The effects of physiological relaxation by natural environment and elucidation of individual differences in those effects

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自然環境がもたらす
生理的リラックス効果と個人差の解明

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Contents

Introduction

It is empirically known that interaction with nature has a relaxation effect on humans. As the interest in quality of life and health promotion has increased, attention has been focused on the role of nature in promoting human health and well-being. Humans have evolved over the course of 6 to 7 million years [1]. Therefore, more than 99.99% of human evolutionary history has been spent in natural environments [2]. Consequently, humans have adapted to nature [2, 3]. This human tendency to be close to nature implies that contact with nature may be an important component of well-being [4].

Many studies have demonstrated the significant psychological and physiological benefits of interactions with nature. Since 1980, many studies have demonstrated a significantly positive relationship between people's exposure to natural environments and their health. Several questionnaire-based studies have reported restorative effects related to psychological stressors or mental fatigue [5–7] and have reported improved mood states and cognitive function [8–11]. Improved physiological measurement techniques in recent years have generated further scientific evidence based on physiological parameters. Studies on the physiological effects of relaxation in forest environments have demonstrated that time spent in a forest environment can decrease blood pressure [12–16] and pulse rate [12–18], suppress sympathetic nervous activity [12, 14–18], increase parasympathetic nervous activity [12, 14–18], decrease cortisol levels [13–19], and decrease cerebral blood flow in the prefrontal cortex [19]. These studies suggest that human beings are more relaxed in forest environments. Moreover, visiting a forest environment enhanced human natural killer cell activity and improved immune function

[20], effects of which lasted for approximately 1 month [21, 22]. A significant amount of scientific evidence has been reported [16, 23, 24]. Park et al. [16] reported that viewing forest scenery and walking in a forest environment mitigated stress and led to biological relaxation, findings of which were based on the results of experiments using 420 subjects in 35 locations throughout Japan.

However, in modern society, interaction with forests is difficult. Recently, increasing attention has been focused on the role of urban green spaces, such as urban parks, that provide natural environments close to where most people live in modern society. However, there is a lack of evidence-based research on the physiological effects of urban green area.

Furthermore, individual differences in the effects of natural environments have been noted, and this phenomenon has posed several questions in a variety of fields that must be clarified. Previous research has led to proposals that scientific research should be conducted on individual differences in response to forest environments [24]. To date, methods for interpreting these individual differences have not been established.

The aim of the present study was to investigate the physiological and psychological effects on humans of an urban park, which is a familiar natural environment, and to elucidate individual differences in the physiological effects of forest environments in subjects with Type A and Type B behavior patterns [25, 26] and that could be explained by the law of initial value [27, 28].

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Ⅰ. Physiological and psychological effects of urban parks on humans

(1) Introduction

In this part, we determined the physiological and psychological effects on humans of an urban park, which is a familiar natural environment.

Nowadays most people live in cities. Although life is easier, rapid urbanization and artificialization have caused environmental changes [1], and these environmental changes threaten human health and quality of life [1, 2]. Furthermore, the rapid spread of information technology over recent years has caused an increase in stress, which was referred to as "techno stress" in 1984 [3]; this is a modern disease of adaptation caused by an inability to cope with new computer technologies in a healthy manner. Many mental disorders and cardiovascular diseases are closely related to stress, and many studies have shown the negative physiological effects of stress on organisms, including humans [4–6]. The combination of all of these factors has a severe effect on humans. Despite this, there is a lack of evidence-based research on the physiological and psychological effects of urban environments.

Initially, we established a baseline by examining the physiological and psychological effects of walking in a city area as a common action in daily life. Subsequently, we determined the therapeutic effects of walking in an urban park and compared these effects with those from walking in the city area.

Recent demographic research found a positive association between exposure to urban green spaces and the perceived general health of residents [7]. Living in areas with walkable green spaces positively influenced the longevity of urban senior citizens independent of their age, sex, marital status, baseline functional status, and socioeconomic status [8]. Most individuals in industrialized countries live in urban areas and will continue to do so for the foreseeable future [9]; therefore, any beneficial effects of urban green space can improve general health and longevity. A previous study reported that walking in an urban green area during summer induced physiological and psychological effects [10]. However, there is a lack of evidence-based research on the physiological effects from walking in an urban green area during another season.

Therefore, we also determined the effects of walking in urban parks in winter and spring.

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Ⅰ. Physiological and psychological effects of urban parks on humans

(2) Effects of walking in an urban environment on autonomic nervous activity

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ABSTRACT

Rapid urbanization and artificialization have caused environmental changes that threaten human health and quality of life. However, there is a lack of evidence-based research focused on the physiological and psychological impacts of urban environments. The aim of this study was to clarify the physiological and psychological impacts of urban environments using a field experiment. Thirty-six Japanese male university students (mean age 22.1 ± 1.8 years) participated in the study, each was instructed to walk a predetermined 13-min course in an urban area (test) and forested area (control). Heart rate and heart rate variability were measured to assess physiological responses to the environment. The semantic differential method for assessing emotions and reports of feeling “refreshed” were used to determine psychological responses. Heart rate was significantly higher and the high-frequency component of heart rate variability, which is an index of parasympathetic nervous activity that is enhanced in relaxing situations, was significantly lower when the subjects walked through urban than through forested areas. Moreover, the psychological indices showed that the subjects felt more artificial and less “refreshed” when walking in the urban areas. In conclusion, these findings provide important scientific evidence of physiological and psychological impacts of walking stress in urban environments.

1. Introduction

Nowadays most people live in urban areas and they will continue to do so for the foreseeable future [1, 2]. Cities have been an important part of civilization. Urbanization has improved the living conditions in areas such as housing, employment, education, equality, quality of living environment, social support, and health services [2] and is a force in the global demographic transition from high to low birth rates and short to long life spans, and in the health and nutritional transitions that are shifting the burden of illness from acute childhood infections to chronic and mostly non-communicable diseases of adults [1].

However, from an evolutionary perspective, urbanization is a very drastic change that has occurred over a very short period. Rapid urbanization and artificialization have caused environmental changes such as increased traffic, polluted air and water, exhausted local resources, and decreased agricultural land and natural open space [3]. These environmental changes threaten human health and quality of life [3, 4]. In particular, cities have been reported to have high temperatures and act as urban heat islands [5, 6]. High temperatures cause sensations of discomfort and sometimes heat stress [7]. The implications of these findings are that individuals living in urban zones will experience increased heat and will thus potentially be at greater risk of heat-related illnesses than those in rural areas [6, 8].

Furthermore, the rapid spread of information technology over recent years has caused an increase in stress, which was referred to as “techno stress” in 1984 [9]; this is a modern disease of adaptation caused by an inability to cope with new computer technologies in a healthy manner. Many mental disorders and cardiovascular diseases are closely related to stress and many studies have shown the negative physiological impacts of stress on organisms, including humans [10–12]. All of these factors in combination have severe impacts on humans.

Several studies have reported that urban environments are associated with increased mortality rates [13]. Although we are now living in a society characterized by urbanization and artificialization, our physiological functions are still adapted to nature [14]. Because of this discrepancy between our bodily requirements and our manner of living, our stress levels are always very high and our sympathetic nervous system is excessively stimulated [14–19]. Despite this, there is a lack of evidence based research focused on the physiological and psychological impacts of urban environments.

The aim of this study was to clarify the physiological and psychological impacts of urban environments compared with forested environments (typical natural environments) using a field experiment. In addition, forest environment in this study directed to safe forests has been developed.

2. Materials and methods

2-1. Study sites and subjects

The field experiments were performed in three areas located in central Japan (Figure 1 from left to right: Tsubata Town, Ishikawa Prefecture; Kofu City, Yamanashi Prefecture; and Matsukawa Town, Nagano Prefecture). Detailed maps of each experimental area are shown in Figures 2–4. The weather on the days of the experiment was sunny, and the average temperature and humidity in the urban area were 32.0℃ and 48.1%, respectively, while those in the forested area were 30.1℃ and 58.4%, respectively.

Twelve young Japanese male university students participated in an experiment at each site, and so the total number of subjects was 36 (mean age 22.1 ± 1.8 years); none reported a history of physical or psychiatric disorders. The consumption of alcohol and tobacco was prohibited and caffeine consumption was controlled during the study period. The study was performed in accordance with the regulations of the Ethics Committee of the Center for Environment, Health, and Field Sciences, Chiba University, Japan.

2-2. Physiological and psychological measurements

Heart rate and heart rate variability (HRV) were measured to assess autonomic nervous activity. These indicators of autonomic nervous activity reflect the response of an organism to external stressors and are simple widely used measures of the body's condition. HRV measures sympathetic nervous activity and parasympathetic nervous activity by frequency analysis using the periods between consecutive R waves (RR intervals) in the electrocardiogram and can quantitatively measure autonomic nervous activity. HRV, which is often used to assess human autonomic activity, was measured using a portable electrocardiograph (Activtracer AC-301A, GMS, Tokyo, Japan). HRV data were obtained at various frequencies using HRV software (MemCalc/Win, GMS, Tokyo, Japan). For real-time HRV analysis using the maximum entropy method, inter beat (R–R) intervals were obtained continuously. In this study, the two major HRV spectral components, low-frequency (LF; 0.04–0.15 Hz) and high-frequency (HF; 0.15–0.40 Hz) band variance, were calculated. The LF/HF ratio in the R–R interval was also assessed. HF components can be a general indication of parasympathetic nervous activity, and the LF/HF ratio can be used as an index of sympathetic nervous activity [20]. To normalize the distribution of HRV parameters, we used the natural logarithmic transformed values for the analysis (that is, ln(HF) and ln(LF/HF)) [21].

Psychological reactions were investigated by subjective evaluations. Evaluations using the semantic differential (SD) method [22] were performed using three pairs of adjectives on seven scales, including “comfortable–uncomfortable,” “soothing–awakening,” and “natural–artificial.” The feeling of being “refreshed” was also examined using a questionnaire with 30 questions and a total score range of 0–90 [23].

2-3. Experimental design

An experimental design was used in this study. The design required performing the same action in different environments (urban and forested areas). Taking a brief walk was considered to be a common action in daily life, thus we instructed the subjects to walk in each environment.

The experiment was performed at each experimental area over 2 days using the same design. On the first day, the experimental protocol was explained and general instructions provided. The twelve subjects were then randomly divided into two groups of six, which eliminated any ordering effect. The first randomly selected group performed the experiment in the urban area, and the other group performed the same experiment in the forested area. All participants stayed in a waiting room before moving to the field site. At each site, measurements were taken from each participant one at a time. All participants were instructed to rest on a chair for 5 min, which mitigated the physiological effects of physical activity before the measurement period, and then to walk in the urban or forested area for 13 min (Figure 5). On the second day, the participants switched field sites. The experimental protocol for the second day was the same as that for the first day.

Physiological data were obtained as the participants walked about in the two environments, and psychological data were obtained before and after the walking environments. There was no difference in the exercise load during walking in the urban and forested environments.

2-4. Data analysis

A paired t-test was used to compare the physiological data values between the urban and forested environments and for the 1-min analysis of continuous data. The latter was used to determine whether physiological responses were changed by the environment and whether these changes were dependent on time. Holm's procedure was used to adjust the significance level for multiple comparisons. In the physiological data analysis, only 30 (urban area) and 27 (forested area) samples were included in the final analysis because of data collection errors.

The Wilcoxon signed-rank test was applied to analyze differences in the psychological indices between the two environments.

Statistical analysis was performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). A one-sided test was used. In all cases, values of $P < 0.05$ were considered statistically significant.

3. Results and discussion

When the physiological indices for the urban and forested environments were compared, important differences were observed. The 1-min heart rate analysis revealed that heart rate was significantly higher in the urban area than in the forested area after 3–4 min ($P < 0.05$), 4–5 min ($P < 0.01$), 5–6 min ($P < 0.05$), 6–7 min ($P < 0.05$), 7–8 min ($P < 0.01$), 8–9 min ($P < 0.05$), 9–10 min ($P < 0.05$) of walking (Figure 6). These results show that heart rates increased over time as the subjects walked through the urban area. Moreover, when the average values after 13 min were compared, heart rates were found to have significantly increased (6.9%) in the urban area (94.9 ± 2.5 bpm) compared with the forested area (88.8 ± 2.4 bpm; $P < 0.01$; Figure 7).

When the HRV data were compared, a significant difference between the two environments was found in ln(HF), which is a marker of parasympathetic nervous activity that is enhanced in relaxing situations. Although there were no significant differences in the 1-min ln(HF) analysis, a trend towards lower values in the urban area compared with the forested area was detected (Figure 8). It may be that the act of walking influenced the ln(HF) values as these showed a tendency to decrease in both the urban and forested areas. Previous research on the relaxation effect of walking in forests and viewing forested landscapes have shown that the HF value during walking is lower than that when sitting in a chair viewing the same forested landscape [24]. In the present study, the average value after 13 min of walking was 6.1% lower in the urban area (3.88 ± 0.14 lnms^2) than in the forested area (4.13 ± 0.18 lnms^2; $P < 0.05$; Figure 9).These results indicate that walking in an urban environment might be a stressor that disturbs a relaxation of autonomic nervous activity. No significant difference in ln(LF/HF) values, a marker of sympathetic nervous activity, were observed between the two environment.

These results are partly in agreement with those of previous studies that have compared physiological reactivity in urban and forested environments [16, 18, 19, 24], and may support the premise that walking in an urban environment induces stress in humans.

The psychological analysis also revealed notable differences between the two environments. The urban environment was perceived as significantly more uncomfortable ($P < 0.01$, Figure 10, left), awakening ($P < 0.01$, Figure 10, middle), and artificial (P <

0.01, Figure 10, right) than the forested environment. Furthermore, scores for feeling "refreshed" were lower by 11.0% in the urban area (53.4 ± 13.9 scores) than in the forested area (60.0 ± 13.9 scores; $P < 0.01$; Figure 11). The analysis of these psychological indices revealed that the subjects felt more uncomfortable, awake, artificial, and less "refreshed" when walking in the urban area than when walking in the forested area.

The results of this study support the notion that walking in an urban environment induces a physiological stress response in humans and negative emotions. Improving our environments by changing the current structure of urban areas may ameliorate these effects. Much attention has been paid to the role of urban green areas such as parks and tree-lined streets in promoting human health and well-being, and the composition of such green areas can be considered one way of improving the urban environment. Recent research has found a positive association between exposures to urban green space and perceived general health as well as lower mortality of residents [25, 26]. Living in areas with walkable green spaces was shown to positively influence the longevity of urban senior citizens independent of their age, sex, marital status, baseline functional status, and socioeconomic status [27]. Moreover, it was evident that walking in an urban park for only 15 min brings physiological and psychological relaxation [28]. Master plans for urban development should pay more attention to maintaining and increasing greenery filled public areas that are easy to walk in and are within easy walking distance of every household.

Although these results cannot be generalized because of the limited sample size and the small number of study sites, it is noteworthy that the impacts of the urban environment were quantitatively measured at the field sites using biological markers. Identifying the physiological and psychological impacts of urban environments is an important issue in biometeorology and the results of this study may further our understanding in the regard.

4. Conclusions

These findings provide important scientific evidence of the physiological and psychological impacts of walking stress in an urban environment, as follows: in the urban environment, (1) heart rates were significantly higher; (2) the HF component, which is a general indication of parasympathetic nervous activity, was significantly lower; and (3) subjects felt more uncomfortable, awake, artificial, and less “refreshed.” In conclusion, the results of this study showed that walking in an urban environment brings about stressed states in the human body and mind. On the other hand, recent research has found a positive association between exposure to urban green space and human health. It considered that master plans for urban development should pay more attention to maintaining and increasing greenery-filled public areas.

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Figures

Figure 1. Map showing the experimental locations.

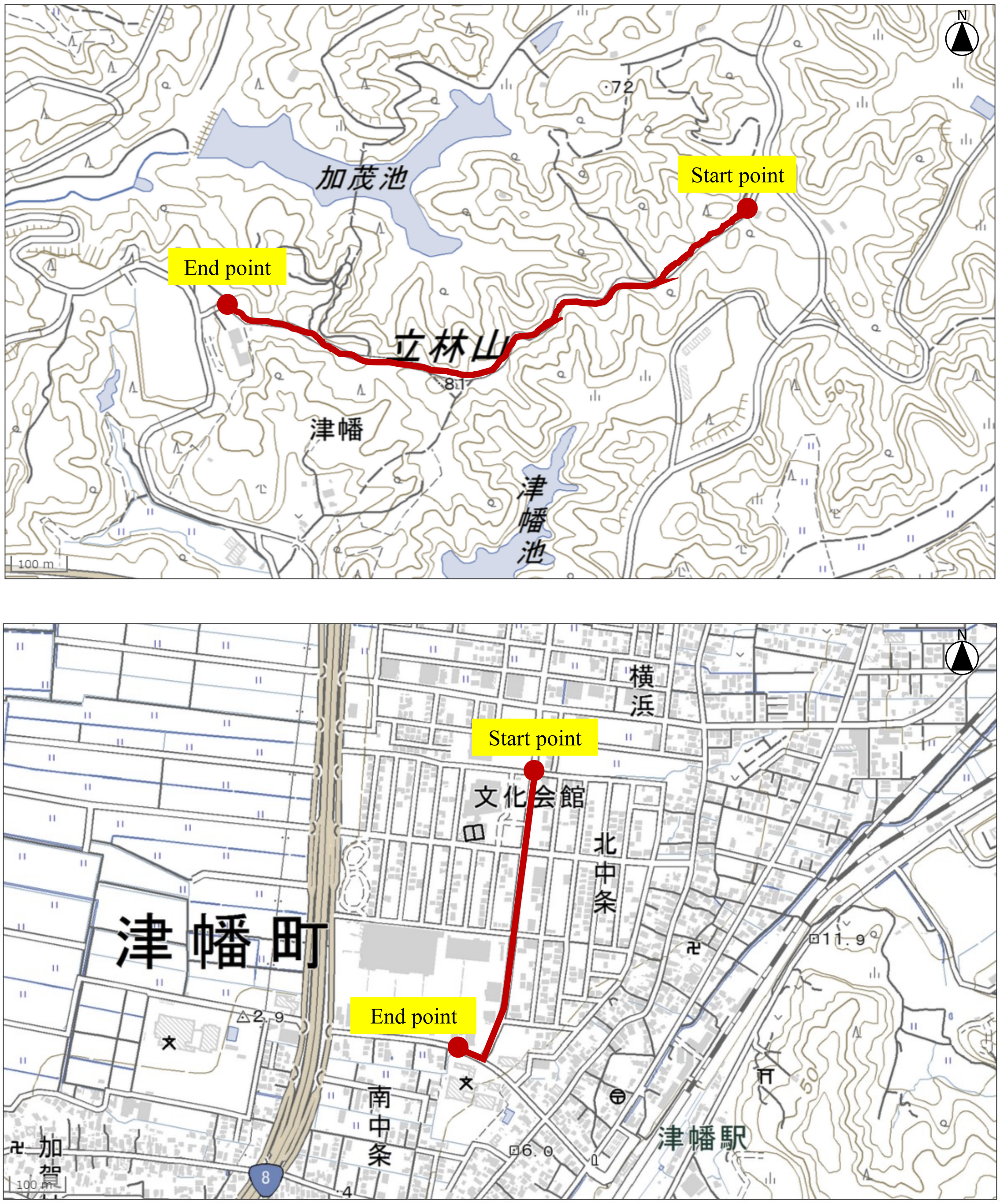
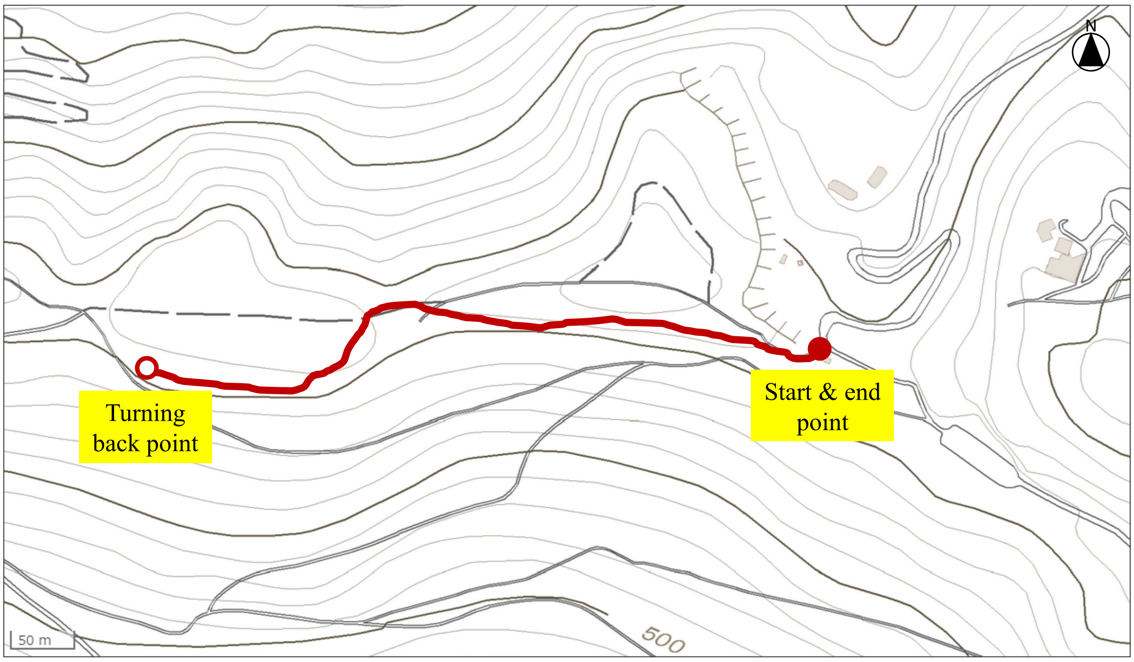


Figure 2. Experimental area in Tsubata Town, Ishikawa Prefecture.

