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ORIGINAL ARTICLE

# Acute effects of walking in forest environments on cardiovascular and metabolic parameters

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**Abstract** We previously found that forest environments reduced stress hormones such as adrenaline and noradrenaline and showed the relaxing effect both in male and female subjects. In the present study, we investigated the effects of walking under forest environments on cardiovascular and metabolic parameters. Sixteen healthy male subjects (mean age 57.4 ± 11.6 years) were selected after obtaining informed consent. The subjects took day trips to a forest park in the suburbs of Tokyo and to an urban area of Tokyo as a control in September 2010. On both trips, they walked for 2 h in the morning and afternoon on a Sunday. Blood and urine were sampled on the morning before each trip and after each trip. Blood pressure was measured on the morning (0800) before each trip, at noon (1300), in the afternoon (1600) during each trip, and on the morning (0800) after each trip. The day trip to the forest park significantly reduced blood pressure and urinary noradrenaline and dopamine levels and significantly increased serum adiponectin and dehydroepiandrosterone sulfate (DHEA-S) levels. Walking exercise also reduced the levels of serum N-terminal pro-B-type natriuretic peptide (NT-proBNP) and urinary dopamine. Taken together, habitual walking in forest environments may lower blood pressure by reducing sympathetic nerve activity and have beneficial effects on blood adiponectin and DHEA-S levels, and habitual walking exercise may have beneficial effects on blood NT-proBNP levels.

**Keywords** Adiponectin · Adrenaline · Blood pressure · DHEA-S · Forest environment · NT-proBNP · Walking

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## Introduction

Humans enjoy forest environments because of the quiet atmosphere, beautiful scenery, mild climate, and fresh clean air. It has been reported that walking in forest environments significantly enhances human immune function, reduces the levels of stress hormones such as urinary adrenaline and noradrenaline, and increases the score for vigor and decreased the scores for anxiety, depression, fatigue, confusion and anger on the Profile of Mood States (POMS) test (Li et al. 2007a, 2008a, b, 2010). Moreover, forest environments reduce sympathetic nervous activity, increase parasympathetic nervous activity, and have a relaxing effect on humans (Li et al. 2007a; Park et al. 2010). Since forests occupy 67% of the land in Japan (Li et al. 2008c), forest parks are easily accessible; therefore, walking in forest parks is very popular in Japan.

Based on the findings mentioned above, because forest environments reduce sympathetic nervous activity and increase parasympathetic nervous activity, we speculated that walking in forest environments reduces blood pressure and has beneficial effects on cardiovascular function. Thus, in the present study, we investigated the acute effects of walking in a forest park on blood pressure and other cardiovascular and metabolic parameters in male subjects.

## Subjects and methods

### Subjects

Sixteen healthy male subjects, who ranged in age from 36 to 77 years (mean ± SD 57.4 ± 11.6), were selected for the present study. Information about the subjects gathered from a self-administered questionnaire that asked about cigarette smoking, alcohol consumption, eating breakfast, sleeping hours, working hours, physical exercise, nutritional balance, and mental stress have been reported previously (Li et al. 2007b). Written informed consent was obtained from all subjects after a full explanation of the study procedures. None of the subjects had any symptoms of disease, used drugs that might have affected the results, or were taking any medication at the time of the study. The Ethics Committee of the Nippon Medical School approved this study.

### Walking in a forest environment and an urban area

The subjects went on a day trip to a forest park in Saitama prefecture in the north of Tokyo, Japan, on September 12, 2010 (Sunday). As a control, on September 5, 2010 (Sunday), a week before they went walking in the forest park, the subjects took a day trip to an urban area in Tokyo where there were almost no trees. We previously found that the effects of walking in forest environments on the immune function (natural killer activity) lasted for more than 1 week, and sometimes even 4 weeks, but not walking in urban environments (Li et al. 2008a, b, 2010). Therefore, to avoid such lasting effects, we designed the study so that all subjects first walked in the urban area and then in the forest. The interval between the two experiments was 1 week. The subjects walked for 2 h each in the morning and afternoon for a total distance of about 6 km in the forest park/urban area and then returned to Tokyo. The subjects consumed the same number of calories during the two trips. To control for the effects of alcohol, the subjects did not consume alcohol during the study period. Blood and urine were sampled on the morning before the trips and on the morning after the trips under fasted conditions. Blood pressure was measured before, during, and after the trips. The physical activity of the subjects was monitored with a pedometer, and their sleep duration was measured with an Actiwatch (R) piezo-electric accelerometer (Mini Mitter Co., Inc., Sunriver) (Li et al. 2007a, 2008a, b, 2010).

