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Physiological and Psychological Impacts of Walking Stress in an Urban Environment on Young Males

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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.

Keyword: Urbanization; City Area; Forested Area; Walking; Stress; Physiological Response; Heart Rate; Heart Rate Variability; Psychological Response

Introduction

Nowadays most people live in urban areas and they will continue to do so for the foreseeable future [1]. 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 [2]. These environmental changes threaten human health and quality of life [2,3]. In particular, cities have been reported to have high temperatures and act as urban heat islands [4,5]. High temperatures cause sensations of discomfort and sometimes heat stress [6]. 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 [5,7].

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 [8]; 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 [9-11].

All of these factors in combination have severe impacts on humans. Several studies have reported that urban environments are associated with increased mortality rates [12]. Although we are now living in a society characterized by urbanization and artificialization, our physiological functions are still adapted to nature [13]. 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 [13-18]. 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.

Materials and Methods

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). 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

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Figure 1: Map showing the experimental locations

of the Center for Environment, Health, and Field Sciences, Chiba University, Japan.

Physiological and psychological measurements

Heart rate and Heart Rate Variability (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 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 [19]. 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)).

Psychological reactions were investigated by subjective evaluations. Evaluations using the semantic differential (SD) method [20] 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 [21].

Experimental design

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 2). 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.

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 (SPSS Inc., Chicago, IL, USA). A one-sided test was used. In all cases, values of $p < 0.05$ were considered statistically significant.

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 3). 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 4).

Figure 2: Representative experimental scene in an urban (top) and forested area (bottom)

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 5). 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 [22]. In the present study, the average value after 13 min of walking was 6.1% lower in the urban area (3.88 ± 0.14 msec^2) than in the forested area (4.13 ± 0.18 msec^2; $p< 0.05$; Figure 6).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.

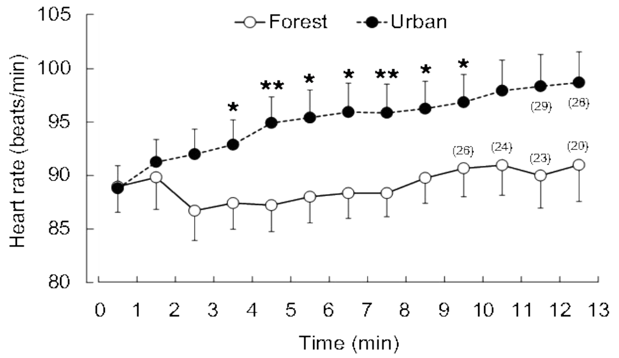

Figure 3: Changes in heart rate at 13 min and comparison of each 1-min value between the two environments
N = 28-30 (in the urban areas), N = 20-27 (in the forests), mean ± SE, The number in parentheses refers to the number of subjects. * $p< 0.05$, ** $p< 0.01$, determined by paired t-test; Holm's procedure was used.

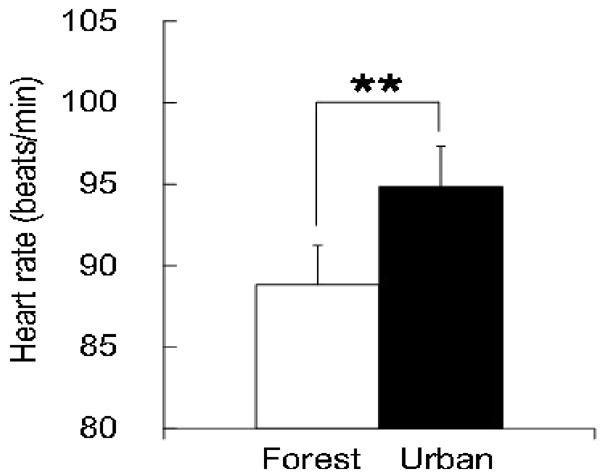

Figure 4: Comparison of the heart rates of subjects walking in urban and forested areas
N = 30 (in the urban areas), N = 27 (in the forests), mean ± SE. ** p< 0.01, determined by paired t-test.