Top: Forest area, Bottom: City area



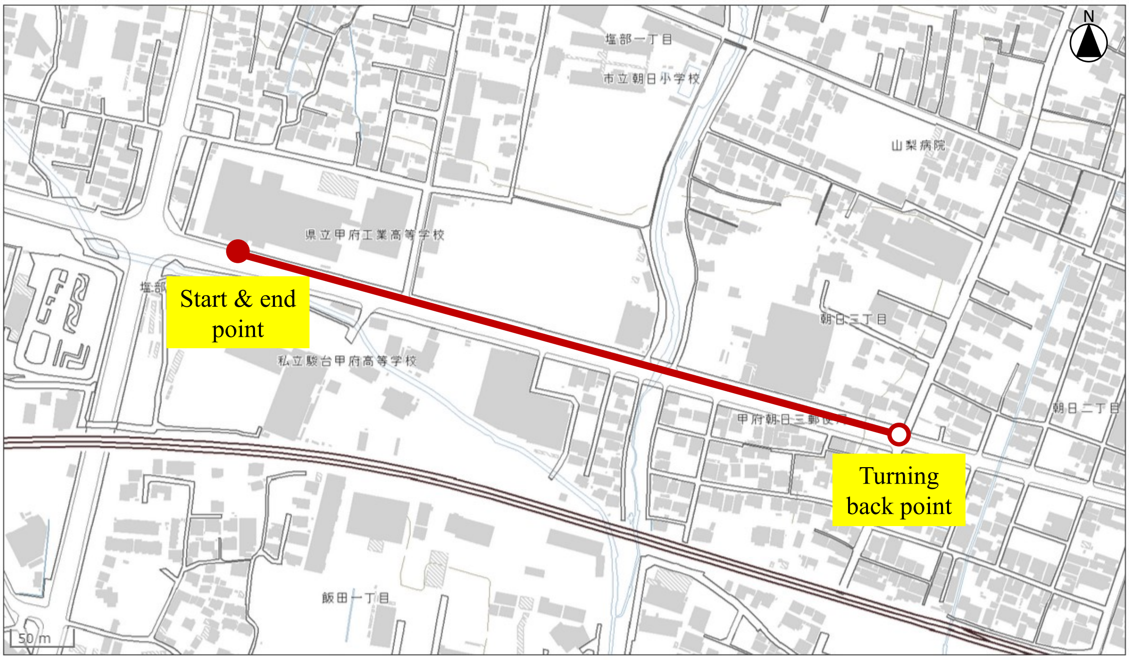


Figure 3. Experimental area in Kofu City, Yamanashi Prefecture.

Top: Forest area, Bottom: City area

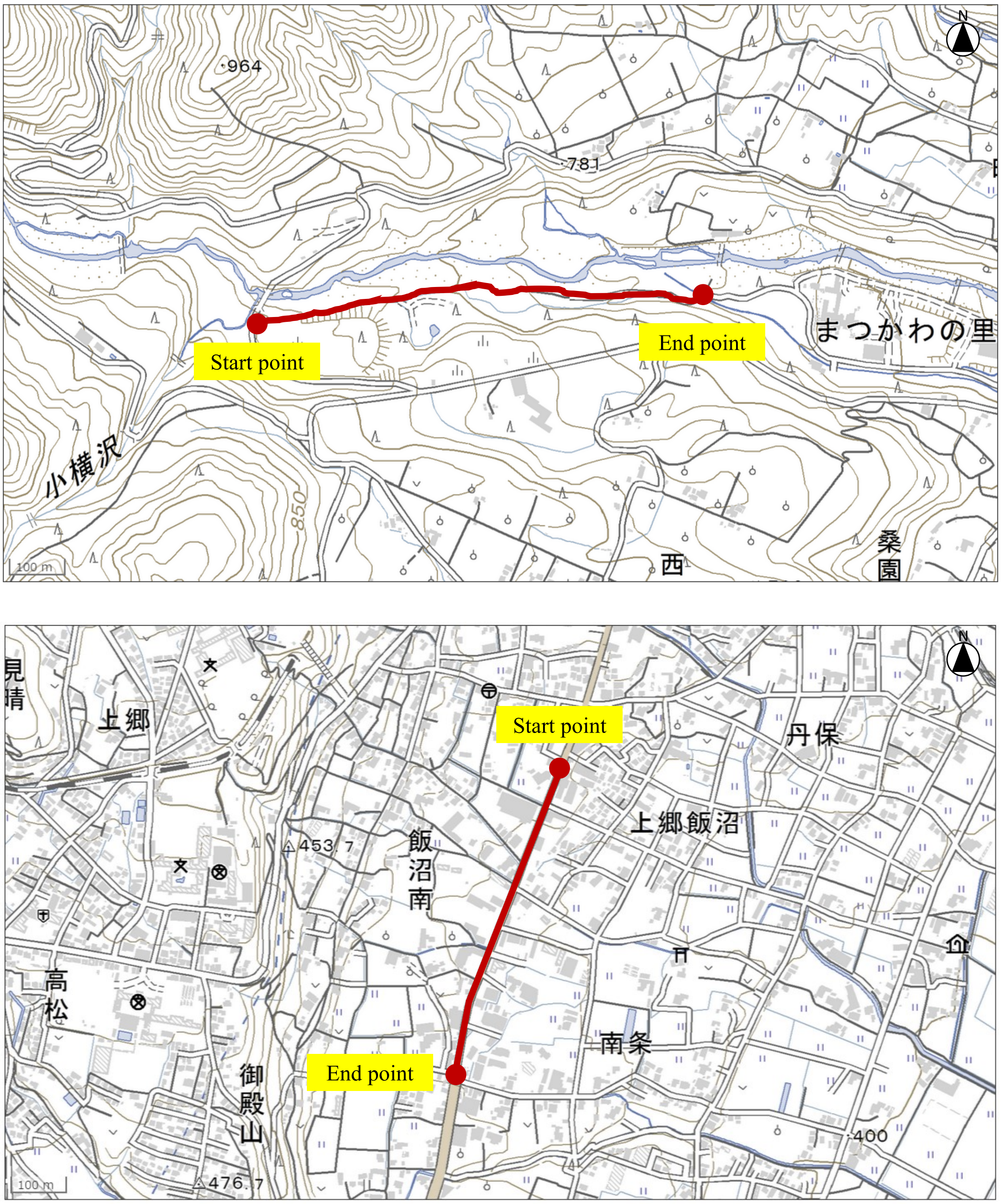


Figure 4. Experimental area in Matsukawa Town, Nagano Prefecture.

Top: Forest area, Bottom: City area

(A) Ishikawa (B) Yamanashi (C) Nagano

Figure 5. Representative experimental scene in an urban (top) and forested area (bottom).

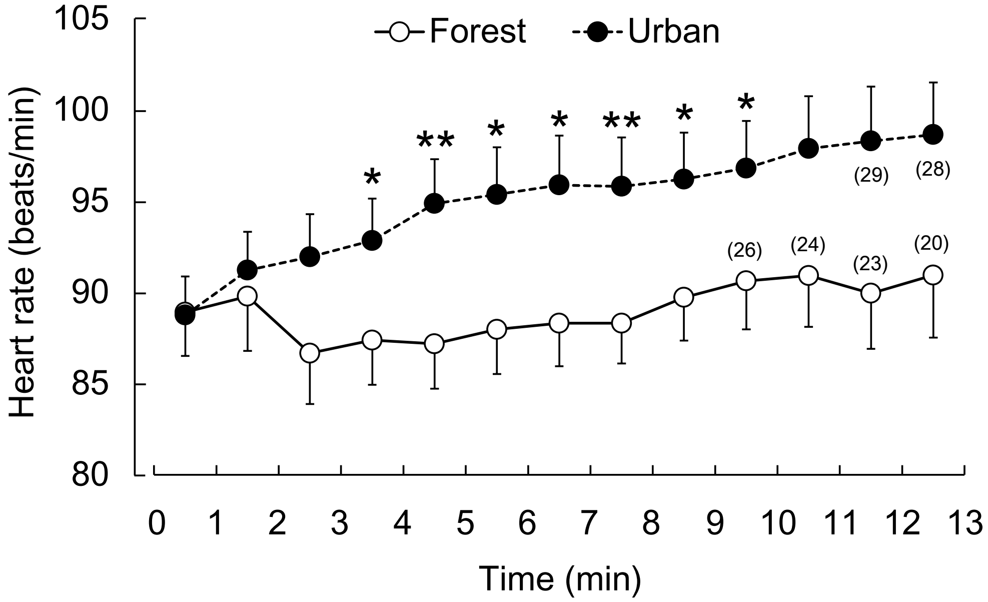


Figure 6. Changes in heart rate at 13 min and comparison of each 1-min value between the two environments.

N = 28–30 (in the urban areas), N = 20–27 (in the forests), mean ± SE, The number in parentheses refers to the number of subjects. * $P < 0.05$, ** $P < 0.01$, determined by paired t-test; Holm’s procedure was used.

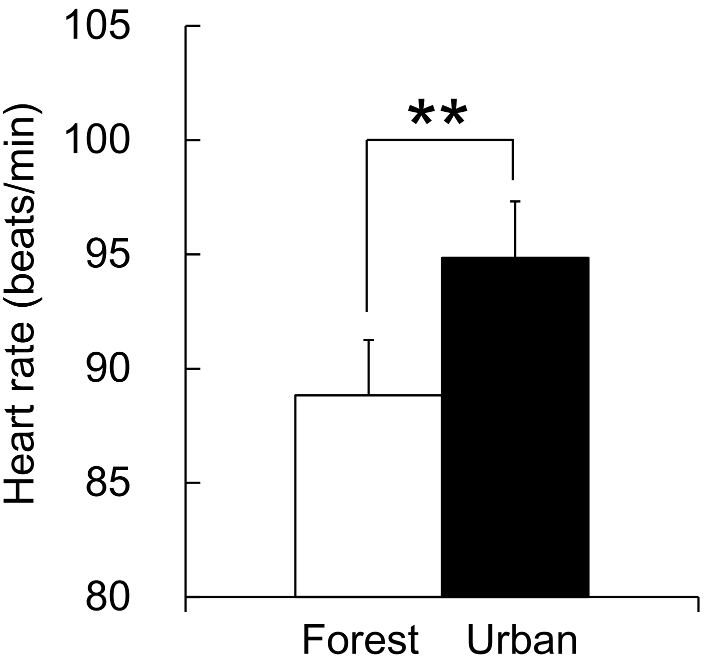


Figure 7. Comparison of the heart rates of subjects walking in urban and forested areas. N = 30 (in the urban areas), N = 27 (in the forests), mean ± SE. ** $P < 0.01$, determined by paired t-test

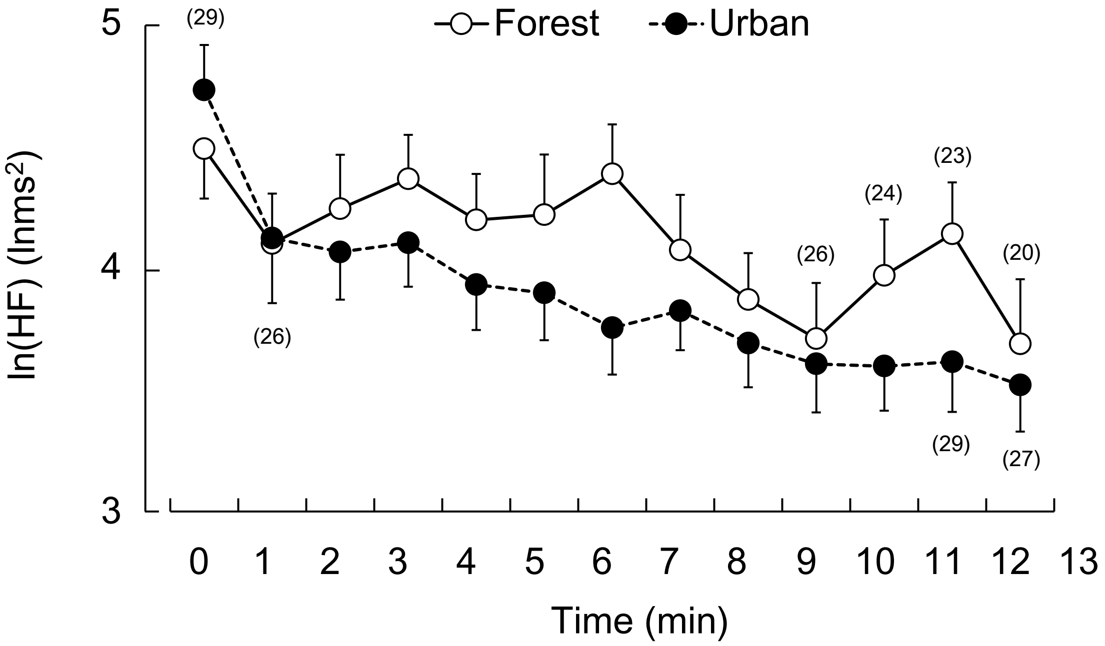


Figure 8. Changes in the ln(HF) of HRV at 13 min and comparison of each 1-min value between the two environments.

N = 27–30 (in the urban areas), N = 20–27 (in the forests), mean ± SE. The number in parentheses refers to the number of subjects.

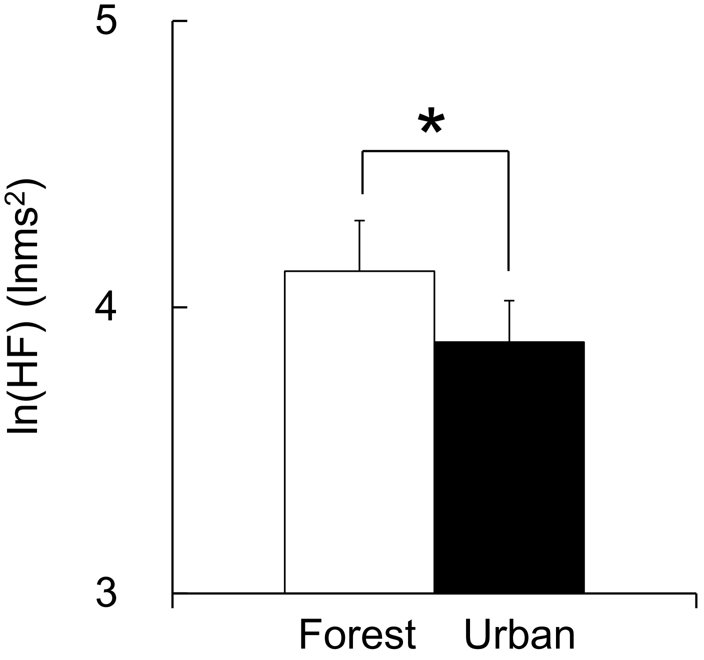


Figure 9. Comparison of ln(HF) of HRV of subjects walking in urban and forested areas. N = 30 (in the urban areas), N = 27 (in the forests), mean ± SE. * $P < 0.05$, determined by paired t-test.

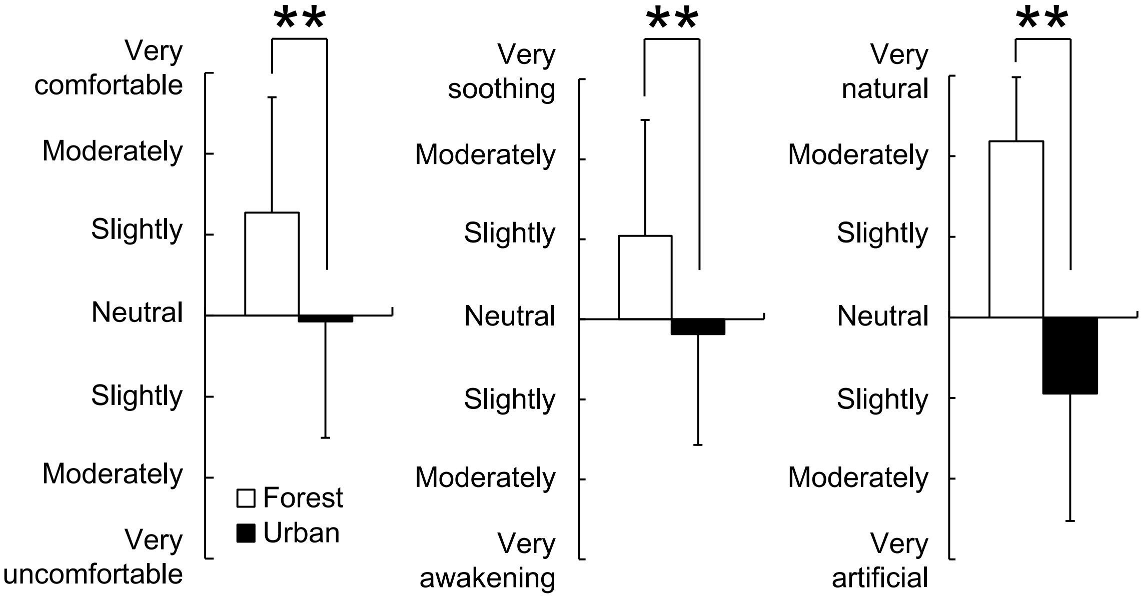


Figure 10. Comparison of subjective scores for comfortable, soothing, and natural feelings between the two environments.

N = 35, mean ± SD. ** $P < 0.01$, determined by Wilcoxon signed-rank test

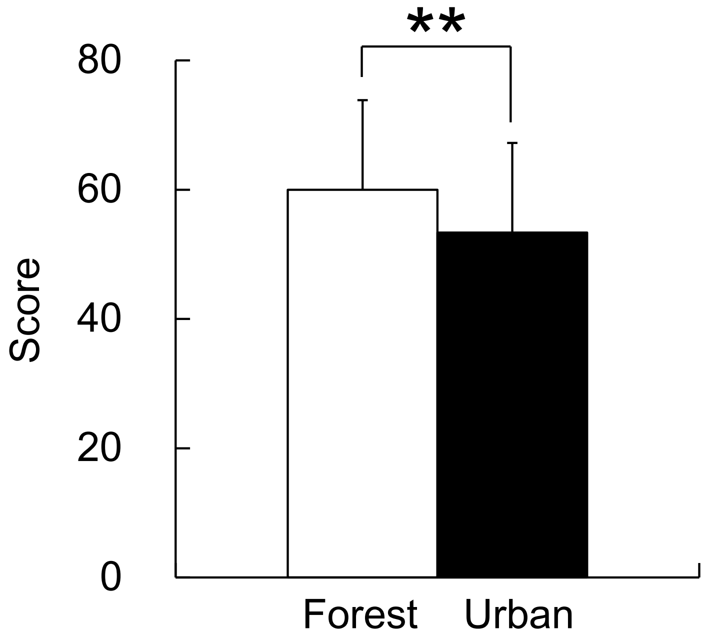


Figure 11. Comparison of subjective scores for a refreshed feeling between the two environments.

N = 35, mean ± SD. ** $P < 0.01$, determined by Wilcoxon signed-rank test

Ⅰ. Physiological and psychological effects of urban parks on humans

(3) Effects of walking in urban parks in winter on autonomic nervous activity

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ABSTRACT

Interaction with nature has a relaxing effect on humans. Increasing attention has been focused on the therapeutic effects of urban green space; however, there is a lack of evidence-based field research. This study provided scientific evidence supporting the physiological and psychological effects of walking on young males in urban parks in winter. Subjects (13 males aged 22.5 ± 3.1 years) were instructed to walk predetermined 15-minute courses in an urban park (test) and in the city area (control). Heart rate and heart rate variability (HRV) were measured to assess physiological responses. The semantic differential (SD) method, Profile of Mood States (POMS), and State-Trait Anxiety Inventory (STAI) were used to determine psychological responses. Heart rate was significantly lower and the natural logarithm of the high frequency component of HRV was significantly higher when walking through the urban park than through the city area. The results of three questionnaires indicated that walking in the urban park improved mood and decreased negative feelings and anxiety. Physiological and psychological data from this field experiment provide important scientific evidence regarding the health benefits of walking in an urban park. The results support the premise that walking in an urban park has relaxing effects even in winter.

1. Introduction

It is empirically known that interaction with nature has a relaxing effect. As the interest in health promotion and quality of life has increased, attention has been focused on the role of nature in promoting human health and well-being.

Humans evolved into what they are today after the passage of six or seven million years [1]. Therefore, more than 99.99% of human evolutionary history was spent in the natural environment. Urbanization can be defined as a post-industrial revolutionary development. Through centuries of evolution within the natural environment, humans adapted to nature [2, 3]. This human tendency to be close to nature implies that contact with nature may be an important component of well-being [4].

Many studies have demonstrated significant positive psychological and physiological benefits of interaction with nature. Interaction with nature aids recovery after attentional fatigue [5] and stress [2] and improves emotional state [6]. Studies of the physiological effects of relaxation in forest environments have tested parameters such as cerebral activity in the prefrontal area [7], pulse rate [8–10], blood pressure [9, 11], heart rate variability (HRV) [8, 10, 11], salivary cortisol concentration [7–10], and natural killer (NK) cell activity [12, 13]. Many results based on scientific evidence have been reported [14–16].

However, in modern society, interaction with nature such as forests is difficult. Recently, increasing attention has been focused on the role of urban green spaces such as urban parks that provide a natural environment close to most people in modern society. Recent demographic research found a positive association between exposure to urban green space and perceived general health of residents [17]. Living in areas with walkable green spaces positively influenced the longevity of urban senior citizens independent of their age, sex, marital status, baseline functional status, and socioeconomic status [18].