### Blood pressure measurements

Blood pressure was measured on the right arm with an HBP-9020 automatic device (OMRON COLIN Co., Ltd., Tokyo) on the morning (0800) before the trips, at noon (1300), in the afternoon (1600) during the trips, and on the morning (0800) after the trips. The measurements were conducted after 10 min rest in a quiet room, and three measurements were taken at 30-s intervals. The mean of the last two measurements at each point was used for the statistical analysis.

### Blood analysis

The serum levels of triglycerides, total cholesterol (Cho), low density lipoprotein (LDL) Cho, high density lipoprotein (HDL) Cho, and remnant-like particles (RLP) Cho were analyzed using an enzymatic assay with an autoanalyzer. The serum total adiponectin concentration was measured using an enzyme immunoassay (EIA). Blood glucose concentration was analyzed using a Glucocard GT-1640 and Diasenser strips (Arkray, Kyoto, Japan). The serum level of insulin was analyzed using a chemiluminescent immunometric assay (CLIA), and the serum level of dehydroepiandrosterone sulfate (DHEA-S) was analyzed using a chemiluminescence enzyme immunoassay (CLEIA). The serum level of N-terminal pro-B-type natriuretic peptide (NT-proBNP) was analyzed with an electrochemiluminescent immunoassay (ECLIA). The serum level of high-sensitivity C-reactive protein (hs-CRP) was analyzed using a latex nephelometric assay.

### Urinary adrenaline, noradrenaline, and dopamine measurements

The levels of adrenaline, noradrenaline, and dopamine in urine were measured by an HPLC method using an HLC-725CAII analyzer. The instrument features a column-switching system composed of two pretreatment columns, a separation column and a high-sensitivity detection unit based on a post-column reaction using the fluorogenic reagent 1,2-diphenylethyleneamine. The detection limits of adrenaline, noradrenaline, and dopamine in urine were all 8 fmol/ml (Li et al. 2008a, b, 2009, 2010).

### Hematological examinations

The white blood cell (WBC), red blood cell (RBC), and platelet (PLT) counts; the percentages of granulocytes, lymphocytes, and macrophages in the peripheral blood; and the concentration of Hb were determined using an automatic cell counter (LC-550, Horiba Co., LTD. Kyoto, Japan), as described previously (Li et al. 2008a, b, 2009, 2010).

### Statistical analysis

As blood pressure shows a circadian rhythm with different levels at different time points during the day; therefore, we could not compare blood pressure between 8:00 (before walking) and 13:00 (after walking), but could only compare blood pressure after walking in an urban setting with that after walking in forest environments at the same time point; i.e. urban versus forest at 8:00 (before walking) or urban versus forest at 13:00 (after walking). From this perspective, paired *t* tests should be used to compare the difference in blood pressure between urban and forest environments at the same time point. Thus, comparisons between different days were made with paired *t* test. The analyses were performed with the Microsoft Excel software package for Windows. The significance level for *p* values was set at <0.05.

## Results

The weather during the trip to the forest park was excellent with temperatures ranging from 25.1 to 32.3, and humidity was 58%, and the weather during the visit to the urban area was also excellent with temperatures 28.0–34.3 and humidity of 52%. The subjects consumed the same number of calories during the two trips. To control for the effects of alcohol, the subjects did not consume alcohol during the study period.

### Caloric consumptions

In the present study, caloric consumption was used to estimate the physical activity of the subjects. Caloric consumption was significantly greater during the walks in the urban area and the forest park than before the trips. However, there was no difference in caloric consumption between the two trips (Fig. 1).

### Effect of walking in forest environments on blood pressure

As shown in Fig. 2, both systolic and diastolic blood pressure levels at noon (1300) in the forest park were significantly lower than those in the urban area. Moreover, the diastolic blood pressure level in the afternoon (1600) in the forest park was significantly lower than that in the urban area. However, there was no significant difference in both systolic and diastolic blood pressure levels before walking (0800) between the urban and forest. This suggests that walking in the forest park, but not in the urban area reduced blood pressure.

