. Exercise area slope.

Table 3. Average distance and altitude traveled.

Group	Walking Distance (m)	Altitude Increase (m)
MFEG (n = 12)	1650	74.8
HFEG (n = 12)	2900	120

Abbreviations: MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group.

2.2.3. Muscular Exercise Using a Resistance Band

Resistance band exercises were performed using sports bands to improve the muscular strength of the body. Movements were performed that focused on strengthening various areas, including the shoulders, chest, arms, and back. The duration of the resistance band exercises was 20 min (Figure 3).



Figure 3. Muscular exercise using a resistance band.

2.2.4. Sensory and Cognitive Enhancement Program

Cognitive activities using natural factors in the forest included aroma foot/hand massage, dancing with nature, forest painting, listening to nature sounds, playing with natural memory cards, and comparing tree leaves and fruits. These cognitive activities stimulated the senses, helped to build social relationships, and took about 20 min (Figure 4).



Figure 4. Sensory and cognitive enhancement program.

2.3. Measurements

2.3.1. Saliva Test

Saliva samples were collected between 9:00 a.m. and 11:00 a.m. The participants were asked to refrain from drinking coffee or smoking for 2 h prior to saliva collection to prevent the influx of foreign substances. Prior to saliva collection, the participants rinsed their mouths with water and placed a saliva tampon under their tongues for 10 min. They were then instructed to spit into a tube, which was sealed with a lid and stored in a freezer at <−18 °C until analysis. The analysis was performed on an ELISAReader (BioTek, Winooski, VT, USA) using the ELISA kit reagents (DRG, Springfield, NJ, USA). The saliva samples were analyzed by an enzyme-linked immunosorbent assay, a method of measuring

antigen or antibody levels using an antigen–antibody reaction with an enzyme as a marker (Figure 5).



Figure 5. Saliva test.

2.3.2. Measuring Exercise Intensity

The DAG did not receive any treatment, and therefore, the exercise intensity was not measured. The exercise intensity in the experimental group was measured using Polar430 (Polar Electro Oy, Finland). Polar430 calculates the exercise intensity by measuring the subject's heart rate. Pola430 receives the subject's date of birth, gender, height, and weight and measures the individual's exercise intensity. The formula for calculating the maximum heart rate is to subtract the subject's age from 220 (220–subject's age). The American College of Sports Medicine (ACSM) limits low- to moderate-intensity exercise to a range from 40 to 70 percent of the maximum heart rate. Given that the average age of the subjects who participated in this experiment was 74 years, the exercise intensity of less than 60% was classified as moderate-intensity exercise, and the exercise intensity of more than 60% was classified as high-intensity exercise.

Exercise intensity measurements for five sessions from sessions 11 to 20 and the av-average were used to categorize the participants into the MFEG (n = 12) and HFEG (n = 12). There were participants who underwent five measurements during odd numbered sessions and some who underwent five measurements during even numbered sessions. The exercise intensity was the average of the 5 sessions. The average exercise intensity was defined as the average intensity of all activities performed in 120 min. Table 4 shows the exercise levels of the experimental groups.

Table 4. The amount of exercise of the experimental groups.

Group	Time (m)	Average Exercise Intensity (HR%)
MFEG (n = 12)	120	59.91
HFEG (n = 12)	120	70.56

Abbreviations: MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group.

2.3.3. View of the Exercise Intensity

The maximum heart rate (HRmax) is the highest heart rate that an individual can achieve in 1 min. The maximum oxygen uptake (VO2max%) is a unit that indicates the maximum amount of oxygen that the human body can consume in 1 min. Considering that VO2max% and HRmax% are proportional, they can be substituted by each other [39].