However, there is a lack of evidence-based research on the therapeutic effects of urban green space. Many scientists have emphasized the importance of field research [19]. Because the therapeutic effects of nature occur without conscious thought, these effects must be clarified in physiological field studies [3]. Furthermore, although we conducted similar experiments during summer [20], there are no experimental examples that can verify the physiological effects during winter.

The aim of this study was to provide scientific evidence supporting the physiological and psychological effects of walking in urban parks in winter.

2. Methods

The field experiment was performed in November 2012 in Kashiwanoha Park (hereinafter referred to as the urban park) in Chiba, Japan. As a control, the city area around the urban park (hereinafter referred to as the city area) was selected. Detailed maps of each experimental area are shown in Figure 1. The urban park contained many hardwood trees such as maple, tulip trees, ginkgo, cherry blossoms, and chestnut. There was also a large pond in the center.

The weather on the day of the experiment was sunny, and the average temperature, humidity, and intensity of illumination in the urban park were 13.8°C, 50.9%, and 7,930 lx, respectively, while those in the city area were 14.0°C, 52.1%, and 8,430 lx, respectively. In addition, the trees in the park had either lost their leaves or the leaves had turned red or yellow, but there was no snow.

Thirteen Japanese male university students (22.5 ± 3.1 years old) participated in this experiment. Each subject walked in the urban park or city area for 15 minutes (Figure 2). None reported a history of physical or psychiatric disorders. This study was performed according to the regulations of the Ethics Committee of the Center for Environment, Health and Field Sciences, Chiba University, Japan.

Heart rate and HRV were measured to assess physiological responses. HRV, which is often used to assess human autonomic activity, was measured using a portable electrocardiograph (Activtracer AC-301A, GMS, Tokyo, Japan). HRV data were obtained at various frequencies using an HRV software tool (MemCalc/Win, GMS). For real-time HRV analysis using the maximum entropy method, inter-beat (R-R) intervals were obtained continuously. In this study, the two major HRV spectral components, low frequency (LF; 0.04 to 0.15 Hz) and high frequency (HF; 0.15 to 0.40 Hz) band variance, were calculated. The LF/HF ratio in R-R interval variability was also assessed. HF components can be a general indication of parasympathetic nervous activity, and the LF/HF ratio can be used as an index of sympathetic nervous activity [21, 22]. To normalize the distribution of HRV parameters, we used natural logarithmic transformed values for the analysis [23]. The heart rate and HRV data, which were collected at 1 minute intervals at each experimental location, were compared based on the average for 15 minutes.

Three different questionnaires were used to investigate psychological responses. The questionnaires were completed after walking at each experimental site. Evaluation using semantic differential (SD) method [24] was performed using three pairs of adjectives on seven scales, including ‘comfortable to uncomfortable’, ‘natural to artificial’, and ‘relaxed to awakening’. The Profile of Mood State (POMS) data were analyzed using the following six subscales: ‘tension–anxiety’, ‘depression’, ‘anger–

hostility', 'vigor', 'fatigue', and 'confusion'. In the POMS test, a short form with 30 questions was used to reduce the burden on the subjects [25, 26]. The State-Trait Anxiety Inventory (STAI) [27] was used to evaluate anxiety.

We performed a within-subject experiment, and to eliminate the effect of the order of sites walked, two subjects were paired. One subject walked in the urban park first and in the city area later, while the other walked in the city area first and then in the urban park. There was no difference in the physiological index before the start of each walk between the two environments. After walking, the subjects returned to the waiting room and completed questionnaires. They rested for approximately 20 minutes and repeated the experiment by walking at the alternate experimental site. In addition, there was no difference in the walking speed between the two environments.

All data were shown as mean ± standard deviation. A paired t-test was used to compare the differences in the mean physiological data scores over a period of 15 minutes while walking in the urban park and city area. Wilcoxon signed-rank test was used to analyze differences in the psychological indices after walking between the two environments. Statistical analysis was performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). A one sided test was used in this study. In all cases, values of $P < 0.05$ were considered statistically significant.

3. Results and discussion

In the comparison of physiological indices between the urban park and the city area, key differences were observed. Most mean heart rate values within one minute epochs were lower during the urban park walk compared with those during the city walk (Figure 3). In the mean heart rate over the entire 15-minute period, subjects' heart rates were significantly lower (4.4%) after walking in the urban park (98.4 ± 0.9 bpm) than after walking in the city area (102.9 ± 1.1 bpm; $P < 0.05$; Figure 4). When the results of HRV data were compared, a significant difference was found in the natural logarithm of HF (ln(HF)), which is a marker of parasympathetic nervous activity, between the two environmental stimuli. Most mean ln(HF) values within one minute epochs were higher during the urban park walk compared with those during the city walk (Figure 5). In the mean heart rate over the entire 15-minute period, the urban park (4.61 ± 1.25 lnms^2) showed a 21.6% higher value than the city area (3.79 ± 1.16 lnms^2; $P < 0.05$; Figure 6). In the comparison of ln(LF/HF) values, which is a marker of sympathetic nervous activity, no significant difference between the two environments was found. However, a trend towards lower values in the urban park (1.06 ± 1.01 ratio) compared with the city area (1.40 ± 1.00 ratio) was detected ($P = 0.06$). These physiological reactivity results correlated partly with those reported by previous studies related to forest therapy [8, 10, 11, 14–16], supporting the hypothesis that urban parks have similar health benefits to natural environments.

The results of the analysis of psychological responses revealed notable differences between the two environments. In the comparison of the SD scores, significantly higher scores were observed in the urban park for the following three adjectives: ‘comfortable’, ‘natural’, and ‘relaxed’ compared with the city area ($P < 0.01$; Figure 7). Significant differences were also detected in the results of the POMS test (Figure 8). The score for the negative subscale ‘tension–anxiety’ was significantly lower after walking in the urban park compared with the city area ($P < 0.01$). Conversely, the positive mood state for ‘vigor’ was significantly higher in the urban park but not in the city area ($P < 0.01$). For the other subscales (‘depression’, ‘anger–hostility’, ‘fatigue’, and ‘confusion’), no significant differences were observed. In the results of analysis of state anxiety using STAI, the score was 18.2% lower in the urban park (37.3 ± 8.7 scores) compared with the city area (45.6 ± 7.1 scores; $P < 0.05$; Figure 9).

Based on the analysis of these three psychological indices, subjects felt more comfortable, natural, relaxed, and vigorous when walking in the urban park than in the city area. In addition, the negative emotions and anxiety levels were significantly lower. These results on the psychological benefits of walking in the urban park are partly consistent with previous findings related to forest therapy [8–11].

For those who desire a higher quality of life, scientific evidence about the relaxation effects of urban green space must be accumulated, as these are the natural environments most accessible to people in modern society.

However, these results cannot be extrapolated to the female population and people of different age groups or ethnicities, because only thirteen young male adults participated in this study. To generalize the findings, further evidence-based studies on a large sample including various subject groups is required.

4. Conclusion

These findings provide important scientific evidence of the health benefits of walking in urban parks. The results support the premise that walking in urban parks has relaxing effects even in winter.

Acknowledgments

This study was performed by permission of the Corporation for Urban Enhancement of Chiba Prefecture, Japan. We appreciate their co-operation. For valuable contributions in the data collection phase of this study, we are grateful to Dr. Yuko Tsunetsugu of the Forestry and Forest Products Research Institute, Japan.

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Figures

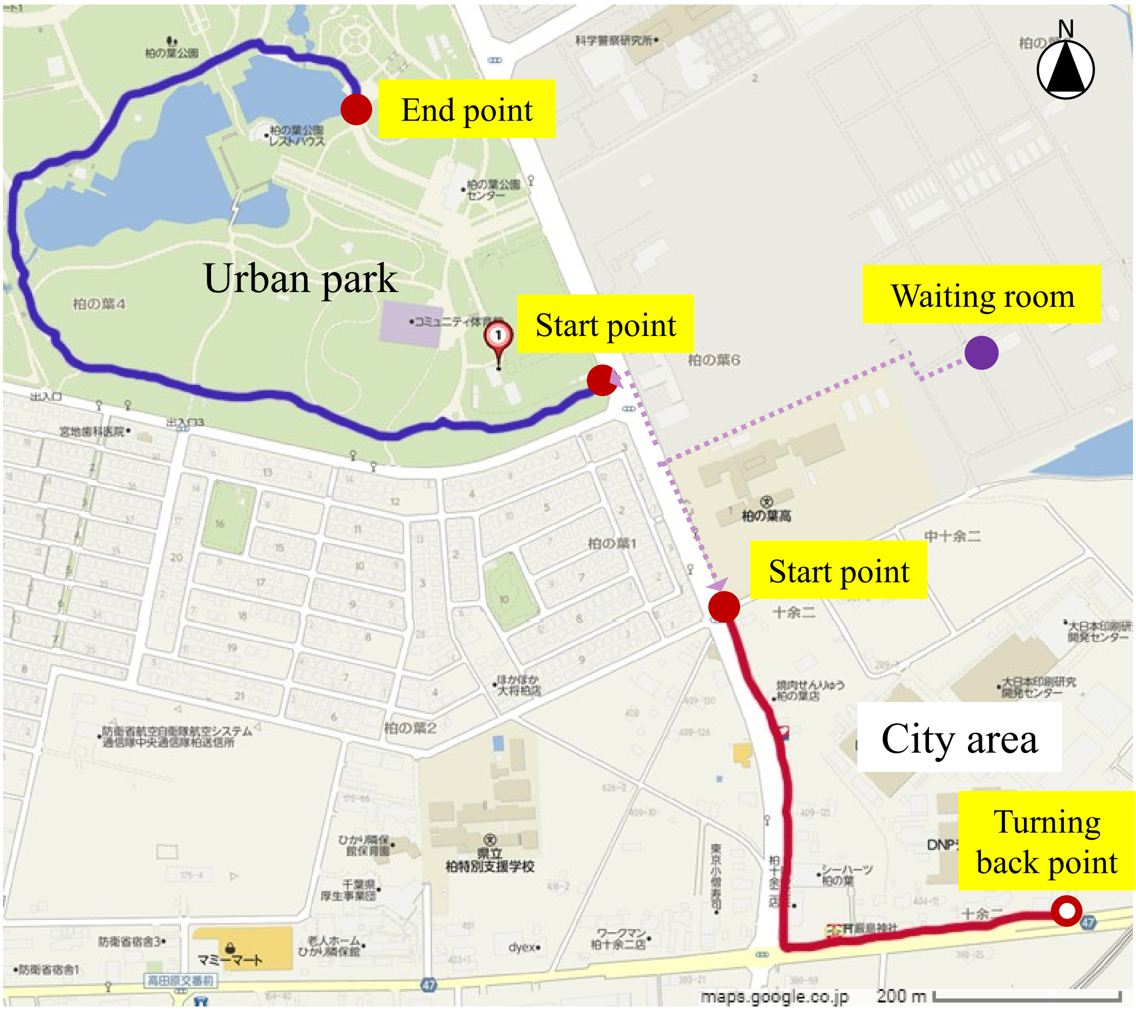

Figure.1. Experimental areas.

Figure.2. Experimental scene of urban park (left) and city area (right).

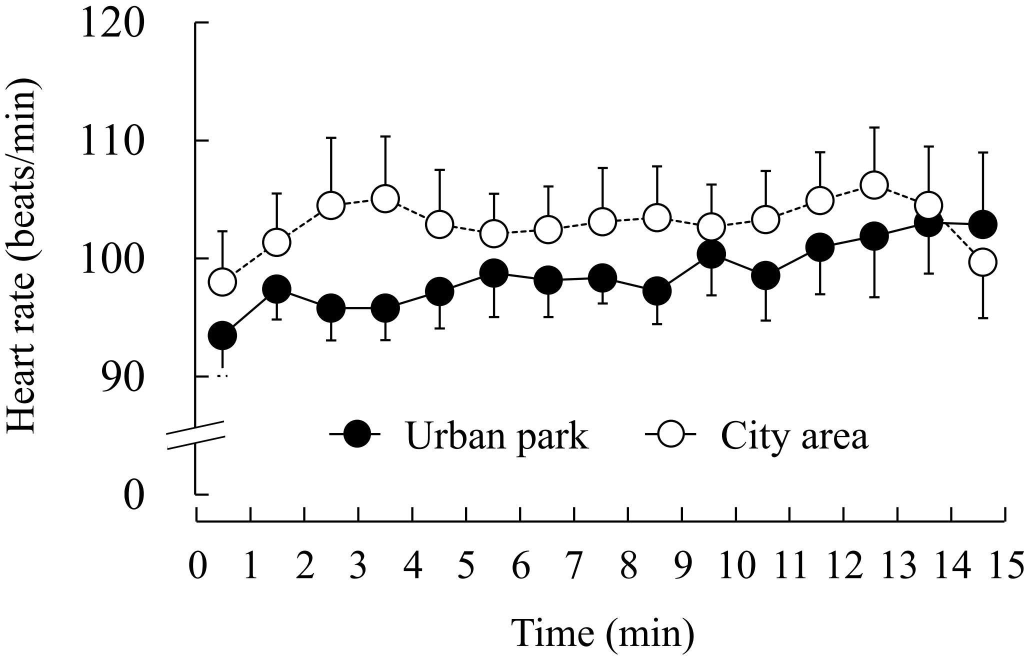

Figure 3. Changes in heart rate at 15 min and comparison of each 1-min value during the urban park walk and the city area walk.

N = 4–8, mean ± SD.

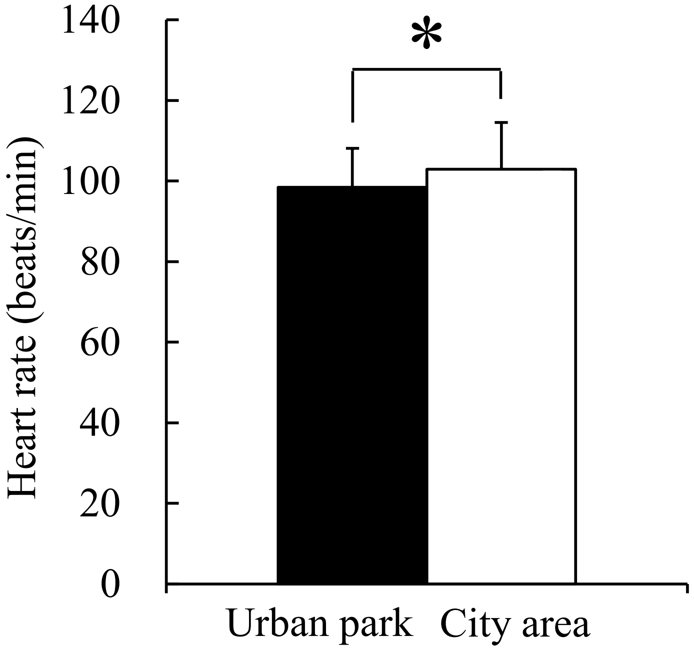

Figure 4. Comparison of heart rates of subjects walking in the urban park and city area.

N = 8, mean ± SD. * $P < 0.05$, determined by paired t-test.

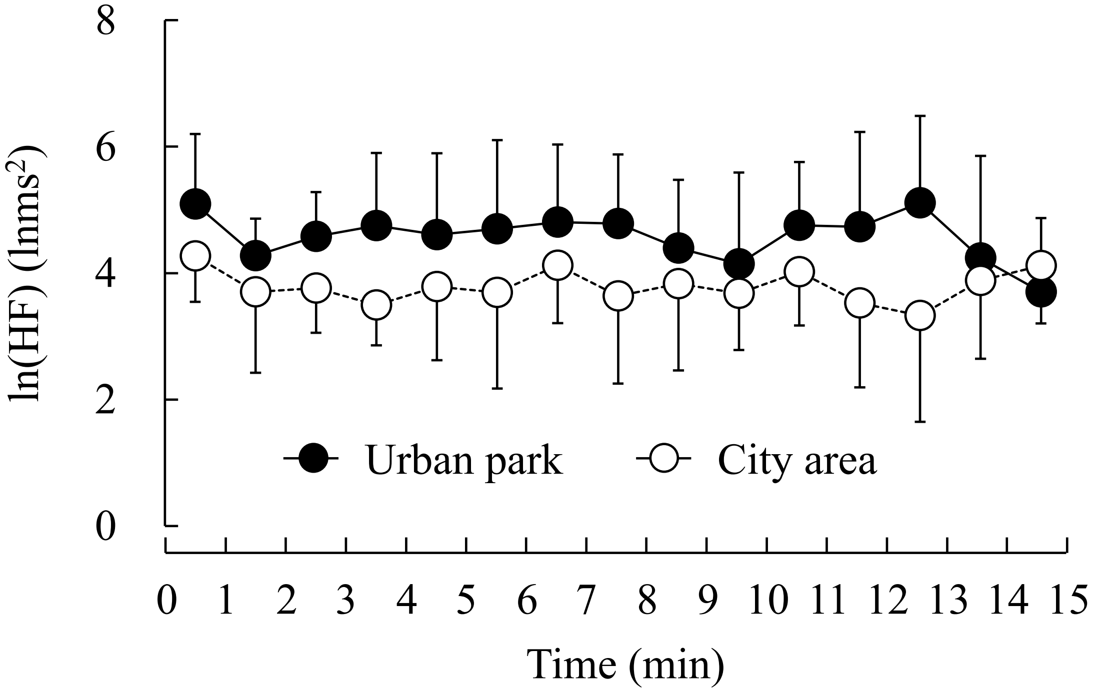

Figure 5. Changes in ln(HF) at 15 min and comparison of each 1-min value during the urban park walk and the city area walk.

N = 4–7, mean ± SD. ln(HF), natural logarithm of high frequency.

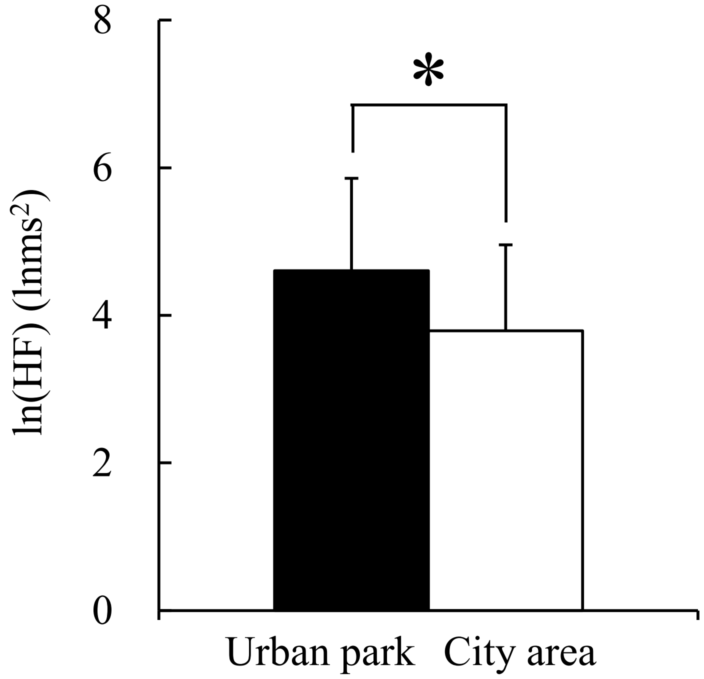

Figure 6. Comparison of ln(HF) values between urban park and city area.

N = 7, mean ± SD. ln(HF), natural logarithm of high frequency. * $P < 0.05$, determined by paired t-test.

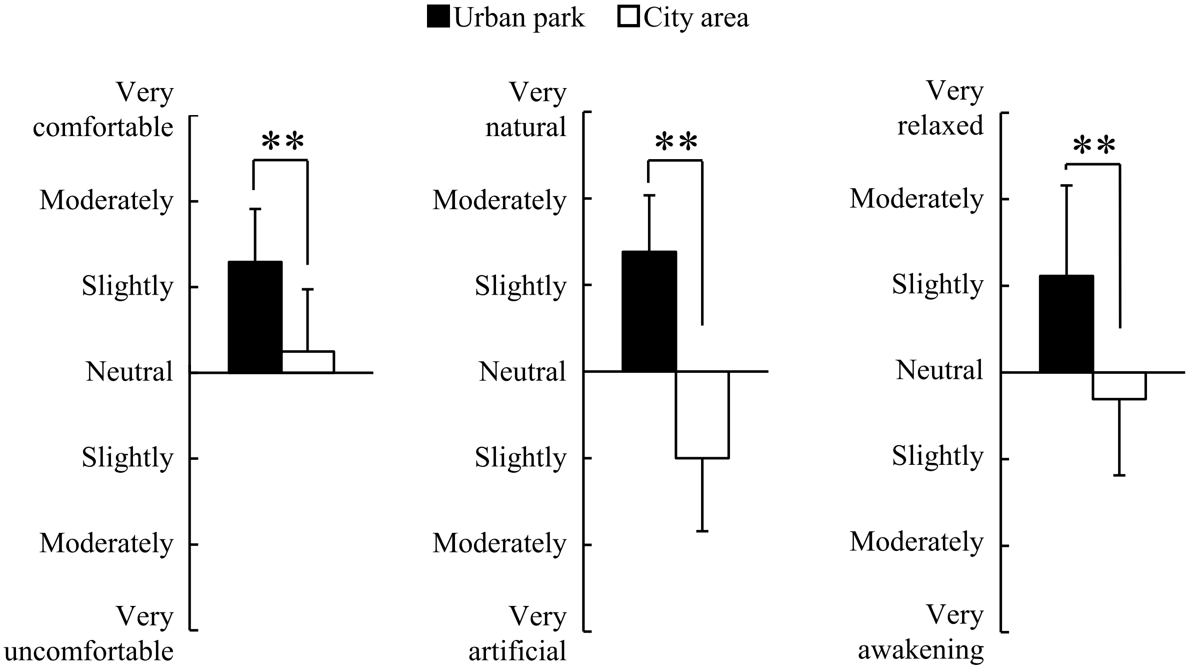

Figure 7. Comparison of subjective scoring for comfortable, natural, and relaxed feelings between the two environments.