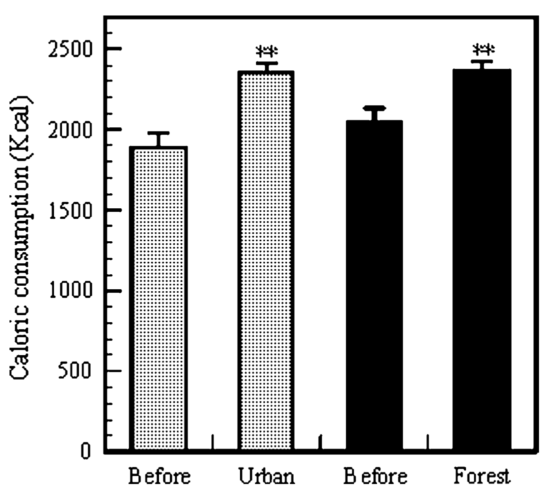


**Fig. 1** Caloric consumption during the experiments. Data are presented as the mean + SE ($n = 16$). ** $p < 0.01$, significantly different from the day before the walk in the urban area or the forest park according to the paired *t* test

### Effect of walking in forest environments on adrenaline, noradrenaline, and dopamine concentrations in urine

The concentrations of urinary noradrenaline and dopamine in two subjects before the forest park trip significantly exceeded the respective normal ranges (noradrenaline: subject 12: 346.0 μg/l, subject 13: 973.4 μg/l, normal range 31–160 μg/day; dopamine: subject 12: 2,228.0 μg/l, subject

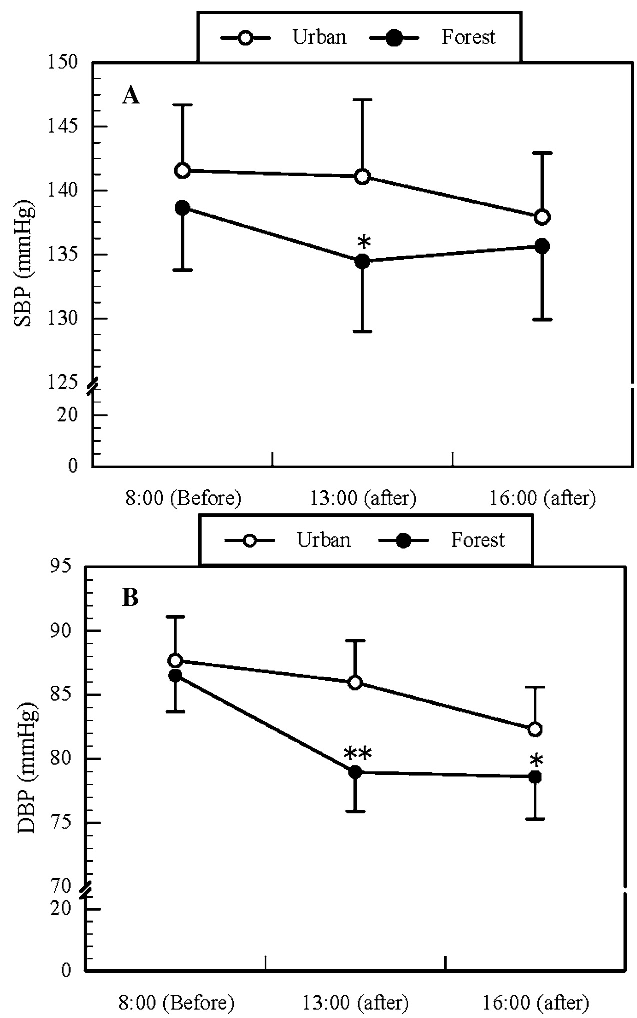


**Fig. 2** Effect of walking in a forest park and walking in an urban area on the levels of systolic (**a**) and diastolic (**b**) blood pressure. Data are presented as the mean + SE ($n = 16$). *$p < 0.05$, **$p < 0.01$, significantly different between the forest and urban trips according to the paired *t* test

13: 15,624.3 μg/l, normal range 280–1,100 μg/day); therefore, the urinary noradrenaline and dopamine concentration data of these two subjects were excluded from the statistical analysis.

The level of urinary adrenaline tended to decrease after walking in the forest park although the difference was not significant ($p = 0.08$, Fig. 3a). On the other hand, walking in the forest environment significantly decreased the concentrations of noradrenaline and dopamine in urine, whereas walking in the urban area also significantly decreased the concentration of dopamine in urine (Fig. 3c), but had no effect on urinary adrenaline or noradrenaline levels (Fig. 3a, b).