2.3.4. Data Analysis

All data values measured in this study were calculated using the Windows SPSS 18.0 statistical program to determine the mean and standard deviation of each variable. A paired sample t-test was performed to analyze the pre–post effects of IgA and DHEA in each group (the analysis of the effect size of the paired sample t-test was later analyzed and added with IBM version 27). The forest therapy group was divided into MFEG and HFEG

based on the exercise intensity. The group and time interaction was assessed by analyzing the measurements in the forest therapy group taken before the program, in week 5, and at the end of the program using a repeated measures analysis of variance (RM ANOVA). Post hoc comparisons were made using the Bonferroni test. Statistical significance (α) was set at 0.05 (Figure 6).

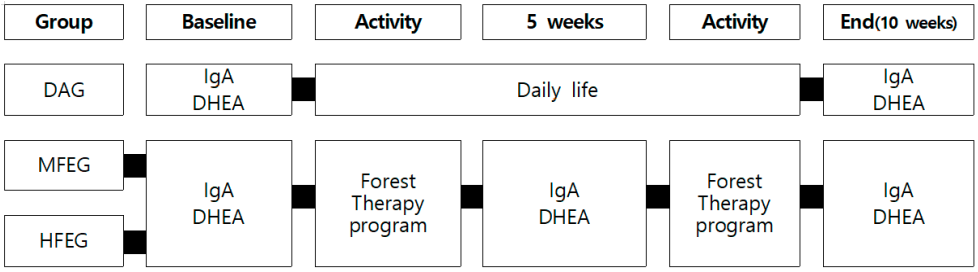


Figure 6. Study design.

3. Results

3.1. IgA Difference Test

Changes in IgA after the program were as follows: In the DAG, IgA increased from 38.59 (SD = 25.88) at baseline to 39.24 (SD = 27.28) at the post-test; however, the change was not significant (p = 0.950). There was a significant increase in the MFEG from 24.50 (SD = 16.45) at baseline to 59.95 (SD = 25.96) at follow-up (p = 0.001). The HFEG showed a positive change from 40.33 (SD = 16.95) at baseline to 45.15 (SD = 22.89) at post-test (p = 0.53), but the change was not significant. Table 5 shows the changes in IgA levels.

Table 5. Changes in IgA levels.

IgA	Baseline	End	Cohen's d	t	*p*
	M (SD)				
DAG (n = 17)	38.59 (25.88)	39.24 (27.28)	−0.016	0.064	0.950
MFEG (n = 12)	24.50 (16.44)	59.95 (25.96)	−0.970	−4.357 **	0.001 **
HFEG (n = 12)	40.33 (16.95)	45.15 (22.89)	−0.353	−0.658	0.524

p < 0.01 **. Abbreviations: DAG, daily activity group; MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group.

A repeated measures ANOVA was used to analyze the changes in IgA over the course of the program in the MFEG and HFEG (Table 6).

Table 6. IgA changes by time point in the experimental groups.

Time Group		Baseline	5 Weeks	End	T	G × T
MFEG (n = 12)	M (SD)	24.50 (16.44)	41.42 (23.00)	59.95 (25.96)	F = 13.192 ** p = 0.000 ** η^2 = 0.441	F = 5.860 ** p = 0.006 ** η^2 = 0.210
HFEG (n = 12)	M (SD)	40.33 (16.95)	28.02 (18.52)	45.15 (22.89)	F = 2.868 p = 0.078 η^2 = 0.156	
Post hoc	MFEG: Baseline < 5 weeks (p = 0.046 *), Baseline < End (p = 0.003 **), 5 weeks < End (p = 0.047 *)					

p < 0.05 *; p < 0.01 **. Abbreviations: DAG, daily activity group; MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group. Post hoc test: Bonferroni.