N = 13, mean ± SD. ** $P < 0.01$, determined by Wilcoxon signed-rank test.

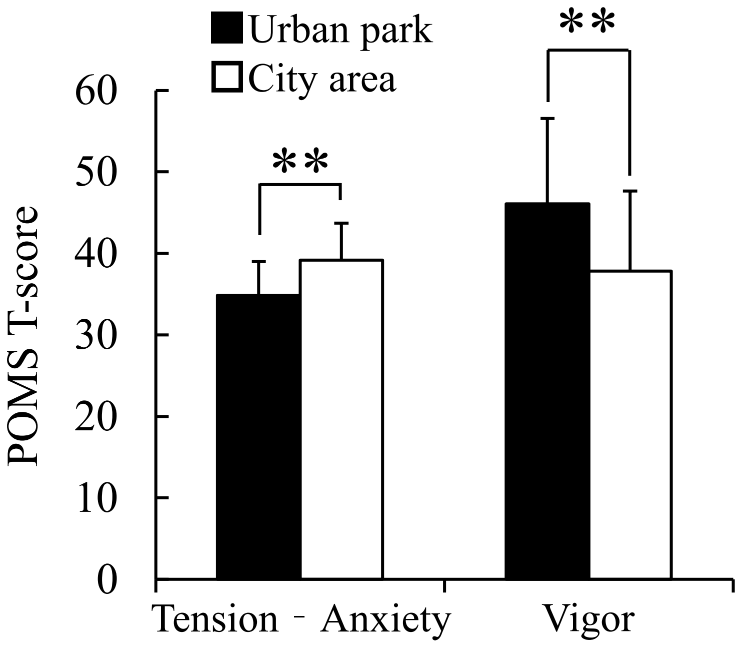

Figure 8. Comparison of subjective scoring for tension – anxiety and vigor by POMS between the two environments.

N = 13, mean ± SD. POMS, Profile of Mood States. ** $P < 0.01$, determined by Wilcoxon signed-rank test.

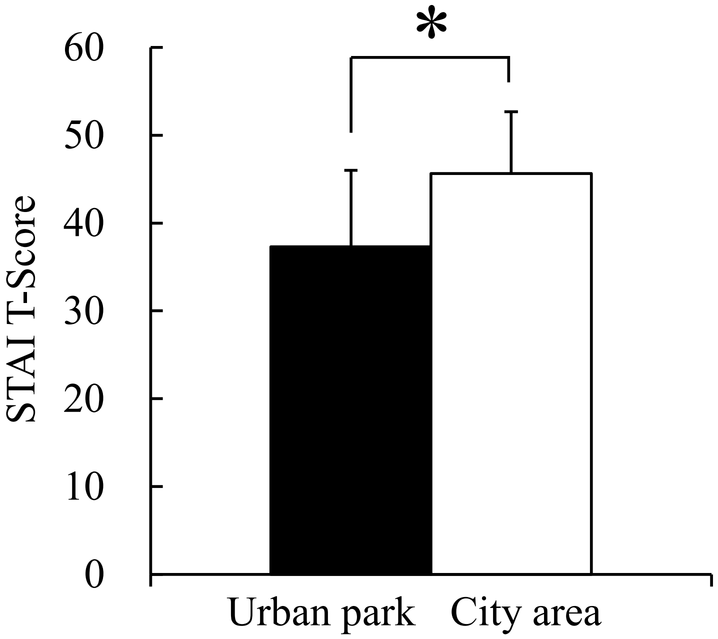

Figure 9. Comparison of subjective scoring for state anxiety by STAI between the two environments.

N = 13, mean ± SD. STAI, State-Trait Anxiety Inventory. * $P < 0.05$, determined by Wilcoxon signed-rank test.

Ⅰ. Physiological and psychological effects of urban parks on humans

(4) Effects of walking in urban parks in spring on autonomic nervous activity

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ABSTRACT

It is widely believed that contact with the natural environment can improve physical and mental health. Urban green spaces may provide city residents with these benefits; however, there is a lack of empirical field research on the health benefits of urban parks. This field experiment was performed in May. Seventeen males aged 21.2 ± 1.7 years (mean ± standard deviation) were instructed to walk predetermined 15-minute courses in an urban park and a nearby city area (control). Heart rate and heart rate variability (HRV) were measured to assess physiological responses. The semantic differential (SD) method, Profile of Mood States (POMS), and State-Trait Anxiety Inventory (STAI) were used to measure psychological responses. Heart rate was significantly lower while walking in the urban park than while walking in the city street. Furthermore, the urban park walk led to higher parasympathetic nervous activity and lower sympathetic nervous activity compared with the walk through the city street. Subjective evaluations were generally in accordance with physiological reactions, and significantly higher scores were observed for the ‘comfortable’, ‘natural’, and ‘relaxed’ parameters following the urban park walk. After the urban park walk, the score for the ‘vigor’ subscale of the POMS was significantly higher, whereas that for negative feelings such as ‘tension–anxiety’ and ‘fatigue’ was significantly lower. The score for the anxiety dimension of the STAI was also significantly lower after the urban park walk.

Physiological and psychological results from this field experiment provide evidence for the physiological and psychological benefits of urban green spaces. A brief spring-time walk in an urban park shifted sympathetic/parasympathetic balance and improved mood state.

1. Introduction

In recent years, the primary focus of healthcare has been shifting from the treatment of disease to health promotion, disease prevention, and improved quality of life. Natural environments such as urban green spaces may provide such benefits, promoting human health and well being. Indeed, many studies have demonstrated a significant positive relationship between exposure to natural environments and physical and mental health. Several questionnaire-based studies reported restorative effect against psychological stressors or mental fatigue [1–4] and improved mood and cognitive function [5–8]. Improved physiological measurement techniques have generated additional empirical evidence that time spent in a forest can decrease blood pressure [9–13] and pulse rate [9–15], suppress sympathetic nervous activity [9, 11–15], increase parasympathetic nervous activity [9, 11–15], decrease cortisol levels [10–16], and decrease cerebral blood flow in the prefrontal cortex [16]. These studies suggest that human beings are more relaxed in forested environments. Moreover, visiting a forested environment enhanced human natural killer cell activity and improved immune function [17], effects that lasted for approximately one month [18, 19]. According to these previous studies, contact with nature brings about physiological and psychological relaxation effects and improves immune function, clearly demonstrating the preventive medical effects of nature [20].

In our modern urbanized society, however, opportunities for such interactions with nature are limited. Of late, the potential health benefits of urban green spaces have been studied. Urban green space can enhance the city environment by influencing temperature, wind, humidity, rainfall, soil erosion, flooding, air quality, scenic quality, and plant and animal diversity [21]. In addition, urban green space may provide important social and psychological benefits that enrich human life [22]. Recent demographic studies have found a positive association between exposure to urban green space and the perceived general health of residents [23, 24]. Living in areas with walkable green spaces also increased the longevity of senior citizens, independent of age, sex, marital status, baseline functional status, and socioeconomic status [25].

Most individuals in industrialized countries live in urban areas and will continue to do so for the foreseeable future [26]; therefore, any beneficial effects of urban green space can improve general health and longevity. However, there is a lack of empirical research on the therapeutic benefits of urban green space [27]. Many investigators have emphasized the importance of field research [6, 10] that can examine the effects of real environments.

We have conducted such a field experiment during winter [28], but there have been no such studies conducted during spring. Therefore, the aim of this study was to examine the physiological and psychological responses of young males during spring-time walks in urban parks.

2. Methods

This field experiment was conducted in May 2013 in Kashiwanoha Park (hereafter referred to as the urban park) in Kashiwa City, Chiba Prefecture, Japan. A city area around the urban park (hereafter referred to as the city area) was selected as a control site. The urban park contained many hardwood trees such as maple, tulip trees, ginkgo, cherry blossoms, and chestnut. There was also a large pond in the center.

Seventeen Japanese male university students aged 21.2 ± 1.7 years (mean ± standard deviation) participated in this experiment. Before the experiment, the subjects were fully informed about the aims and procedures involved. After receiving a description

of the experiment, the subjects signed an agreement to participate. On the experimental day, alcohol and tobacco were prohibited. This study was performed according to the regulations of the Ethics Committee of the Center for Environment,
Health and Field Sciences, Chiba University, Japan.

The subjects were instructed to walk predetermined courses through the urban park and the city area. Each course took about 15 minutes to complete. Subjects walked both courses on the same day (at 10 to 12 am and 1 to 3 pm), and the site order was counterbalanced across subjects. On the day of the experiment, the weather was sunny. A 15-minute walk was taken under direct sunlight in the city area at a temperature of 27.0 ± 1.7°C (mean ± standard deviation) and relative humidity of 37.3 ± 8.4% (mean ± standard deviation). In the urban park, the walk was taken under both direct sunlight and shade at a temperature of 24.7 ± 1.6°C and relative humidity of 39.2 ± 5.3%. The trees in the park had light green leaves, and the azaleas were in full bloom (Figure 1). There were no significant differences in baseline physiological indices or average walking speed between the two environments. After walking, the subjects returned to a waiting room and completed several questionnaires. They rested for approximately 20 minutes, after which they walked the other experimental course.

Heart rate and heart rate variability (HRV) were measured to assess cardiovascular and autonomic nervous system responses. The HRV was measured using a portable electrocardiograph (Activtracer AC-301A, GMS, Tokyo, Japan), and frequency spectra were generated using an HRV software tool (MemCalc/Win, GMS, Tokyo, Japan). For real-time HRV analysis using the maximum entropy method, interbeat (R-R) intervals were obtained continuously. In this study, two broad HRV spectral components were calculated: low frequency (LF; 0.04 to 0.15 Hz) and high frequency (HF; 0.15 to 0.40

Hz). The HF component is an estimate of parasympathetic nervous activity, while the LF/HF ratio is an estimate of sympathetic nervous activity [29, 30]. To normalize HRV parameters across subjects, we used natural logarithmic transformed values for the analysis [31]. The heart rate and HRV data were collected at 1-minute intervals at each experimental location, and the 15-minute average was compared between sites.

Three different questionnaires were used to investigate psychological responses after walking at each experimental site. The semantic differential (SD) method [32] used three pairs of adjectives on seven scales, including 'comfortable to uncomfortable', 'natural to artificial', and 'relaxed to awakening'. The Profile of Mood State (POMS) scores were determined for the following six subscales: 'tension-anxiety', 'depression', 'anger-hostility', 'fatigue', 'confusion', and 'vigor'. A short form of the POMS with 30 questions was used to decrease the burden on the subjects [33–35]. The State-Trait Anxiety Inventory (STAI) [36] was used to evaluate anxiety.

A paired t-test was used to compare the mean physiological parameters between the two walking sites. The Wilcoxon signed-rank test was used to analyze differences in psychological indices reported after walking in the two environments. All statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). For all cases, $P < 0.05$ (one sided) was considered statistically significant.

3. Results

The subjects exhibited significant differences in physiological responses during a fifteen-minute walk in two distinct environments, an urban park and a nearby city area. The mean baseline heart rate did not differ significantly between sites before the walk (urban park: 87.5 ± 3.1 bpm (mean ± standard error), city area: 86.1 ± 2.9 bpm; $P > 0.05$); however, all mean heart rate values within one minute epochs were lower during the urban park walk compared with those during the city walk (Figure 2A). The mean heart rate over the entire 15-minute period was significantly lower (by 4.0%) during the urban park walk than during the city walk (urban park: 86.7 ± 2.9 bpm, city area: 90.3 ± 2.6 bpm; $P < 0.05$; Figure 2B).

In addition, there were significant differences in HRV between the two sites. The mean normalized high frequency (HF) component (ln(HF)), an estimate of parasympathetic nervous activity, was not significantly different at the start of the walk (urban park: 4.0 ± 0.2 lnms^2, city area: 4.3 ± 0.3 lnms^2; $P > 0.05$), while most mean ln (HF) values within one-minute epochs were higher during the urban park walk than during the city walk (Figure 3A). For the entire 15-minute duration, ln(HF) was 17.1% higher during the urban park walk than during the city area walk (urban park: 4.1 ± 0.2 lnms^2, city area: 3.5 ± 0.2 lnms^2; $P < 0.01$; Figure 3B). In contrast, the natural logarithm of LF/HF (ln(LF/HF)), an estimate of sympathetic nervous activity, was lower for most one-minute epochs during the urban park walk (Figure 4A), while the average ln(LF/HF) over 15 minutes was 20.3% lower than that for the city walk (urban park: 1.65 ± 0.18, city area: 2.07 ± 0.18, $P < 0.01$; Figure 4B). Again, there was no significant difference in baseline ln(LF/HF) values between sites (urban park: 2.14 ± 0.23, city area: 1.67 ± 0.35; $P > 0.05$).

Analysis of responses to three questionnaires completed after the urban park and city area walks, the SD method, the POMS scores, and the STAI scores revealed differences in psychological responses between the two environments. Significantly higher SD scores were observed following the urban park walk compared with those following the city walk for the following three adjectives: ‘comfortable’, ‘natural’, and ‘relaxed’ ($P < 0.05$; Figure 5). Differences were also detected in the POMS test (Figure 6), with scores for the negative subscales of ‘tension-anxiety’ and ‘fatigue’ being significantly lower after walking in the urban park than after walking in the city area ($P < 0.05$). Conversely, the positive mood state ‘vigor’ was significantly higher after the urban park walk ($P < 0.05$). There were no significant differences in the scores for ‘depression’, anger-hostility’, and ‘confusion’. Finally, the total STAI score was 14.3% lower after the urban park walk compared with that after the city area walk (urban park: 41.6. ± 7.0 (mean ± standard deviation), city area: 48.6 ± 6.3; $P < 0.05$; Figure 7).

4. Discussion

Access to urban green spaces may have significant physiological and psychological effects on urban residents. Compared with those after a brief walk in the city area, the heart rate was significantly lower (−4.0%), parasympathetic nervous activity was enhanced (17.1%), and sympathetic nervous activity was suppressed (−20.3%) during a brief walk in the urban park. These results are consistent with those from previous studies on physiological responses to forest settings [9, 11−15], suggesting that even small natural areas within a larger urban area can confer similar health benefits. These same HRV responses are often detected during massage [37, 38] or yoga [39], so walking in an urban park may be a simple, accessible, and cost-effective method to improve general cardiovascular and mental health.

According to the analysis of the three questionnaires, the subjects in this study felt more ‘comfortable’, ‘natural’, ‘relaxed’, and ‘vigorous’ after a walk in the urban park. In addition, negative emotions and anxiety were significantly lower after the urban park walk. These results on the psychological benefits of walking in an urban park are partly consistent with previous findings [5, 9–12, 15]. Because mental health is considered to be important in modern times [40], the psychological benefits of urban green space are expected to play a very important role in the promotion of mental health.

In a previous study, we examined the effects of an urban green space in winter by using the same experimental design and locations [28]. The current results corroborate our previous findings with one notable difference. In winter, a significant difference in sympathetic nervous activity was not detected between sites, while all other parameters (parasympathetic nervous activity, heart rate, and psychological indices) showed similar differences between the walking environments. We do not know the exact reason for these differences; however, we suppose they resulted from seasonal differences in environmental conditions, such as temperature (winter: 13.8°C, spring: 24.7°C), humidity (winter: 50.9%, spring: 39.2%), and wind speed, and the state of trees, such as the color or amount of leaves. However, in the winter experiment, because the number of subjects was very small, it was difficult to determine a reason for differences by using only this data. This issue will need to be considered in more depth in the future after accumulating more data.

Although we are now living in largely artificial urban environments, our physiological functions evolved in the natural environment [3, 20, 41]. The human tendency to seek natural environments implies that contact with nature may be important for promoting human health and well being [42]. The beneficial effects of urban green space suggest a simple accessible pathway to improved health. Furthermore, urban planners should pay more attention to maintaining and increasing accessible greenery in urban areas to improve the quality of life of the residents.

These findings provide empirical evidence for the physiological and psychological benefits of brief walks in an urban park. However, these results cannot be extrapolated to the female population or to other age groups because only 17 young male adults participated in this study. To generalize the findings, further studies based on larger and more heterogeneous cohorts are required. Identification of differences in physiological states between natural and artificial environments is a critical issue in physiological anthropology, given the increasing disconnect between our evolutionary history and the modern living environment.

5. Conclusions

The physiological and psychological responses elicited by this field experiment provide evidence for the physiological and psychological benefits of urban green space. A brief spring-time walk in an urban park shifted sympathetic/parasympathetic balance and improved mood state.

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Figures

The urban park

The city area

Figure 1. Experimental sites.

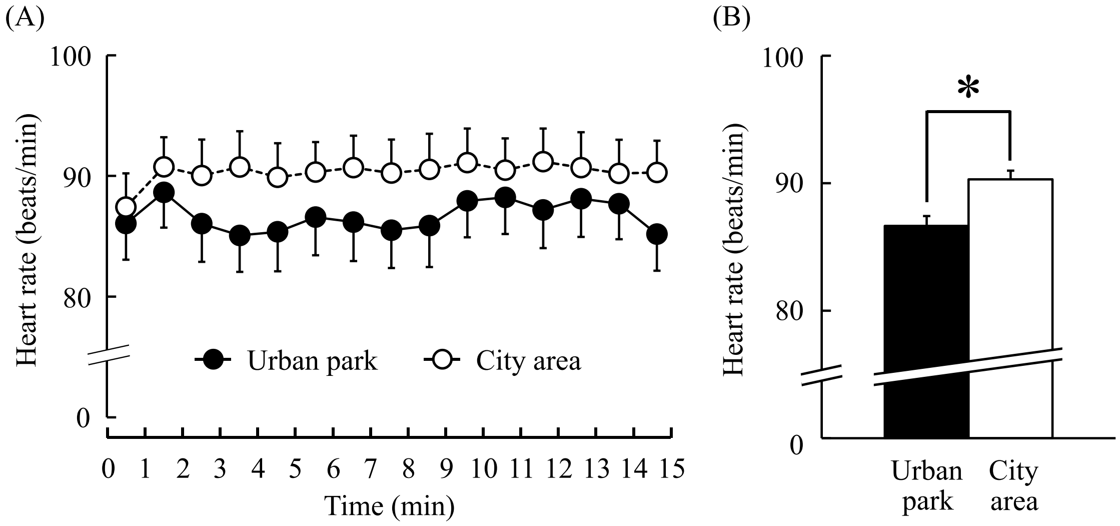

Figure 2. The one-minute averages and the overall mean heart rate during the urban park walk and the city area walk.

(A) Changes in each 1-minute average heart rate over the 15-minute walk.

(B) Overall mean heart rates.

N = 12, mean ± SE. * $P < 0.05$ determined by the paired t-test.

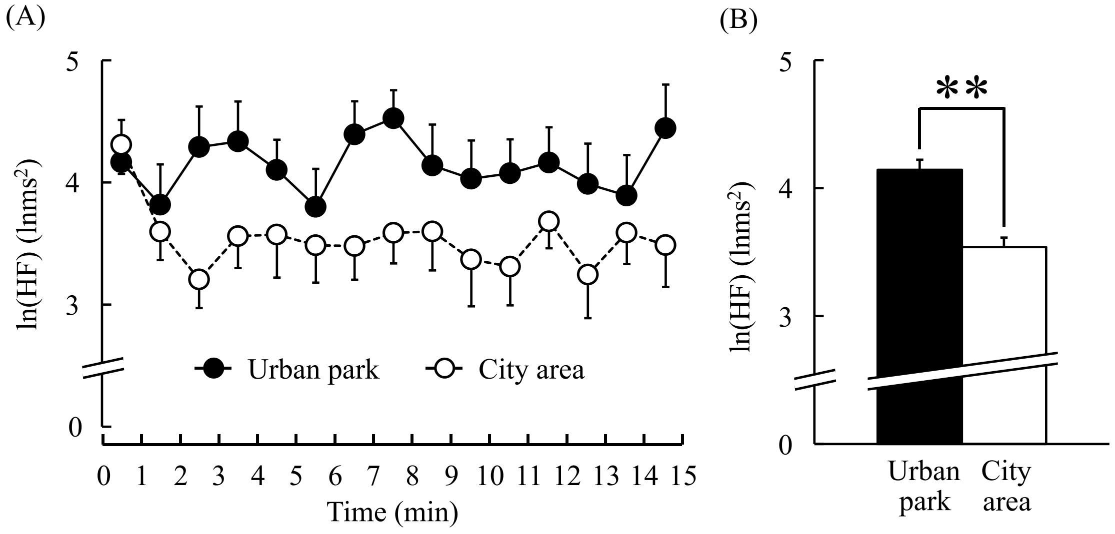

Figure 3. The one-minute averages and the overall mean ln(HF) value of heart rate variability (HRV) during the urban park walk and the city area walk.

(A) Change in each one-minute ln(HF) value.

(B) Overall mean ln(HF) values.

N = 12, mean ± SE. ** $P < 0.01$, determined by the paired t-test.