These results are partly in agreement with those of previous studies that have compared physiological reactivity in urban and forested environments [15,17,18, 22], 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 7, left), awakening ($p< 0.01$, Figure 7, middle), and artificial ($p< 0.01$, Figure 7, 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 8). 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 [23,24]. 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 [25]. Moreover, it was evident that walking in an urban park for only 15 min brings physiological and psychological relaxation [26]. 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.

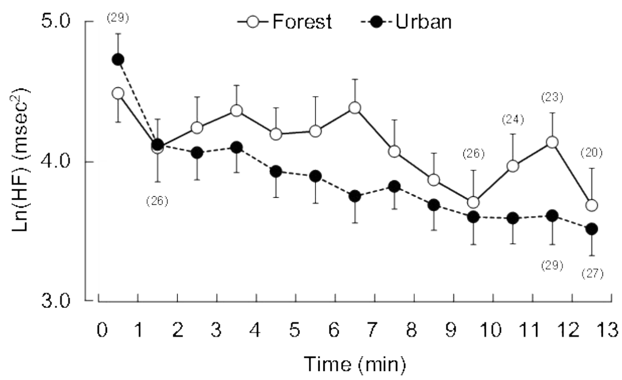

Figure 5: Changes in the ln(HF) of HRV at 13 min and comparison of each 1-min value between the two environments
N = 27-30 (in the urban areas), N = 20-27 (in the forests), mean ± SE. The number in parentheses refers to the number of subjects.

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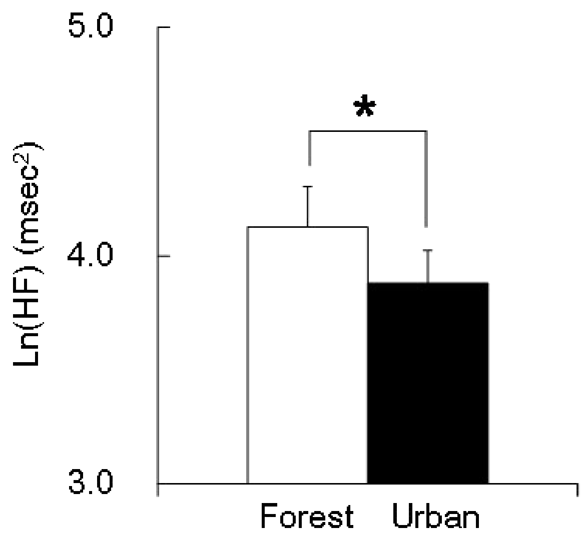

Figure 6: Comparison of ln(HF) of HRV of subjects walking in urban and forested areas
N = 30 (in the urban areas), N = 27 (in the forests), mean ± SE. * *p*< 0.05, determined by paired t-test.

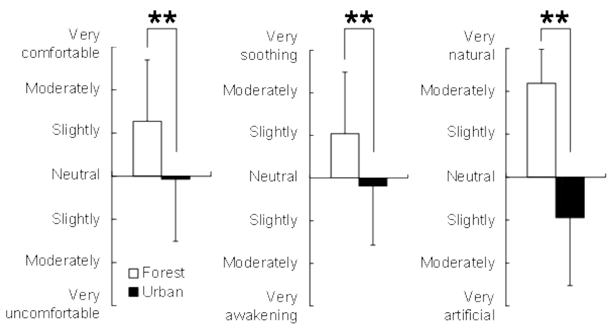

Figure 7: Comparison of subjective scores for comfortable, soothing, and natural feelings between the two environments
N = 35, mean ± SD. ** p< 0.01, determined by Wilcoxon signed-rank test

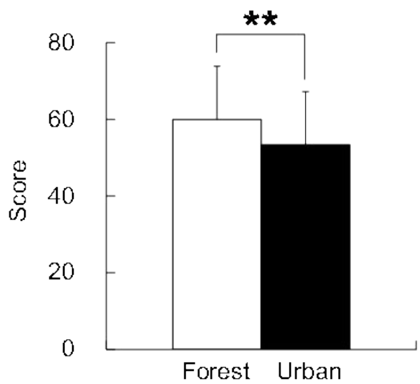

Figure 8: Comparison of subjective scores for a refreshed feeling between the two environments
N = 35, mean ± SD. ** *p*< 0.01, determined by Wilcoxon signed-rank test

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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