For the changes in IgA levels according to the intensity and duration of the forest therapy, a significant interaction between the intensity and duration of the forest therapy was initially observed at F = 5.86, p = 0.006, η^2 = 0.210. This result indicates significant

differences in the changes in IgA between the MFEG and HFEG. Figure 7 shows that. in the MFEG, IgA increased significantly in weeks 5 and 10 compared to the baseline (pre-program). However, in the HFEG, IgA initially decreased in week 5, but then increased in week 10. In addition, a repeated measures ANOVA was performed to examine the changes in IgA in weeks 5 and 10 compared to the baseline in each group, and only the MFEG showed significant changes, F = 13.19, $p = 0.000$, $\eta^2 = 0.441$. The post hoc test (Bonferroni) confirmed that the MFEG showed significant changes, with IgA levels increasing from 24.50 (SD = 16.44) at baseline to 41.42 (SD = 23.00) in week 5 ($p = 0.046$) and 59.95 (SD = 25.96) in week 10 ($p = 0.003$). IgA also showed a significant difference between week 5 (M = 41.42, SD = 23.00) and week 10 (M = 59.95, SD = 25.96) ($p = 0.047$). The IgA levels in the HFEG did not change over time.

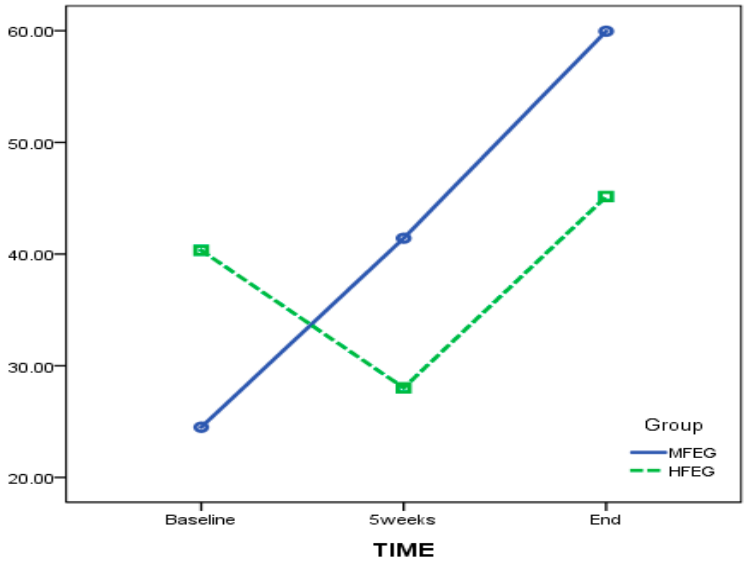


Figure 7. IgA changes by period in the exercise groups.

3.2. DHEA Difference Test

For changes in DHEA levels, the mean in the DAG decreased from 2.99 (SD = 0.91) at baseline to 2.50 (SD = 0.77) at post-test (t = 2.053, $p = 0.057$, Cohen's d = 0.498). The MFEG showed a significant change from 2.01 (SD = 0.65) at baseline to 2.96 (SD = 1.10) at post-test (t = −3.971, $p = 0.002$, Cohen's d = −0.956). The HFEG showed a positive change from 2.20 (SD = 0.84) at baseline to 2.28 (SD = 0.76) at post-test (t = −0.297, $p = 0.772$, Cohen's d = −0.270); however, the change was not significant. The statistical significance was set at $p < 0.05$, and the results are shown in Table 7.

Table 7. Changes in the DHEA values.

DHEA	Baseline	End	Cohen's d	t	*p*
	M (SD)				
DAG (n = 17)	2.99 (0.91)	2.50 (0.77)	0.498	2.053	0.057
MFEG (n = 12)	2.01 (0.65)	2.96 (1.10)	−0.956	−3.971 **	0.002 **
HFEG (n = 12)	2.20 (0.84)	2.28 (0.76)	−0.270	−0.297	0.772

$p < 0.01$ **. Abbreviations: DAG, daily activity group; MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group.

A repeated measures ANOVA was performed to analyze the changes in the DHEA levels in the MFEG and HFEG across time points (Table 8).

Table 8. DHEA changes by time point in the experimental groups.