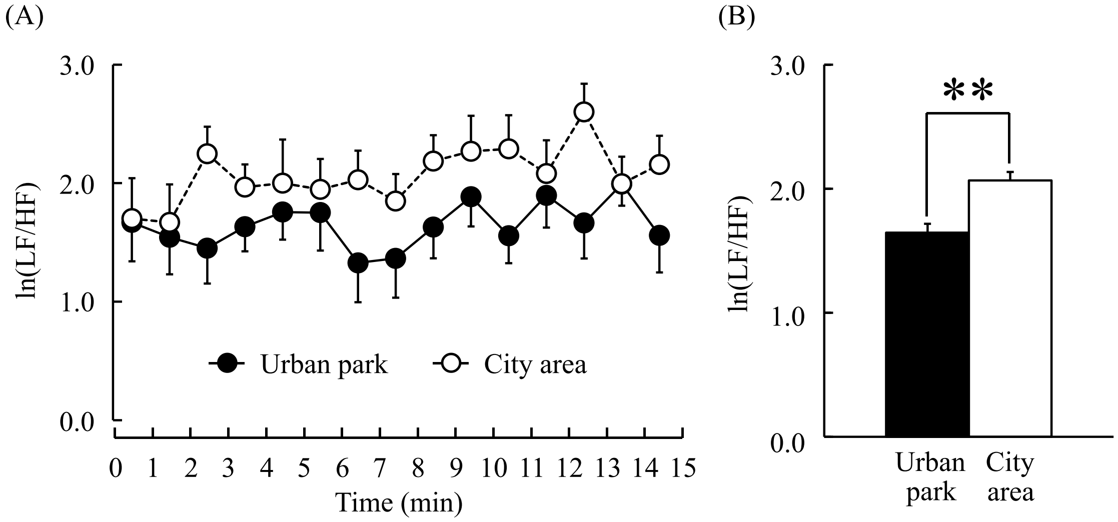

Figure 4. The one-minute averages and the overall mean ln(LF/HF) value of heart rate variability (HRV) during the urban park walk and the city area walk.

(A) Change in each one-minute ln(LF/HF) value.

(B) Overall mean ln(LF/HF) values.

N = 12, mean ± SE. ** $P < 0.01$, determined by the paired t-test.

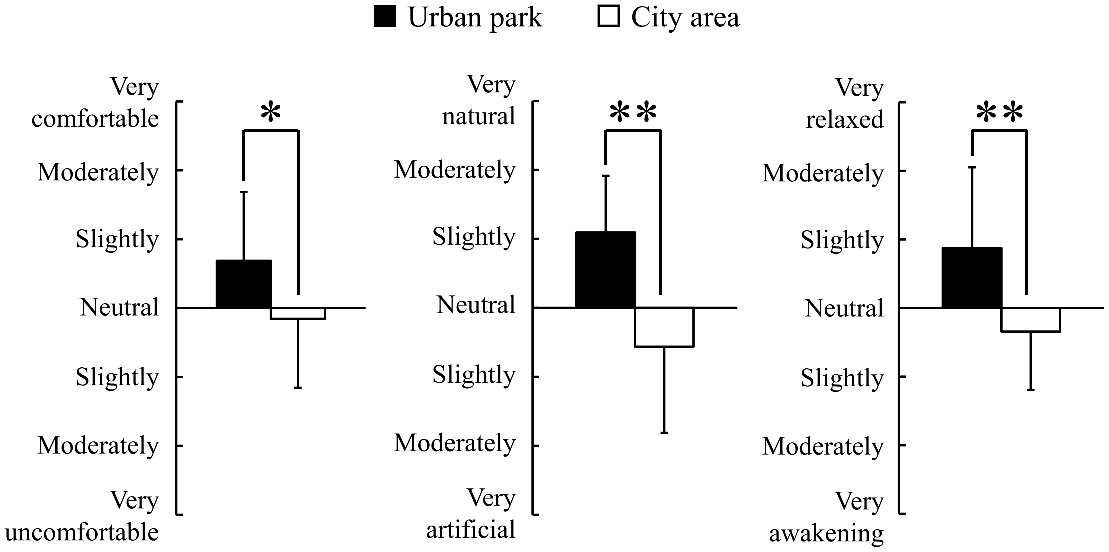

Figure 5. Comparison of subjective scoring for 'comfortable', 'natural', and 'relaxed' feelings between the two environments according to the semantic differential (SD) method.

N = 17, mean ± SD. * $P < 0.05$, ** $P < 0.01$, determined by the Wilcoxon signed-rank test.

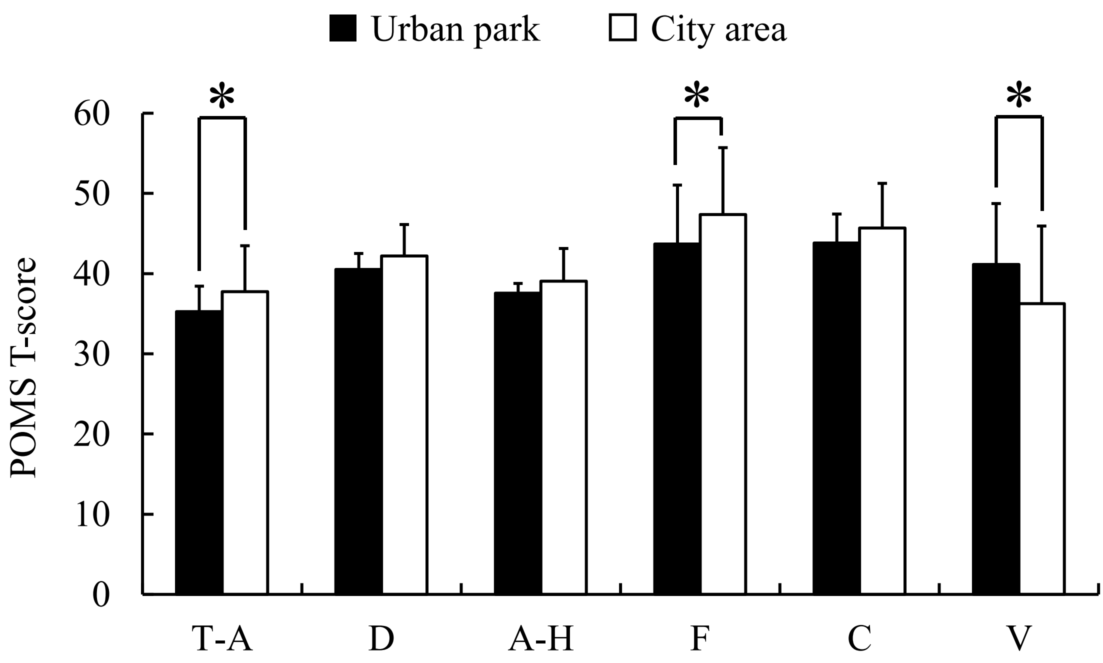

Figure 6. Comparison of subjective Profile of Mood State (POMS) scores between the two environments.

T−A, tension−anxiety; D, depression; A−H, anger−hostility; F, fatigue; C, confusion; V, vigor.

N = 17, mean ± SD. * $P < 0.05$, determined by the Wilcoxon signed-rank test.

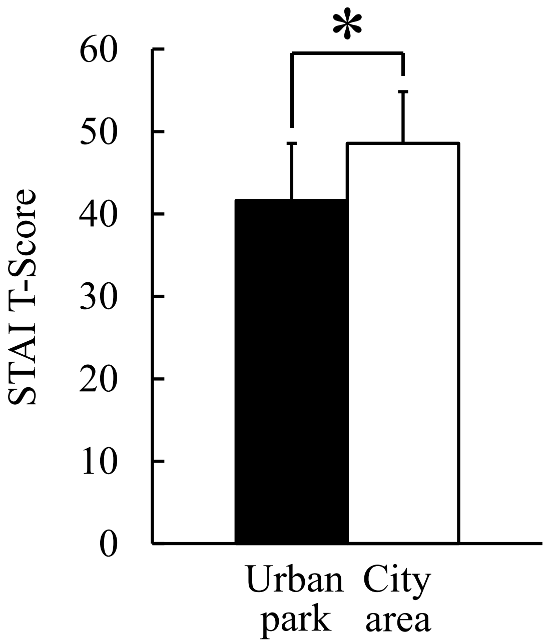

Figure 7. Comparison of subjective State-Trait Anxiety Inventory (STAI) scores between the two environments.

N=17, mean± SD. * $P < 0.05$, determined by the Wilcoxon signed-rank test.

Ⅱ. Individual differences in the physiological effects of a forest environment on humans

(1) Introduction

In this part, we determined individual differences in the physiological effects of a forest environment on humans classified as having Type A and Type B behavior patterns [1, 2]. Previous studies on individual differences in responses have produced distinctive results for individuals with Type A and Type B behavior patterns [3−5]. Type A and Type B behavior patterns were proposed by Friedman and Rosenman [1] on the basis of specific behavior patterns in patients with heart disease. The Type A behavior pattern can be defined as an overt behavioral syndrome related to lifestyle that is characterized by excessive competitiveness, striving for achievement, aggressiveness, time urgency, acceleration of common activities, restlessness, hostility, hyperalertness, explosiveness of speech amplitude, facial musculature tension, feelings of struggling against the limitations of time, and insensitivity to the environment [2]. The Type B behavior pattern is characterized by the absence of Type A characteristics [2]. However, the majority of the previous studies were laboratory experiments, which were limited by small sample sizes [3−5]. It is necessary to use both laboratory experiments and field experiments with large sample sizes to assess individual differences. Therefore, we collected field experimental data to study individual differences in the physiological effects of a forest environment on humans classified as having Type A and Type B behavior patterns in a sample size of 485 subjects.

We then determined the relationship between individual differences in physiological effects of a forest environment on humans and the initial levels of the measured physiological parameters, a concept that has been expressed by Wilder as the "Law of initial value" [6, 7]. This law describes the extent and direction of a response to a physiological function relative to initial measurements; the higher the initial value, the smaller the response to function-raising stimuli and the larger the response to function-depressing stimuli. Wilder mentioned that a wide range of physiological responses, such as white blood cell count, blood sugar, blood pressure, and heart rate, follow this law, which applies to 75–85% of all physiological data [8]. Many studies using this law have been conducted [9−12]. However, these previous studies have mainly examined the relationship to responses caused by function-raising stimuli and initial values [9−12]. There has been little research on the relationship between initial values and responses caused by function-depressing stimuli, such as the relaxation effect of a forest environment. Therefore, we examined the relationship between individual differences in the physiological relaxing effects of a forest environment on humans and initial physiological parameter values.

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Ⅱ. Individual differences in the physiological effects of a forest environment on humans

(2) Elucidation of individual differences in the physiological effects of viewing a forest environment in subjects with Type A and Type B behavior patterns

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ABSTRACT

In recent years, the physiological relaxation effects of natural environments have been widely exploited, and although individual differences in the effects of forest therapy are known, assessment methods have not been clearly established. This study used a classification based on Type A and Type B behavior patterns to explain individual differences in physiological responses to forest environments. We performed physiological experiments in 44 forest and urban (controls) areas. In total, 485 male university students (age, 21.8 ± 1.6 years) participated in the study. The subjects were asked to visit forest or urban environments randomly and observe each landscape for 15 min. The subjects' pulse rates and blood pressures were tested to evaluate their physiological responses. The Kwansei Gakuin daily life questionnaire was used to identify Type A and Type B behavior patterns in subjects. The pulse rate was significantly lower in the Type B group after exposure to forest areas than after exposure to urban areas, whereas no significant difference was observed in the Type A group. In addition, the pulse rate was significantly lower in the low scoring subjects in the Type B group, which was consistent with changes in their diastolic blood pressure.

These results suggest that individual differences in pulse rate and blood pressure in response to forest environments can be explained by Type A and Type B behavior patterns.

1. Introduction

It is widely believed that contact with the natural environment can improve the physical and mental health of people. Since 1980, many studies have demonstrated a significantly positive relationship between people's exposure to natural environments and their health. Several questionnaire-based studies have reported restorative effects related to psychological stressors or mental fatigue [1−3] and improved mood states and cognitive function [4−7]. Improved physiological measurement techniques in recent years have generated further scientific evidence based on physiological parameters. Studies on the physiological effects of relaxation in forest environments have tested such parameters as cerebral activity in the prefrontal cortex [8], pulse rate [9−13], blood pressure [10, 11, 13, 14], heart rate variability [9, 10, 12−14], salivary cortisol concentration [8, 9, 11−13], and natural killer cell activity [15−18]. A significant amount of scientific evidence has been reported [19−21]. Park et al. [20] reported that forest therapy mitigated stress and led to biological relaxation based on the results of experiments using 420 subjects in 35 locations throughout Japan. Forest therapy is a health-promotion method and uses medically proven effects of forests, such as relaxation, that can improve the health of the body and mind. It is aimed at achieving a preventive medical effect by improving the immune system response.

However, individual differences within these effects have been noted, and this phenomenon has posed several questions in a variety of fields that must be clarified.

Thus far, methods for interpreting these individual differences have not been established. Previous studies on individual differences in the generated responses have produced distinctive results for individuals with Type A and Type B behavior patterns. Type A and Type B behavior patterns were proposed by Friedman and Rosenman [22] on the basis of specific behavior patterns in patients with heart disease. The Type A behavior pattern can be defined as an overt behavioral syndrome related to lifestyle that is characterized by excessive competitiveness, striving for achievement, aggressiveness, time urgency, acceleration of common activities, restlessness, hostility, hyperalertness, explosiveness of speech amplitude, facial musculature tension, feelings of struggling against the limitations of time, and insensitivity to the environment [23]. Type B behavior pattern is characterized by the absence of Type A characteristics. Miyazaki and Tsunetsugu [24] examined individual differences in hemoglobin concentration in the prefrontal cortex when chocolate was used as a gustatory stimulus. The activities of the prefrontal cortex stimulated by chocolate significantly increased in the Type B group, whereas the Type A group showed no changes in their activities. The results showed that physiological responses in Type B and Type A subjects were significantly different.

Park et al. [25] investigated changes in cortisol concentration after administering a eucalyptus-flavored drink. The concentration of salivary cortisol significantly decreased after ingestion of a eucalyptus-flavored drink in the Type B group, but changes in the Type A group were statistically insignificant. Furthermore, Lee and Watanuki [26] reported differences in the cardiovascular responses of Type A and Type B subjects after visual stimulation using displeasure-evoking images and nature video clips. However, the majority of the previous studies were laboratory experiments, which were limited by small sample sizes. It is necessary to use both laboratory experiments and field experiments with large sample sizes to assess individual differences.

Therefore, a field experimental design was used to study individual differences in the physiological effects of forest therapy based on Type A and Type B behavior patterns in a sample size of 485 subjects. Furthermore, because this study used a large sample size, we examined additional details from the classification of the Type A and Type B groups.

2. Methods

2-1. Subjects and study sites

From 2005 to 2010, we performed physiological experiments in 44 areas of Japan (Figure 1). Two study sites, a forest and an urban environment, were selected for each of the 44 areas. Twelve male university students participated in each of the experiments (in total, 528 subjects), and no student reported a history of physical or psychiatric disorder. Of these, we were able to measure the blood pressure and pulse rate of 485 subjects (21.8 ± 1.6 years old) for analysis. The study was performed according to the regulations of the Ethics Committee of the Center for Environment, Health, and Field Sciences, Chiba University or the Institutional Ethics Committee of the Forestry and Forest Products Research Institute in Japan.

2-2. Measurements

A digital blood pressure monitor based on oscillometric methods (HEM1000, Omron, Japan) was used to measure the pulse rate and blood pressure (systolic and diastolic blood pressure) in the right upper arm.

We used the KG daily life questionnaire to determine Type A and Type B behavior patterns [27]. The KG daily life questionnaire comprises 55 items (44 that determine Type A and Type B behavior patterns and 11 irrelevant or dummy questions). The subjects were asked to choose one of the three options as a reply (yes, ?, or no) for each question; with respective scores of 2, 1, or 0 for the replies. It was found that a score of <43 points indicated a Type B behavior pattern, while >44 points indicated a Type A behavior pattern.

2-3. Experimental design

On the day before the experiment, the subjects were fully informed about the aims and procedures involved. After receiving a description of the experiment, the subjects signed an agreement to participate. All subjects were instructed to reside in a hotel with identical single rooms and eat the same category of food during the ongoing procedure, to minimize individual differences caused by these factors. Alcohol and tobacco were prohibited, and caffeine consumption was controlled. After orientation, the subjects visited and previewed the forest and urban study sites before commencement of the experiment. Measurement practice of the physiological indices was performed at the hotel. The subjects were asked to complete the KG daily life questionnaire in their individual rooms after dinner.

Twelve subjects were randomly assigned to the forest or urban environment groups for each of the 44 areas, to eliminate the ordering effect. On the first day of the experiments, six subjects were sent to a forest site, and the other six subjects were sent to an urban site. On the second day, the sites were interchanged. After arriving at the site, each subject was asked to sit on a chair and view the landscape (the forest or urban environment) for a period of 15 min in the afternoon. Figure 2 shows examples of two experimental viewing areas. Physiological measurements were recorded before and after viewing. We measured each physiological index three times; mean values were used for comparative purposes.

2-4. Data analysis

We used the differences in the physiological values, i.e., ‘postviewing’ minus ‘previewing’, to determine the change in the physiological response to viewing. The response data from forest and urban environments were compared between Type B and Type A subject groups and between four subgroups, which were obtained by dividing each of the Type A and Type B subject groups according to their KG daily life questionnaire scores. We divided each group according to the median. The below-median Type B subgroup (N = 252) was the low scoring Type B subgroup (N = 126), and the above median Type B subgroup was the high scoring Type B subgroup (N = 126). The Type A group was subdivided in the same way.

A two-way repeated measures analysis of variance (ANOVA) with one between-subjects factor (that is, Type A or B behavior pattern with two or four levels) and one within-subjects factor (that is, environment with two levels) was performed, to determine whether the individual responses to the two environments differed significantly with respect to the Type A and Type B behavior patterns. Furthermore, a simple effect test with Bonferroni correction was performed for the post-hoc analysis. SPSS 20.0 (IBM Corp., Armonk, NY, USA) was used to perform statistical analysis of the physiological data. In all cases, values of $P < 0.05$ were considered to indicate statistical significance.

3. Results

The distribution of the KG questionnaire scores is shown in Figure 3. Based on the scores in the KG daily life questionnaire, we divided the subjects into Type B group (12 to 43 points, N = 252) or Type A group (44 to 82 points, N = 233). Figure 4 shows a comparison of the changes in the pulse rates of Type B and Type A subjects. The ANOVA showed a significant main effect for the environment [$F(1,483) = 5.720$, $P < 0.05$] and environment × the behavior pattern interaction [$F(1,483) = 4.464$, $P < 0.05$], which indicated that the pulse rates were changed by the environment and that the differences in the pulse rates for the forest environment and urban environment depended on the subject's behavior type (i.e., Type A or Type B behavior pattern). The simple main effect of the difference between the two environments was significant in the Type B subject group ($P < 0.01$). For this group, viewing a forest environment decreased the pulse rate by 2.5 beats/min (from 65.7 beats/min to 63.2 beats/min); this was significantly lower than the change after viewing an urban environment. However, the results for Type A subjects exhibited no significant differences between the forest and urban environments.

In addition, we analyzed four subgroups, which were obtained by dividing each of the two Type A and Type B subject groups on the basis of the scores of the KG daily life questionnaire. Figure 5 shows a comparison of changes in the pulse rates of the four subgroups. The ANOVA detected a significant main effect for the environment [$F(1,481) = 5.428$, $P < 0.05$] and a trend in the environment × the behavior pattern interaction [$F(3,481) = 2.121$, $P = 0.097$], which indicated that the pulse rates for the environment and forest and urban environments varied among the four subgroups. The simple main effect of the difference between the two environments was significant in the low scoring Type B subgroup (12 to 35 points, $N = 126$, $P < 0.01$). The low scoring Type B subgroup exhibited a significant reduction of 1.7 beats/min after the subjects were exposed to the forest area compared with the pulse rate of the subjects after exposure to urban areas. In the other three subgroups (high scoring Type B subjects: 35 to 43 points, $N = 126$; low scoring Type A subjects: 44 to 50 points, $N = 116$; and high scoring Type A subjects: 51 to 82 points, $N = 117$), differences in the pulse rates on exposure to the forest and urban areas were statistically insignificant.

Analysis of diastolic blood pressure showed no significant difference between the forest and urban environments compared with: the Type B subject group (12 to 43 points, N = 243) and Type A subject group (44 to 82 points, N = 232); however, ANOVA of the four subgroups, which were obtained by dividing each of the two Type A and Type B subject groups on the basis of the scores in the KG daily life questionnaire, showed a trend in the environment × the behavior pattern interaction [$F(3,471) = 2.457$, $P = 0.062$], which suggested that there were differences in the diastolic blood pressure for the forest environment and urban environments in the four subgroups (Figure 6). The simple main effect of the difference in the diastolic blood pressure between the two environments was significant in the low scoring Type B subgroup (12 to 34 points, N = 121, $P < 0.05$). The low scoring Type B subgroup exhibited a more significant reduction for forest environments than for urban environments. In the other three subgroups (high scoring Type B subjects: 35 to 43 points, N = 122; low scoring Type A subjects: 44 to 50 points, N = 116; and high scoring Type A subjects: 51 to 82 points, N = 116), there was no significant difference in the forest and urban environments.

4. Discussion

In this study, we aimed to elucidate individual differences in the physiological response to forest therapy by evaluating changes in the pulse rates and blood pressures in 485 subjects after forest therapy in field experiments, in which individuals were classified as having a Type A or Type B behavior pattern. The results showed that there was a significant reduction in the pulse rate after viewing forest scenes compared with that found after viewing urban areas, and that the reduction was related to the subject's behavior pattern.