Time Group		Baseline	5 Weeks	End	T	G × T
MFEG (n = 12)	Mean (SD)	2.01 (0.65)	2.85 (0.58)	2.96 (1.10)	F = 6.835 * p = 0.016 * η^2 = 0.383	F = 3.578 * p = 0.036 * η^2 = 0.140
HFEG (n = 12)	Mean (SD)	2.20 (0.84)	2.17 (0.68)	2.28 (0.76)	F = 0.099 p = 0.906 η^2 = 0.009	
Post hoc (Bonferroni)	MFEG: Baseline < 5 weeks (p = 0.005 **), Baseline < End (p = 0.007 **)					

$p < 0.05$ *; $p < 0.01$ **. Abbreviations: DAG, daily activity group; MFEG, medium-intensity forest exercise group; HFEG, high-intensity forest exercise group. Post hoc test: Bonferroni.

The changes in the DHEA levels according to the intensity and duration of the forest therapy were as follows. First, there was a significant interaction between the intensity and duration of the forest therapy (F = 3.578, p = 0.036, η^2 = 0.140), indicating significant differences in the DHEA changes between the MFEG and HFEG. Figure 8 shows that DHEA increases at week 5 and continues to increase slightly until week 10 in the MFEG. However, in the HFEG, DHEA decreases at week 5 and then increases at week 10. In addition, a repeated measures ANOVA was again performed to examine the changes in DHEA in weeks 5 and 10 compared to the baseline in each group, and only the MFEG showed significant changes (F = 6.835, p = 0.016, η^2 = 0.383). The post hoc test (Bonferroni) showed that the MFEG changed significantly from 2.01 (SD = 0.65) at baseline to 2.85 (SD = 0.58) in week 5 (p = 0.005) and 2.96 (SD = 1.10) in week 10 (p = 0.007). However, the DHEA levels did not show a significant difference between weeks 5 (M = 2.85, SD = 0.58) and 10 (M = 2.96, SD = 1.10).

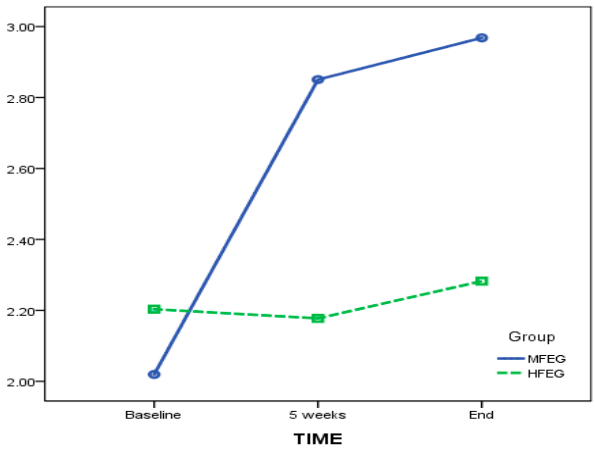


Figure 8. DHEA changes according to time in the exercise groups.

4. Discussion

The forest serves as a therapeutic environment to promote physical and mental health due to various environmental factors. Exercising in the forest is an activity that requires considerable physical energy, unlike exercising on flat ground. This is a special healing factor that only forests can provide, as each place is unique and not the same. This feature provides a special exercise stimulation for those who walk in the forest. The uneven terrain and irregular repetition of uphill and downhill slopes increase the participant's joint range of motion and stimulate the cardiovascular system [40]. We conducted a study to determine how the exercise stimulation of forest slopes affects IgA and DHEA levels.

This study showed a significant increase in IgA levels in the MFEG. Although the DAG and HFEG showed increases, the changes were minimal and insignificant. Regarding

the changes in IgA levels over time in the forest exercise groups, significant group and time interactions were observed. The MFEG showed a significant increase in IgA levels in weeks 5 and 10 compared to the baseline, suggesting that moderate-intensity forest exercise is effective in increasing IgA levels, with the most pronounced increase observed in week 5 and these significant increases maintained in week 10. However, the interaction effect in the HFEG was not significant, and there were no significant changes between time points.

IgA, a critical component of the primary immune response and the most abundant immune protein in mucosal epithelial cells, decreases after strenuous exercise and increases during rest and recovery [41]. Regular moderate-intensity exercise has been shown to increase IgA levels [42], whereas irregular and prolonged high-intensity exercise may impair immune function [43]. Aerobic exercise at intensities below 70% VO2max is known to minimize oxidative damage while enhancing immune functions [44]. Our results are consistent with this notion, as the MFEG showed significant changes in IgA levels. During exercise, the type and intensity of exercise serve as stressors. The inclines in the forest terrain require significant physical energy and stimulate the muscles, resulting in exercise-induced stress. The proper management of this stress is essential. The MFEG regularly attended weekly sessions and participated in a moderate-intensity forest exercise program tailored to the physical capabilities of older adults; this approach provided favorable exercise stress and contributed to positive changes in IgA. The HFEG also underwent regular and continuous exercise. However, given that most of the participants were older adults, the HFEG's high-intensity exercise regimen likely lacked the adequate recovery needed to restore the body's metabolic functions. As a result, the effects observed in the HFEG were lower than those observed in the MFEG. Therefore, a moderate-intensity woodland walking exercise program and a program structure that ensures adequate recovery are recommended to facilitate effective changes in IgA, which is involved in the primary immune response in older adults.

DHEA, a hormone used to assess aging, decreased at post-test compared to the baseline in the DAG, although the change was not significant. In the forest therapy groups, there was a significant interaction between the intensity and duration of the forest therapy. In the MFEG, DHEA was significantly higher in weeks 5 and 10 than at baseline, indicating that regular, moderate-intensity forest exercise affects DHEA levels. In the HFEG, DHEA was higher in weeks 5 and 10 than at baseline, but not to a significant extent. In essence, the results show that a 10-week (20-session) moderate-intensity forest exercise program effectively increases DHEA levels. These results are consistent with the findings of Lee, where DHEA was elevated in middle-aged men [45]. Pritchard et al. reported an increase in DHEA and weight loss after exercise on a bicycle ergometer at 50%–55% VO2max in middle-aged men [46], and this exercise intensity was similar to the exercise intensity applied to the MFEG (50%–60% HRmax). However, a study in middle-aged women showed significant increases in DHEA at both 55% and 75% VO2max [47], while a study in 15-year-old adolescents reported more effective changes in DHEA levels after high-intensity exercise (70% VO2max) than after moderate-intensity exercise [48]. The study results regarding changes in DHEA as a function of exercise intensity have been inconsistent. One reason for this may be the effect of exercise volume. To control for the amount of exercise, the duration of the exercise was adjusted appropriately for each intensity, such that the high-intensity exercise program was shorter than the moderate-intensity exercise program. With the amount of exercise set at equivalent levels, the moderate-intensity (55% VO2R) and high-intensity (70% VO2R) exercise programs were effective on DHEA levels.

The ACSM (2020) suggests 30 to 60 min of exercise per day, five days per week, at HRmax of 40%–60% exercise intensity as the appropriate exercise intensity and time for older adults, and recommends three days per week of 20–30 min per day of high-intensity exercise [49]. Exercise intensities greater than 75% can lead to exercise injuries [22,50]. The comparison of our forest therapy program with these ACSM recommendations shows that the exercise intensity recommended by the ACSM is equivalent to that of our MFEG.

During the 120 min program, the MFEG performed breathing exercises, forest walks, strength training, and cognitive activities divided into 30–40-min segments. The overall exercise program provided an average exercise intensity of 60% HRmax, which was considered to provide an adequate amount of exercise. Even the high-intensity forest exercise produced positive results on IgA and DHEA levels in older adults, suggesting that effective study results can be observed when the exercise duration is limited according to the amount of exercise. Elderly women with an average age of 76 years were shown to have a reduced incidence of heart failure by 15%, even with light physical activity (walking 3600 steps for 33 min), suggesting a benchmark for exercise in the elderly [51]. This echoes the results of the present study, demonstrating that even low levels of exercise are effective in inducing physiological changes in older adults.