The reductions in the pulse rate and blood pressure after viewing the forest for 15 min confirmed that forest therapy induced a relaxed state. Although we only used blood pressure and pulse rate data in this study to examine the individual difference, previous studies that have used various physiological indexes have been reported. According to previous studies, staying in a forest also suppressed sympathetic nervous activity [10, 12−14], increased parasympathetic nervous activity [9, 10, 12−14], decreased cortisol level [8, 9, 11−13], and reduced cerebral blood flow in the prefrontal cortex [8]. It has been suggested that human beings are more relaxed in forest environments. Thus, we considered that the reduced pulse rate and blood pressure in the present study reflected a relaxed physiological state. Classification into Type A and Type B subjects showed that the pulse rate reduction was significant in the Type B group; however, there was no significant difference in the Type A group. Thus, the differences in the physiological effects of forest therapy were only present in the subjects with the Type B behavior pattern. When all of the subjects were divided into four subgroups, there was only a significant decrease in the low scoring group of Type B subjects.

The Type A behavior pattern can be defined as an overt behavioral syndrome related to lifestyle, which is characterized by excessive competitiveness, striving for achievement, aggressiveness, time urgency, restlessness, hostility, feelings of struggling against the limitations of time, and insensitivity to the environment [23]. The Type A behavior pattern is also known to be linked to patients with heart disease. Therefore, previous studies of the Type A behavior pattern have primarily investigated increases in stress-related conditions related to sympathetic activity in Type A individuals. In general, the heart rate and systolic blood pressure of Type A individuals increased more than those of Type B individuals under stressful conditions [28], and muscular vasodilation and secretion of norepinephrine, epinephrine, and cortisol were more pronounced in Type A individuals [29, 30]. Dembroski et al. [31] also reported that stressed Type A individuals exhibited a higher response in their sympathetic activity than Type B individuals, and Oishi et al. [32] suggested that stressors do not affect the parasympathetic activity in Type A individuals.

We observed that the pulse rate and blood pressure were significantly reduced in the Type B group after forest therapy but that there were no differences in the Type A group. This result is consistent with the findings of previous studies that investigated the Type A behavior pattern response to natural stimulation. Lee et al. [33] examined the correlation between the Type A behavior pattern and changes in systolic blood pressure after walking in a forest environment for 14 min. The systolic blood pressure was reduced in the Type B group, whereas it increased in the Type A group. Park et al. [25] investigated changes in the cortisol concentration in response to a eucalyptus-flavored drink. The cortisol levels were significantly reduced in the Type B group, whereas there were no changes in the Type A group. Miyazaki and Tsunetsugu [24] investigated the response of hemoglobin concentration changes in the prefrontal cortex to gustatory chocolate stimuli. There was a significant change in the Type B group, but no changes were observed in the Type A group. These studies also revealed that Type B subjects exhibited a more profound change in response to exposure to natural stimuli than Type A subjects, which agreed with our findings. However, the reasons for a higher response in the Type B group, particularly in the low scoring subgroup of Type B subjects, are currently unknown. Several previous studies have detected an increase in the sympathetic activity of Type A individuals under stressed states. However, forest therapy aimed to enhance parasympathetic activity [9, 10, 12−14, 17]; thus, our results may require a different explanation from that given in previous studies. A possible future research area would be to investigate the mechanism of the physiological reaction in Type A and Type B individuals.

This study used forest therapy to evaluate the effects of physiological relaxation in a large sample of 485 subjects and detected individual differences in the relaxation effects, particularly in the subjects who exhibited a Type B behavior pattern. We suggest that the results of this study may help to elucidate physiological polymorphism, which is an important concept in physiological anthropology. However, this study was limited to men in their 20s; thus, verification of our results using subjects with different attributes is necessary.

5. Conclusions

The pulse rate was significantly lowered by forest therapy, and the level of the reduction varied depending on whether the subjects exhibited a Type A or Type B behavior pattern. Individual differences related to changes in pulse rate and diastolic blood pressure after forest therapy were related to the Type A and Type B behavior patterns.

Acknowledgments

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Figures

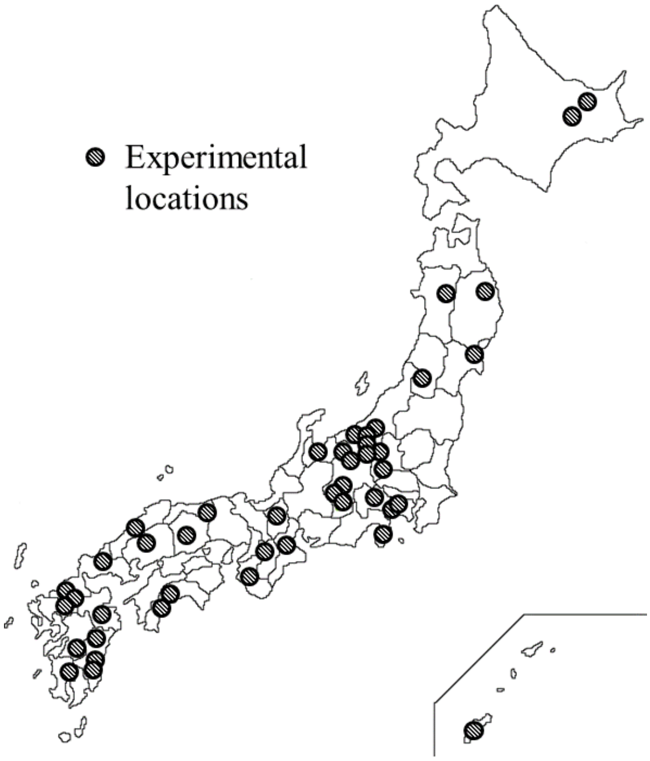

Figure 1. Map showing experimental locations

Figure 2. An example of experimental landscapes in the experimental area.

Top: Forest area, Bottom: City area

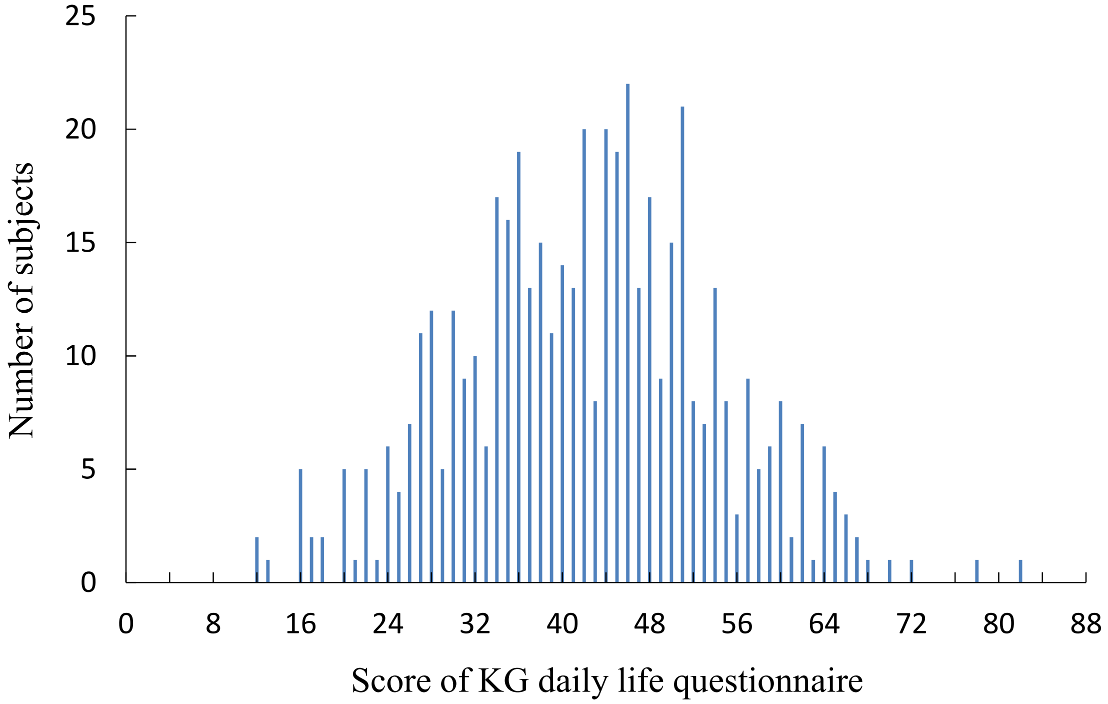

Figure 3. Distribution of the Kwansei Gakuin (KG) daily life questionnaire scores.

N = 485.

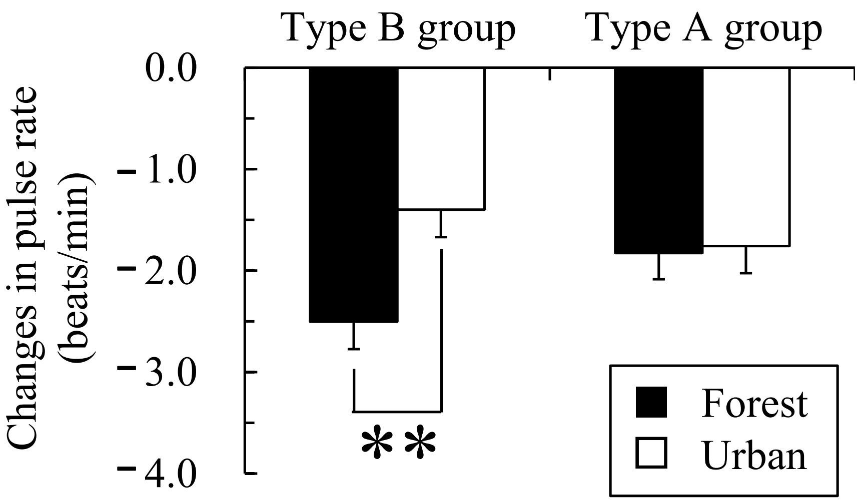

Figure 4. Changes in pulse rates in the Type B and Type A groups after exposure to the two environments.

Type B group: N = 252, Type A group: N = 233, mean ± SE. ** P < 0.01 by two-way analysis of variance (ANOVA) for repeated measures with post-hoc contrasts.

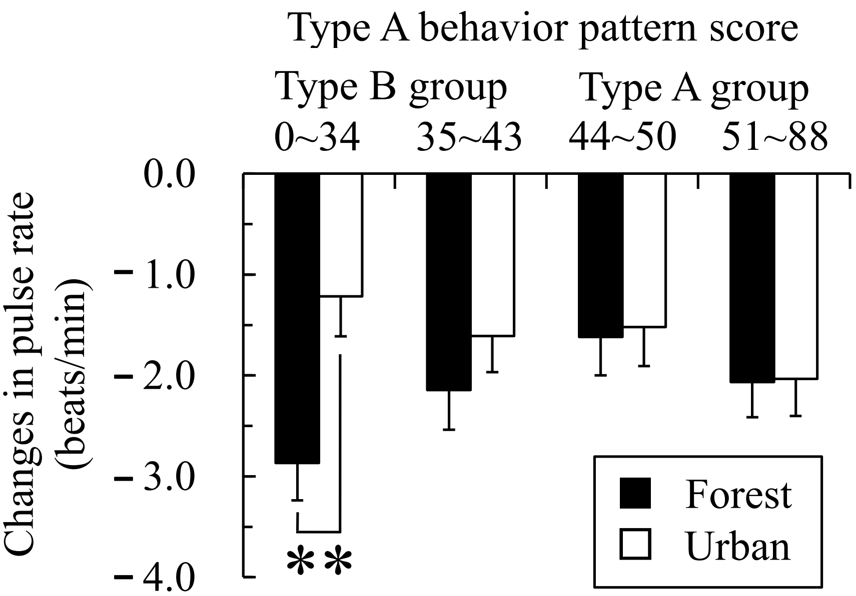

Figure 5. Changes in the pulse rates of the four subgroups after exposure to the two environments.

Low scoring Type B subgroup: N = 126, high scoring Type B subgroup: N = 126, low scoring Type A subgroup: N = 116, high scoring Type A subgroup: N = 117, mean ± SE. ** P < 0.01 by two-way analysis of variance (ANOVA) for repeated measures with post-hoc contrast

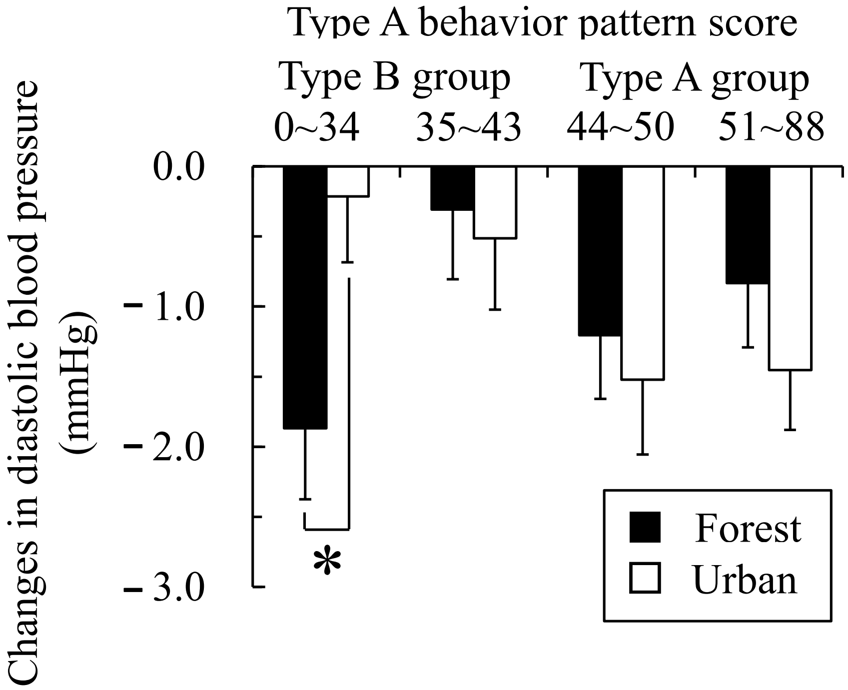

Figure 6 Changes in diastolic blood pressure of the four subgroups after exposure to the two environments.

Low scoring Type B group: N = 121, high scoring Type B group: N = 122, low scoring Type A subgroup: N = 116, high scoring Type A subgroup: N = 116, mean ± SE. * $P < 0.05$ by two-way analysis of variance (ANOVA) for repeated measures with post-hoc contrasts.

Ⅱ. Individual differences in physiological effects of a forest environment on humans

(3) Elucidation of individual differences in the physiological effects of viewing a forest environment as a consequence of the law of initial value

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Japanese Journal of Hygiene 69(2): 111–116, 2014.

ABSTRACT

The aim of this study was to elucidate the physiological adjustment effect of forest therapy based on the Law of Initial Value. The experiments were conducted in nine forest and urban areas in Japan during the period from 2011 to 2012. There were 12 male Japanese university students participating in each of the nine experiments (total, 108 participants). Of these, 98 subjects (mean age ± standard deviation, 21.4 ± 1.6 years) were analyzed. The subjects were instructed to view a real forest landscape or urban area for 15 min. The systolic blood pressure, diastolic blood pressure, and pulse rate of each subject were measured. We analyzed the correlation between the initial values (after city viewing) and the differences in values between the two environments (after forest viewing–after city viewing). There was a negative correlation between the initial values and the differences in values between the two environments. The subjects whose initial systolic blood pressure, diastolic blood pressure, and pulse rate were high showed marked decreases in these parameters as their response after viewing the forest environment, whereas those whose initial systolic blood pressure, diastolic blood pressure, and pulse rate were low showed increases in these parameters as their response. These results support the premise that the physiological effect of a forest environment can differ depending on a subject's initial response values. Moreover, it was clear that forest therapy caused physiological adjustment, normalizing blood pressure and pulse rate.

1. Introduction

With the rapid urbanization and artificialization, modern people are often likely to experience stress state in their daily lives. According to Miyazaki et al. [1], “The men and women living in modern times have spent more than 99.99 percent of their evolutionary history in natural environments. We have become the humans we are today, living in modern civilization, through a process of evolution that took place in a natural environment. The human body is thus made to adapt to nature. Artificialization is taking place at such a rapid rate that we now find ourselves in stressful situations in our daily lives and are forced to deal with the resultant pressures.”

With the rapid progress of physiological measurement technology, scientific data using physiological parameters have been recently accumulated. Studies on the physiological relaxation effects induced by exposure to forest environments have tested parameters such as cerebral activity in the prefrontal area [2], pulse rate [3−7], blood pressure [3, 6, 7], heart rate variability (HRV) [4−8], salivary cortisol concentration [2−5, 7], and natural killer (NK) cell activity [9−11]. On the basis of these findings, reviews on physiological relaxation effects induced by exposure to forest environments have been submitted [12−15]. Park et al. [13] demonstrated that viewing forest landscapes for just 15 min mitigated the stressed state and led to physiological relaxation using the result of 420 subjects in 35 forests throughout Japan.

On the other hand, because nature therapy asks for “active comfort” [16, 17], which aimed for the acquisition of plus α, it is known that there are individual differences within these effects [14, 18]. Attention is now focused on individual differences as an issue that requires clarification in a variety of research fields. Tsunetsugu et al. [14] proposed that it is necessary to conduct scientific research on individual differences in response to forest therapy; however, the approach to elucidate these differences has not been established.

Until now, studies on the elucidation of individual differences have generally been performed using the “Law of the Initial Value,” which was proposed by Wilder [19, 20]. This law uses the extent and direction of a response to a physiological function relative to initial measurements; the higher the initial value, the smaller the response to function-raising stimuli and the larger the response to function-depressing stimuli. Wilder mentioned that a wide range of physiological responses, such as white blood cell count, blood sugar, blood pressure, and heart rate, are in accordance with this law, and 75–85 percent of all physiological data is applicable to this law [21]. Many studies using this law were subsequently performed. Lacey [22] examined the correlation between initial values and changes in systolic/diastolic blood pressure and heart rate caused by a stressor and reported that subjects whose initial values were high poorly responded to function-raising stimuli, such as a stressor. Hord et al. [23] demonstrated the relationship of initial values and changes in heart rate and respiratory rate caused by a stressor. They found that there were significant correlations between initial values and changes in heart rate and respiratory rate.

However, previous studies have been mainly conducted in relationship to the response by function-raising stimuli and the initial value [22−26], and the statistical treatment method was employed to clarify this relationship [21, 27]. Research to clarify the relationship between the initial value and the response by function-depressing stimuli, such as natural therapy, hardly exists.

The aim of the present study was to clarify individual differences in the physiological relaxing effects of forest therapy using the Law of The Initial Value and elucidate the physiological adjustment effect of forest therapy.

2. Materials and Methods

2-1. Study sites and subjects

The present study was conducted in forest and city areas in nine locations (Fukaura town, Aomori; Kamiichi town, Toyama; Tsubata town, Ishikawa; Matsukawa town, Nagano; Kofu city, Yamanashi; Yoshino town, Nara; Akiota town, Hiroshima; Buzen city, Fukuoka; and Oita city, Oita; Figure 1) in Japan over 2 years from 2011–2012.

Twelve young Japanese male university students participated in an experiment at each site. Of these, we used data of 98 subjects (21.8 ± 1.6 years old) who were able to measure physiological measurements for analysis. The consumption of alcohol and tobacco was prohibited, and caffeine consumption was controlled during the study period. The study was performed in accordance with the regulations of the Ethics Committee of the Center for Environment, Health, and Field Sciences, Chiba University, Japan. After receiving a description of the experiment, the subjects signed an agreement to participate.

2-2. Physiological measurements

Systolic and diastolic blood pressure and pulse rate were measured by oscillometry using a digital blood pressure monitor (HEM1010; Omron, Japan). We measured subject’s blood pressure and pulse rate in his right upper arm.

2-3. Method

Twelve subjects in each experimental area were deployed on the morning of the experiment. After receiving the description of experiments, study individuals signed the participation agreement. To eliminate order effects, subjects were randomly divided into two groups, each group containing six subjects. On the first day, one group performed the experiment in the forest area, and the other group performed the same experiment in the city area. On the second day, participants switched field sites. City areas were downtown or nearby the JR (Japan Railway) station. On arrival, subjects would await their turn in waiting rooms and eventually be taken, one by one, to the experimental site. After having rest for 5 min sitting in a chair, they viewed forest or city landscapes for 15 min, after which physiological measurements were recorded. We measured each physiological index three times; mean values were used for comparative purposes. Figure 2 shows forest landscape sceneries, and Figure 3 shows urban area sceneries.

2-4. Data analysis

We analyzed the relationship between initial values and changes in systolic blood pressure, diastolic blood pressure, and pulse rate before and after forest viewing. To examine these relationships, the absolute value "after city viewing" were used as the initial value, considering that modern people are mainly living in cities, and values of "after forest viewing–after city viewing" were used as changes induced by forest viewing. Statistical analysis was performed using SPSS 20.0 (IBM Corporation, Armonk, NY, USA). Pearson's correlation test was used to analyze the correlation. In all cases, probability (p) values < 0.05 were considered statistically significant.

3. Results

Figure 4 shows the large extent of individual changes in systolic blood pressure, diastolic blood pressure, and pulse rate after viewing forest environments. Although many subjects' blood pressure and pulse rate decreased by viewing forest landscapes compared with those in urban areas, these parameters were increased in some subjects. As seen in Figure

4, large individual differences were registered.

Figure 5 shows the relationship between initial values (after city viewing) and changes (after forest viewing–after city viewing) in systolic blood pressure. This value would be zero in case of no difference in systolic blood pressure between values registered after forest viewing and after city viewing, and significant correlation was not observed. However, a significant negative correlation between the “initial value” and “changes” was observed (Figure 5, $r = -0.545$, $P < 0.01$). Subjects whose initial systolic blood pressure was high showed a decrease in this value after viewing forest environments, whereas those whose initial systolic blood pressure was low showed an increase in this value.