Muscle energy requirements increase during exercise, and proper energy delivery from muscles, the blood, and the liver is essential to maintain an effective metabolism [52] and to achieve positive post-exercise outcomes. An inadequate recovery period after exercise, during which energy sources are provided, could turn exercise into a negative stressor, thereby preventing its beneficial effects on the body. Walking or hiking in the woods provides resistance due to the inclines, which can lead to excessive exercise beyond an individual's physical capacity. Therefore, it is crucial to maintain an acceptable level of stress through relaxation. For this purpose, the personal health conditions, heart rate, walking ability, age, and other physical capacities must be evaluated, and the distance and duration of the exercise should be adjusted based on these data, as well as the incline in the forest terrain. It is especially important to design forest therapy programs that recognize the importance of relaxation and recovery for older adults, as the body's ability to recover declines with age.

This study has several limitations that need to be addressed in future studies to ensure the generalizability of the findings. First, the participants in this study were older adults, with an average age of 74 years or older, and had age-related chronic conditions, making it difficult to control their medication use. To minimize confounding by medications, future studies should examine participants who are not taking medications or analyze the effects of forest exercise on the body based on the specific medications used. Second, we could not control for voluntary engagement in the exercise within the DAG and activities other than the forest therapy program in the experimental groups. The participants had the choice to maintain their usual lives, and controlling for these activities proved challenging. Third, a high percentage of the DAG was lost during follow-up at the time of the post-test, and because the experimental group was divided into the MFEG and HFEG, the sample sizes for each group were small, resulting in a smaller effect size. In addition, the sex distribution between the groups was different, which limits the generalizability of the results. Fourth, no identities for height and age were obtained when screening subjects. Fifth, we were unable to assess the effects of the non-exercise components of the program when measuring the effects of exercise intensity during the 120 min program. Sixth, in the IgA report, the MFEG started at a lower level (24.50) than the other groups (DAG = 38.59; HFEG = 40.33). To address these limitations, future studies should ensure a sufficient sample size reflecting the demographic characteristics and ensure a power of analysis through the preliminary homogeneity testing of subjects By exclusively including forest exercise without other components and controlling the exercise intensity and amount of exercise. Finally, various healing factors, such as the abundance of oxygen in the forest, pleasant climate, indirect sunlight, and plant essential oils, as well as social and psychological positive factors related to forests, affect physiological changes. Future studies should reflect the influence of forest healing factors and study the effects of psychological factors on changes in IgA and DHEA levels.

Therapeutic forest or forest therapy programs typically use 120 min sessions. This study is important in shedding light on the optimal exercise intensity of these forest therapy programs for older adults. Our findings suggest that forest therapy programs (120 min) should be designed to include moderate-intensity exercise (60% HRmax). We recommend

designing forest exercise programs that measure the exercise volume based on factors such as distance, duration, and the incline in the forest and tailor them to the age and physical abilities of the participants. In addition, for older adults who may recover more slowly, especially when exercising in woods with inclines, we recommend allowing sufficient time for recovery. In addition, the program should include relaxation exercises to ensure that the body has enough energy to cope with the increased physical demands of exercising in an uphill forest.

5. Conclusions

The purpose of this study was to investigate the effect of forest exercise on the physical health of the elderly by classifying forest exercise according to intensity and ultimately determining the optimal intensity and duration of forest exercise.

This study shows that forest exercise has a positive effect on IgA (primary immune response) and DHEA levels (a hormone used to assess aging) in the elderly. Participation in a 120-minute exercise-based forest therapy program has the benefits of immune response and aging hormone changes, especially at moderate intensity (60% HRmax). We present guidelines for adjusting the daily exercise time to 30–60 min, 3–5 times per week with exercise at a moderate intensity (60% HRmax), starting at a low intensity (40%–50% HRmax) and gradually increasing it, in forest exercise programs for the elderly. When progressing to high-intensity exercise (70% HRmax), it is recommended to include 20 to 30 min of daily exercise time and sufficient rest and recovery time to allow the body to more comfortably adapt to the physical demands of exercising. The results of this study provide important insights for the advancement of exercise programs specifically designed for the elderly population.

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