The relationship between initial values and changes in diastolic blood pressure is shown in Figure 6. There was a significant negative correlation between the “initial value” and “changes” (Figure 6, $r = -0.313$, $P < 0.01$). Subjects whose initial diastolic blood pressure was high showed decreased diastolic blood pressure values after viewing the forest scenery, whereas those whose initial diastolic blood pressure was low showed an increase similar to the result of the systolic blood pressure measurements.

With regard to pulse rate, a significant negative correlation between the “initial value” and “changes” was observed (Figure 7, $r = -0.558$, $P < 0.01$). Subjects whose initial pulse rate was high showed a decrease in this value after viewing the forest scenery, whereas those whose initial pulse rate was low showed an increase in this value.

4. Discussion

Because nature therapy asks for “active comfort” [16, 17], there are individual differences within these effects [14, 18]. “Active comfort” is not a desire for safety and elimination of discomfort but is rooted in the desire for personal growth and an urge to achieve something extra. Because of these characteristics, it causes individual differences.

Previous research, which aimed to elucidate individual differences, has attempted to use the classification of Type A or Type B behavioral patterns [28−31]. The Type A behavioral pattern can be defined as an overt behavioral syndrome related to a lifestyle characterized by striving for achievement, aggressiveness, time urgency, acceleration of common activities, hostility, and so on, whereas the Type B behavioral pattern is characterized by the absence of the Type A characteristics [32, 33].

In a previous study on physiological response using observations on 485 subjects in 44 locations throughout Japan, Song et al. [28] demonstrated differences between the physiological response generated by forest and city viewing in the Type A and Type B subjects. As a result, the pulse rate was significantly lowered by forest viewing than that by city viewing in the Type B subjects; however, results for the Type A subjects exhibited no significant differences between the forest and urban environments. Park et al. [29] reported that the concentration of salivary cortisol significantly decreased after ingestion of a eucalyptus-flavored drink in the Type B group, whereas changes in the Type A group were statistically insignificant. Miyazaki and Tsunetsugu [30] found that activities in the prefrontal cortex stimulated by chocolate significantly increased in the Type B group, whereas the Type A group showed no changes in these activities. In addition, Song et al. [31] examined the psychological effects of walking in an urban green space and compared the response in the Type A and Type B groups. On the basis of results obtained using the obsessive-compulsive scale of SCL-90, the Type B subjects showed a significant decrease. However, there was no significant difference in the Type A group. This result showed that psychological responses differ between the Type A and Type B subjects. From these results, it was speculated that the response by natural stimulation is larger in the Type B subjects than that in the Type A subjects.

On the other hand, there are few studies using the Law of the Initial Value. Tsunetsugu and Miyazaki [34] demonstrated a significant negative correlation between a subject's initial salivary cortisol concentrations and changes observed after walking in a forest environment (after forest walking – before forest walking). Lee et al. [15] reported that subjects with higher initial salivary immunoglobulin A concentrations showed a reduction in concentrations after walking in forest environments, whereas those with lower initial concentrations showed smaller decreases and some showed increases in concentrations. These previous studies used the value of "after forest stimulation – before forest stimulation" as changes induced by walking in forests. Because the original purpose was to study differences between forest and city environments, the present study used the value of "after forest stimulation – after city stimulation" as the change induced by the forest environment.

In the present study, we elucidated individual differences on the basis of the Law of The Initial Value using the results of 98 subjects in nine locations. It was observed that there was a significant negative correlation between initial values (absolute values after city viewing) and changes (after forest viewing – after city viewing) in systolic blood pressure, diastolic blood pressure, and pulse rate. These results are consistent with those from previous studies, and it is shown that individual differences on the physiological relaxation effect induced by forest therapy can be described using the Law of The Initial Value. Furthermore, people whose initial systolic blood pressure, diastolic blood pressure, and pulse rate were high showed a decrease in this value after viewing forest environments, whereas those whose initial blood pressure and pulse rate were low showed an increase in this value. Therefore, it can be concluded that exposure to forests have a physiological adjustment effect that is close to an appropriate value.

In future, it is necessary to examine these individual differences using multiple indices, such as prefrontal cortex activity, heart rate variability, NK cell activity, and others. In addition, further studies should ascertain these indices in diverse groups, including females and different age groups because all participants in this study were healthy males in their twenties.

5. Conclusion

The present study clarified that there is a significant negative correlation between initial values (absolute values after city viewing) and changes (after forest viewing – after city viewing) in systolic blood pressure, diastolic blood pressure, and pulse rate, and it is possible to identify a factor of individual difference in the physiological effect of forest therapy using the Law of the Initial Value. Furthermore, on the basis of the fact that people whose initial value was low showed an increase in this value, whereas those whose initial value was high showed a decrease in this value, it is concluded that forests have a physiological adjustment effect that is close to an appropriate value.

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Figures

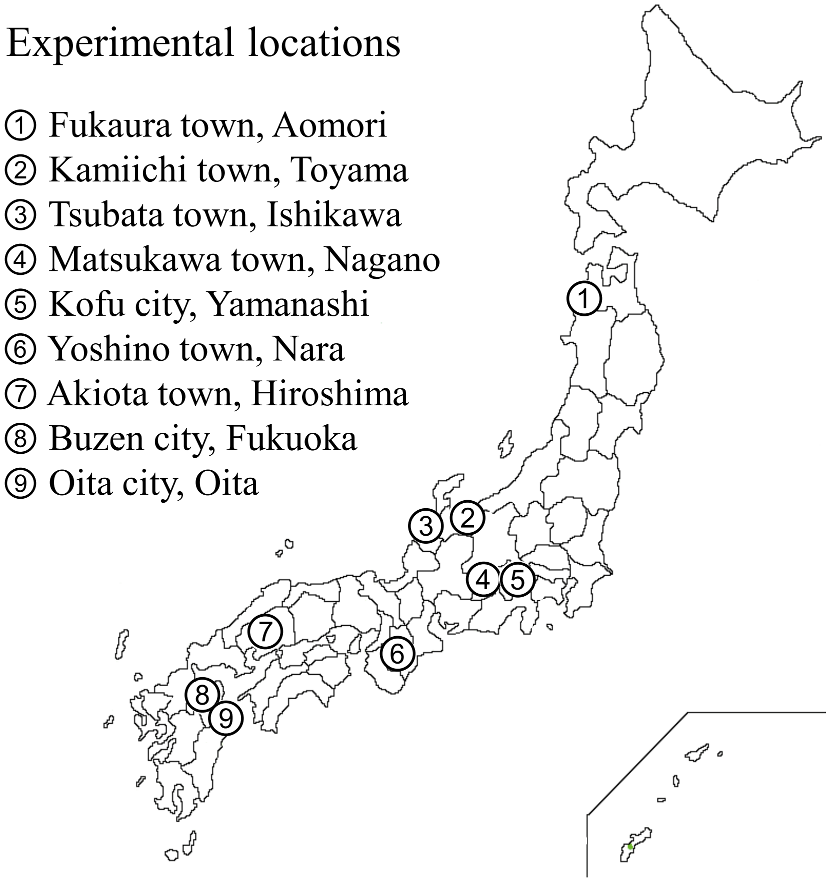

Figure 1. Map showing experimental locations.

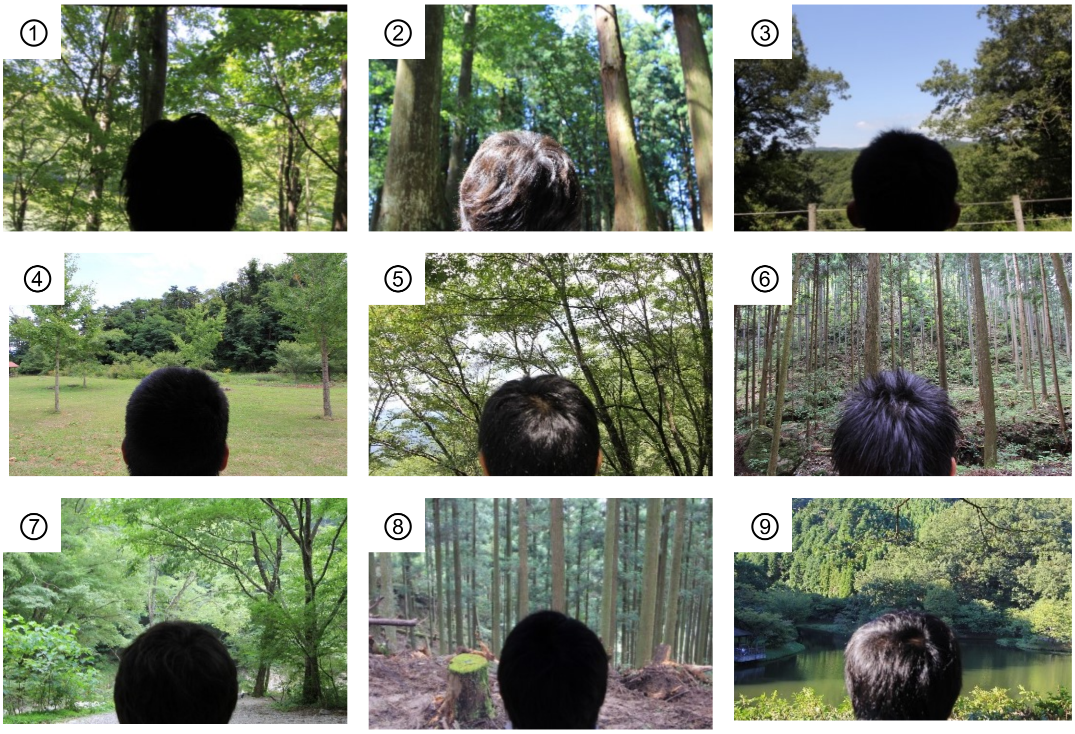

Figure 2. Forested area landscape scenery that was viewed.

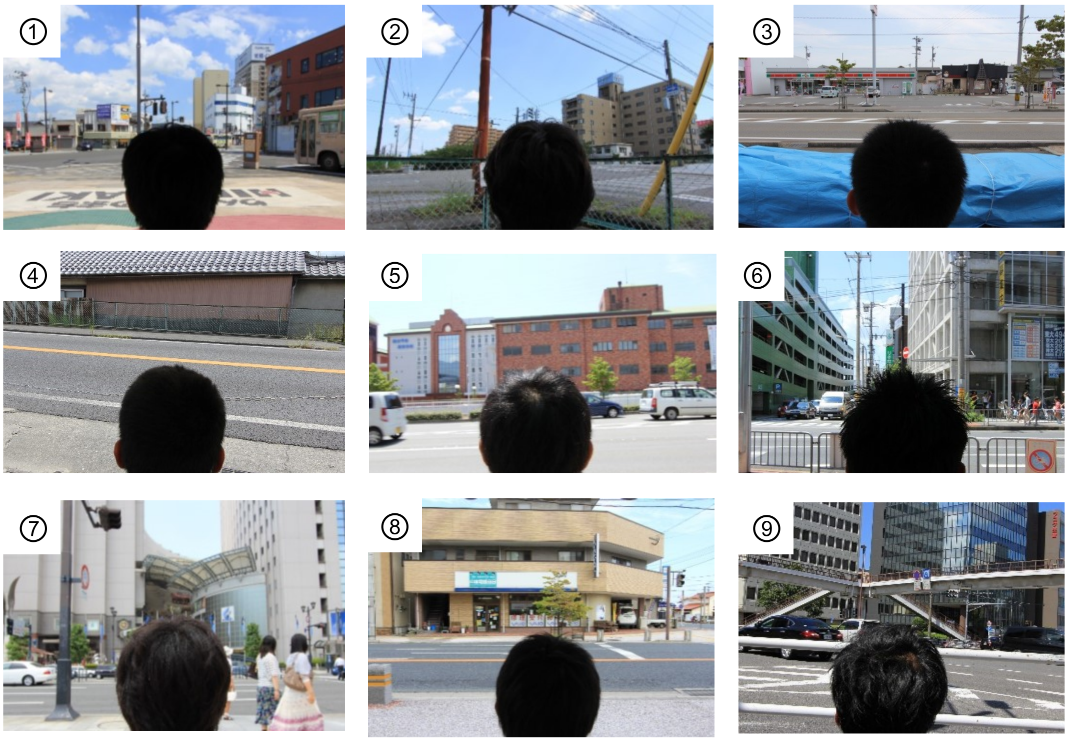

Figure 3. City area scenery that was viewed.

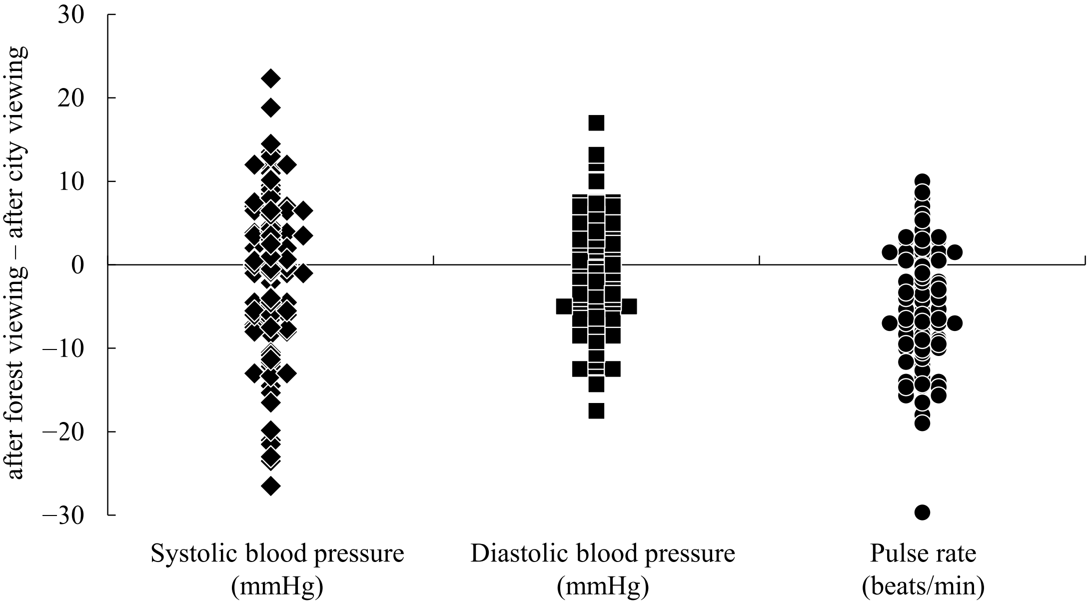

Figure 4. Individual differences in each physiological index.

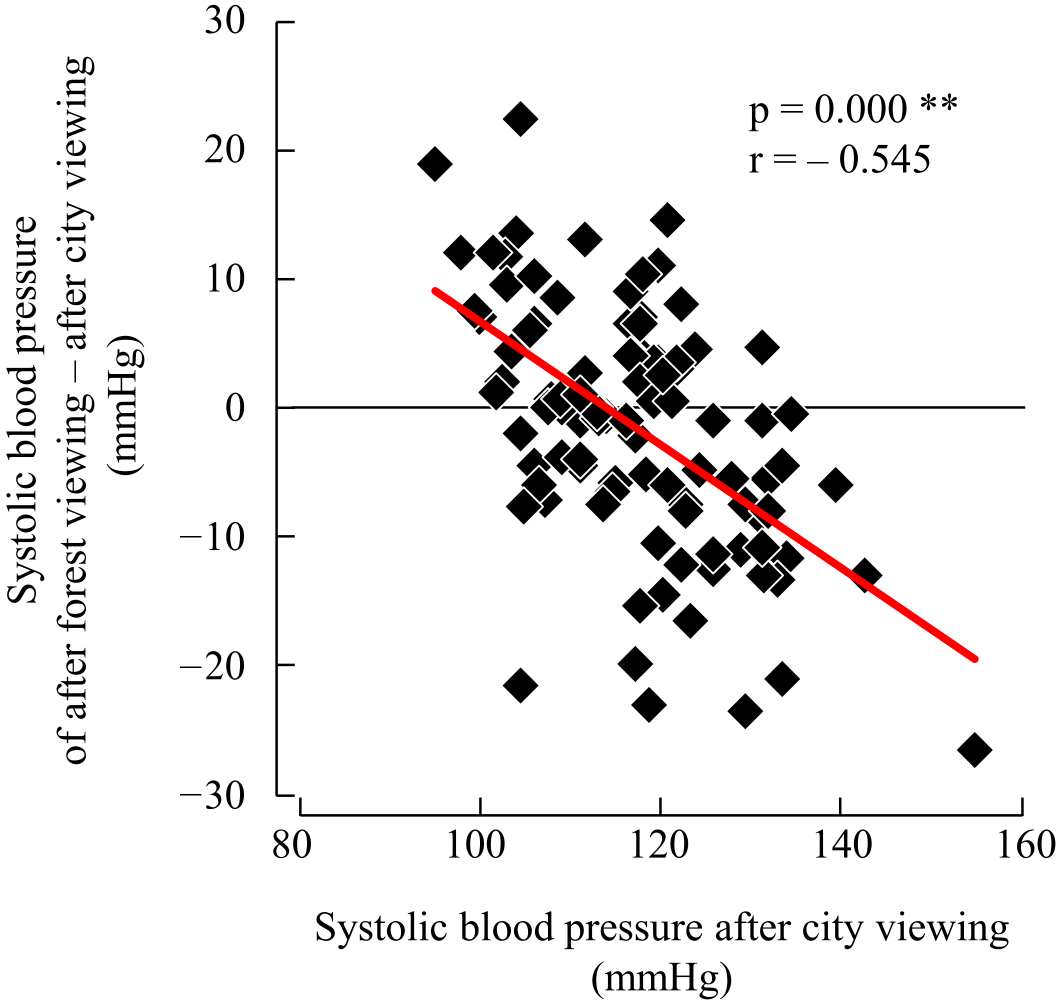

Figure 5. The relationship between the "initial value" and "value difference of the two environments" in systolic blood pressure.

N = 98, ** P < 0.01 by Pearson's correlation test.

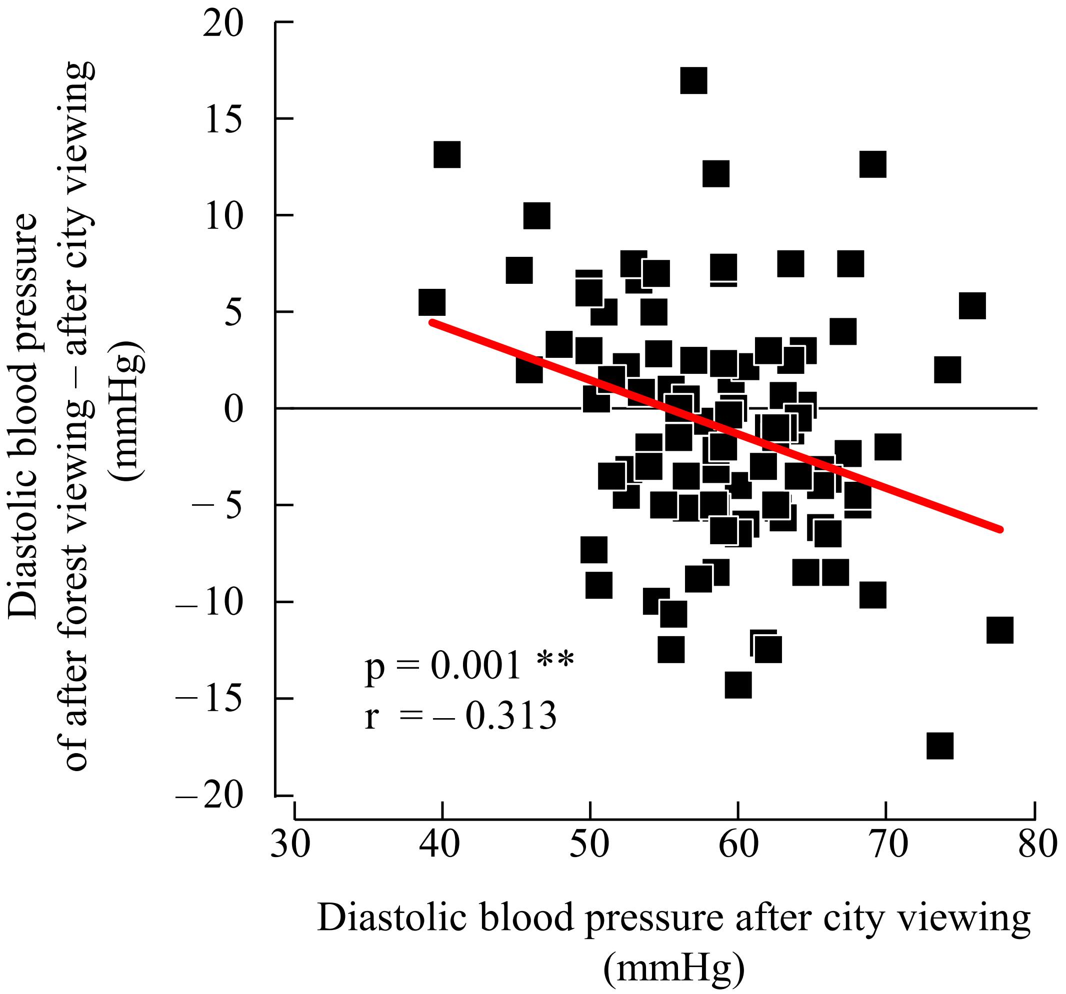

Figure 6. The relationship between the “initial value” and “value difference of the two environments” in diastolic blood pressure.

N = 97, ** P < 0.01 by Pearson’s correlation test.

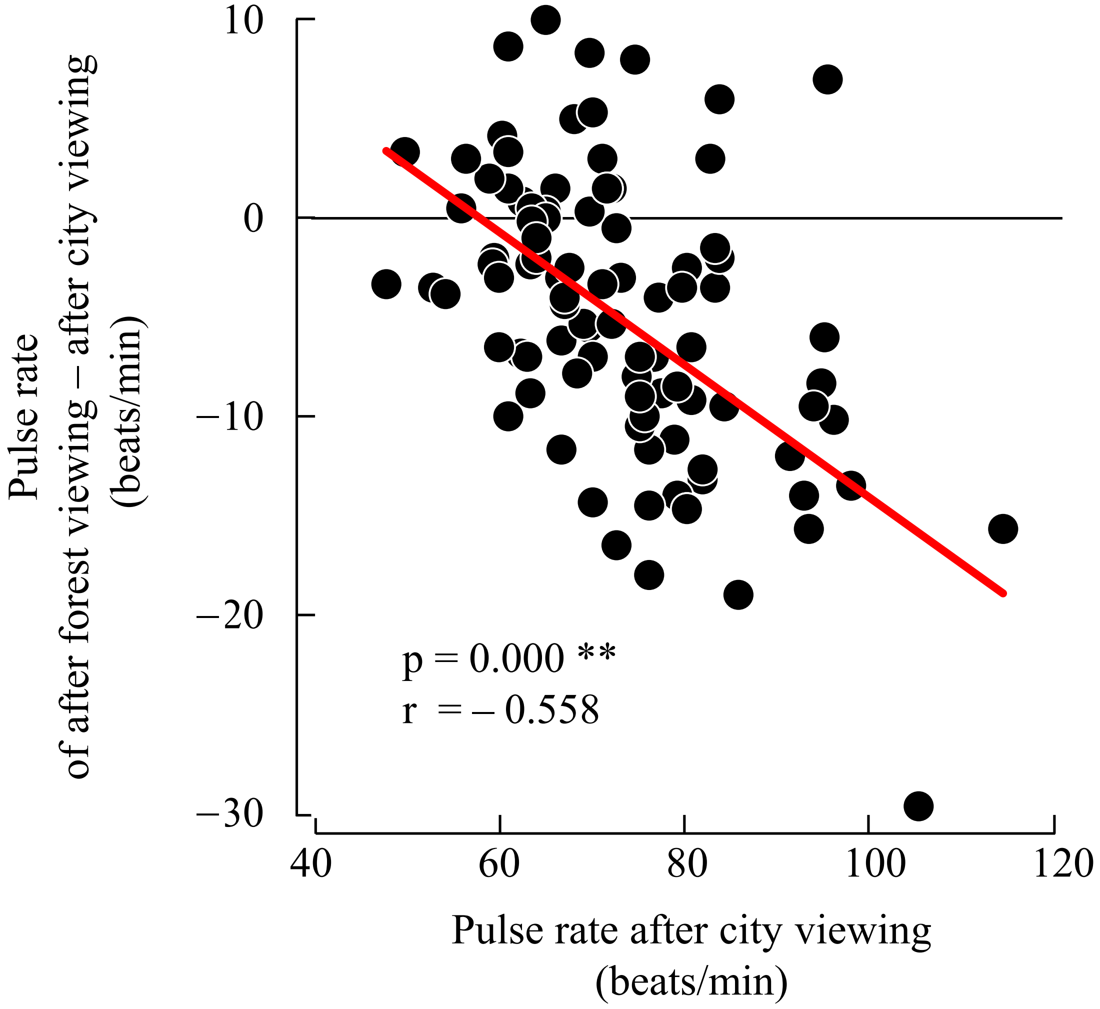

Figure 7. The relationship between the “initial value” and “value difference of the two environments” in pulse rate.

N = 96, ** P < 0.01 by Pearson’s correlation test.

Appendix

We examined the correlation between the absolute values of physiological responses "after city viewing" and "after forest viewing." Statistical analysis was performed by using SPSS 20.0 (IBM Corporation, Armonk, NY, USA). Pearson's correlation test was used to analyze the correlation. In all cases, probability (P) values < 0.05 were considered to indicate statistical significance.

A significant correlation between the absolute value "after city viewing" and "after forest viewing" was observed for systolic blood pressure (Figure 1, $r = 0.569$, $P < 0.01$), diastolic blood pressure (Figure 2, $r = 0.642$, $P < 0.01$), and pulse rate (Figure 3, $r = 0.793$, $P < 0.01$).

Differences in physiological parameters between the forest and urban viewing environments can be clearly shown by using this method. If there had been no difference between the two environments, then the regression lines would have overlapped the dotted lines that represent the theoretical values in all scatter grams (Figures 1–3). However, the regression lines differ from the theoretical values. The slopes of systolic blood pressure and diastolic blood pressure were significantly different ($P < 0.01$) than the theoretical values.

With respect to systolic blood pressure, the regression and theoretical lines intersected at 115 mmHg. It was observed that subjects with systolic blood pressure higher than the intersection value (i.e., 115 mmHg) exhibited a decrease in it after forest viewing, whereas those with systolic blood pressure lower than the intersection value exhibited an increase after forest viewing.

Similar results were observed for diastolic blood pressure, with the intersection value being 56 mmHg. Subjects with diastolic blood pressure higher than the intersection value exhibited a decrease in it after forest viewing, whereas those with diastolic blood pressure lower than the intersection value exhibited an increase after forest viewing.

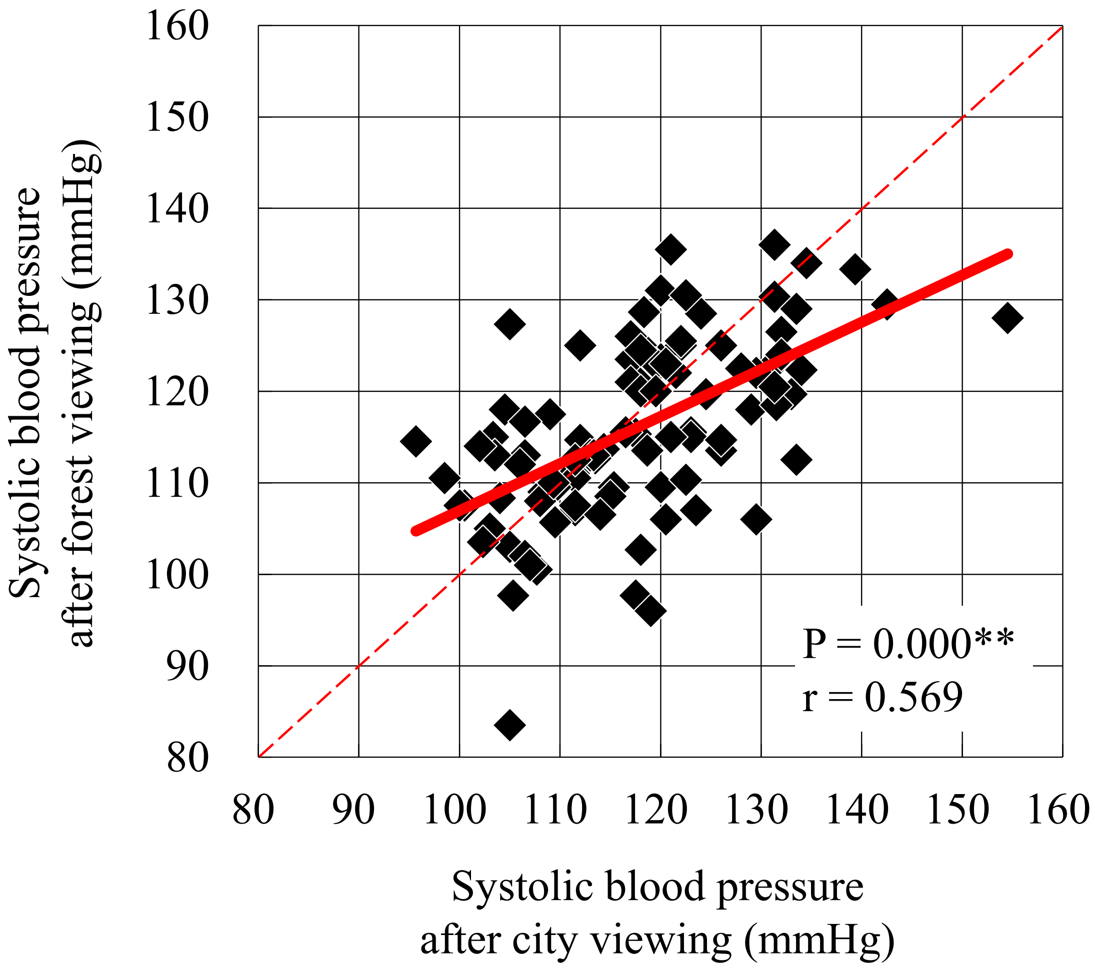

Figure 1. Relationship between systolic blood pressure “after city viewing” and “after forest viewing.”

N = 98, ** $P < 0.01$ by Pearson’s correlation test.

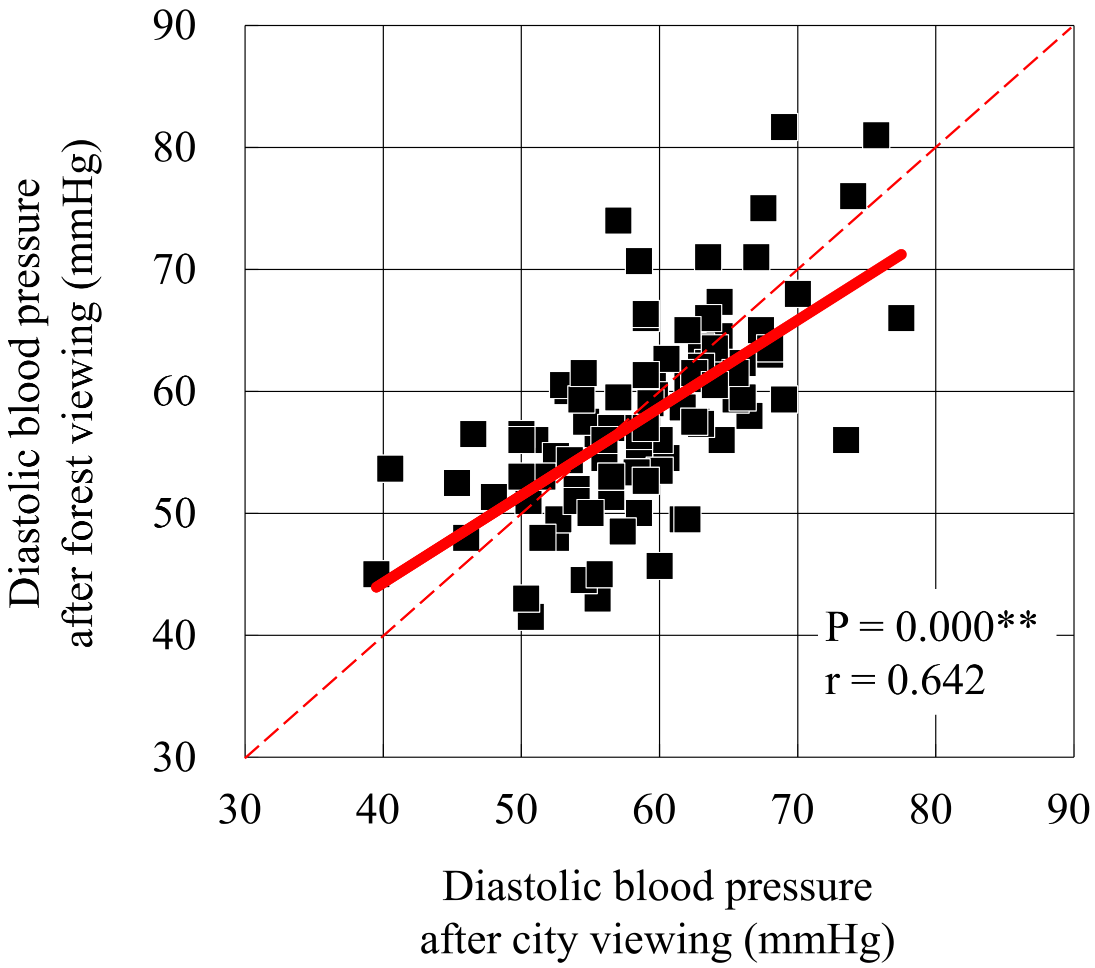

Figure 2. Relationship between diastolic blood pressure “after city viewing” and “after forest viewing.”

N = 97, ** $P < 0.01$ by Pearson’s correlation test.

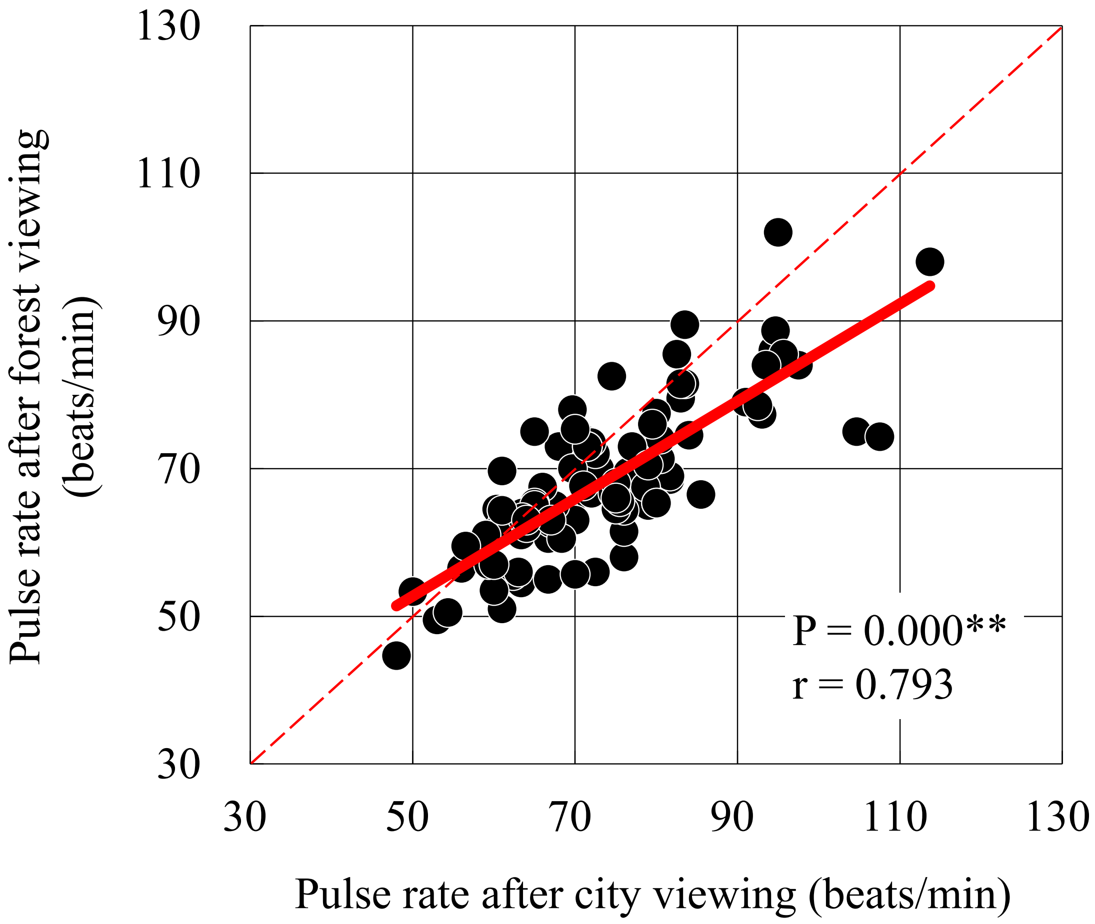

Figure 3. Relationship between pulse rate “after city viewing” and “after forest viewing.”

N = 96, ** P < 0.01 by Pearson’s correlation test.

Conclusion

I. Physiological and psychological effects of urban parks on humans

(1) Effects of walking in an urban environment on autonomic nervous activity

These findings provide important scientific evidence of the physiological and psychological effects of walking in an urban environment. In the urban environment, heart rate was significantly higher, and the high-frequency component of heart rate variability, which is an index of parasympathetic nervous activity that is enhanced in relaxing situations, was significantly lower, and the subjects felt more uncomfortable, awake, artificial, and less “refreshed.” Overall, the results showed that walking in an urban environment creates physiologically and psychologically stressed states in humans.

(2) Effects of walking in urban parks in winter on autonomic nervous activity

In the comparison between walking in the urban park and in the city area, key differences were observed. Heart rate was significantly lower and the natural logarithm of the high-frequency component of HRV was significantly higher when walking through the urban park than through the city area. The results of the three questionnaires indicated that walking in the urban park improved mood and decreased negative feelings and anxiety. The physiological and psychological data from the field experiments provides important scientific evidence regarding the health benefits of walking in an urban park. The results support the premise that walking in an urban park has relaxing effects, even in winter.

(3) Effects of walking in urban parks in spring on autonomic nervous activity

A brief spring-time walk in the urban park also had physiological and psychological relaxation effects. Compared with the responses after a brief walk in the city area, heart rate was significantly lower, parasympathetic nervous activity was enhanced, and sympathetic nervous activity was suppressed during a brief walk in the urban park. Furthermore, the subjective evaluations were generally in accordance with the physiological reactions, and improved mood and decreased negative feelings and anxiety were reported. The results showed that a brief spring-time walk induced physiologically and psychologically relaxed states in humans.

II. Individual differences in the physiological effects of a forest environment on humans

(1) Elucidation of individual differences in the physiological effects of viewing a forest environment in subjects with Type A and Type B behavior patterns

Our findings suggest that individual differences in pulse rate and blood pressure in response to exposure to the forest environment varied depending on whether the subjects exhibited a Type A or Type B behavior pattern. The pulse rate was significantly lower in the Type B group after exposure to forest areas than that after exposure to urban areas, whereas no significant difference was observed in the Type A group. In addition, the pulse rate was significantly lower in the low-scoring subjects in the Type B group, which was consistent with the changes in their diastolic blood pressure levels. These results suggest that individual differences in pulse rate and blood pressure in response to forest environments can be explained by Type A and Type B behavior patterns.

(2) Elucidation of individual differences in the physiological effects of viewing a forest environment as a consequence of the law of initial value

We examined the correlation between initial physiological response values and the differences in these values after walking in the two environments. There was a negative correlation between the initial values and the differences in values between the two environments. The subjects whose initial systolic blood pressure, diastolic blood pressure, and pulse rate were high showed marked decreases in these parameters after viewing the forest environment, whereas those whose initial systolic blood pressure, diastolic blood pressure, and pulse rate were low showed increases in these parameters. These results support the hypothesis that the physiological effect of a forest environment can differ depending on a subject's initial values. Moreover, it was clear that the forest environment caused a physiological adjustment, closing to an appropriate value.

This study demonstrated that walking in an urban environment induces physiologically and psychologically stressed states in humans, and a brief walk in an urban park had physiological and psychological relaxation effects, even in winter and spring. The beneficial effects that can be realized from exposure to nearby natural environments suggest a simple accessible pathway to improved health. As a preventive medicine, increased exposure to such environments is expected to contribute to improved quality of life and to promote health in people suffering stress-related conditions.

In addition, we demonstrated that individual differences in physiological relaxation effects of viewing a forest environment were related to Type A and Type B behavior patterns in the subjects and to the law of initial values. These findings will contribute to a better understanding of how variations in data observed in a variety of research fields can be caused by differences in individual subjects. Furthermore, in forest therapy, consideration of individual differences is considered to be useful in designing forest therapy programs.

In conclusion, walking in urban parks, which are familiar natural environments, induced physiological and psychological relaxation effects, and the individual differences in the physiological responses to forest environments can be explained by the subject’s behavior patterns and their initial response values.

Challenges and future steps

I. Physiological and psychological effects of urban parks on humans

The current study demonstrated that walking in an urban environment induces physiological and psychological stress states in humans, but a brief walk in an urban park had physiological and psychological relaxation effects even during the winter and spring. However, there are some limitations. Below we discuss challenges arising from the study and concerns for future research.

First, the study only included Japanese male university students in their twenties, and the sample size was limited. To generalize the findings, further evidence-based studies with a larger sample size including various subject groups are required.

Second, the present study only used HRV and heart rate, which are indices of autonomic nervous system activity. For a comprehensive discussion, future studies should examine the effects of walking in an urban park using additional physiological indices such as brain activity and endocrine activity.

Third, there are differences in the results between the experiments conducted in winter and those conducted in spring. We believe that these differences are due to seasonal differences in environmental conditions, such as temperature, humidity, and wind speed as well as the state of trees, such as color and amount of leaves. Future studies should investigate these differences through laboratory experiments. It is important to clarify the influence of different temperature conditions and the effect of visual conditions by conducting the experiment in urban parks in all four seasons.

Fourth, the study focuses on urban parks with limited experimental sites. Further research involving a variety of urban parks is needed. In addition, examination of the effects of other urban green space using a field experimental design is needed.

II. Individual differences in the physiological effects of a forest environment on humans

We demonstrated that individual differences in the physiological relaxation effects of viewing a forest environment were related to Type A and Type B behavior patterns in the subjects and the law of initial values. However, there are some limitations. Below, we discuss the challenges arising from the study and concerns for future research.

First, the study also only includes Japanese male university students in their twenties. To generalize the findings, further research using diverse groups including females and different age groups is required.

Second, the present study only used blood pressure and pulse rate as the measured parameters. Future research should examine individual differences using multiple indices such as brain activity, autonomic nervous system activity, and endocrine activity.

Third, individual differences in the effects of natural environments have been noted, and this phenomenon has posed several questions in a variety of fields that must be clarified. Future research using different approaches is needed.

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