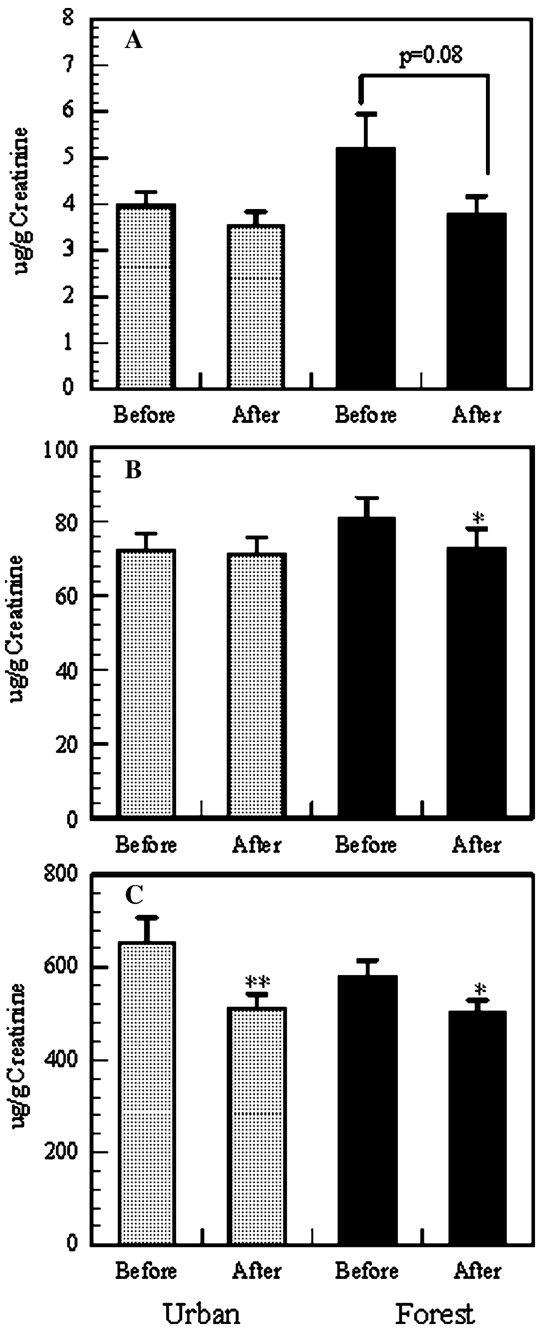


**Fig. 3** Effect of walking in a forest park and walking in an urban area on urinary adrenaline (**a**), noradrenaline (**b**), and dopamine concentrations (**c**). Data are presented as the mean + SE ($n = 16$ for adrenaline and $n = 14$ for noradrenaline and dopamine). *$p < 0.05$, **$p < 0.01$, significantly different between after and before according to the paired $t$ test

### Effect of walking in forest environments on serum adiponectin

As shown in Fig. 4, walking in the forest park significantly increased the level of adiponectin in serum, but walking in the urban area did not affect the level of adiponectin, suggesting that forest environments affect serum adiponectin levels.

### Effect of walking in forest environments on serum DHEA-S

As shown in Fig. 5, walking in the forest park significantly increased the serum level of DHEA-S, but walking in the

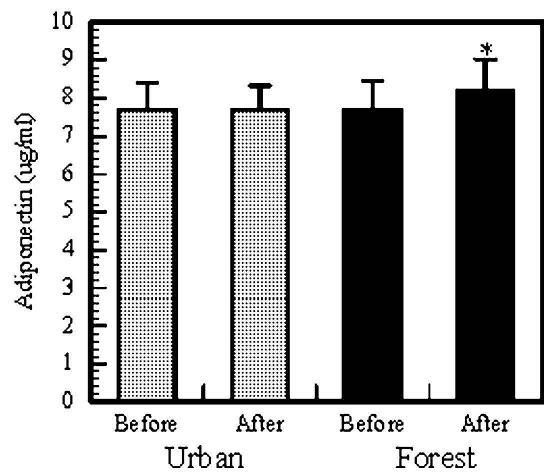


**Fig. 4** Effect of walking in a forest park and walking in an urban area on the serum adiponectin concentration. Data are presented as the mean + SE ($n = 16$). *$p < 0.05$, significantly different between after and before the forest walk according to the paired $t$ test

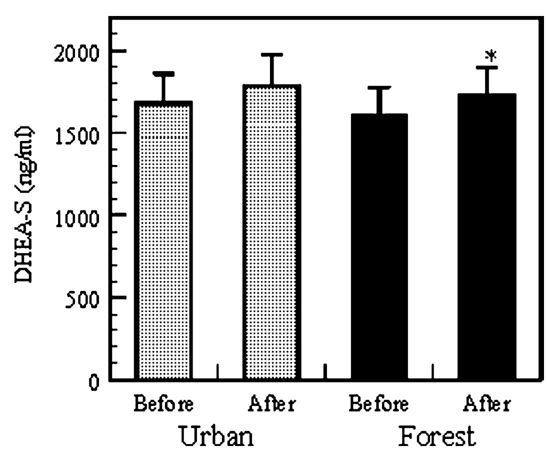


**Fig. 5** Effect of walking in a forest park and walking in an urban area on the serum DHEA-S concentration. Data are presented as the mean + SE ($n = 16$). *$p < 0.05$, significantly different between after and before the forest walk according to the paired $t$ test

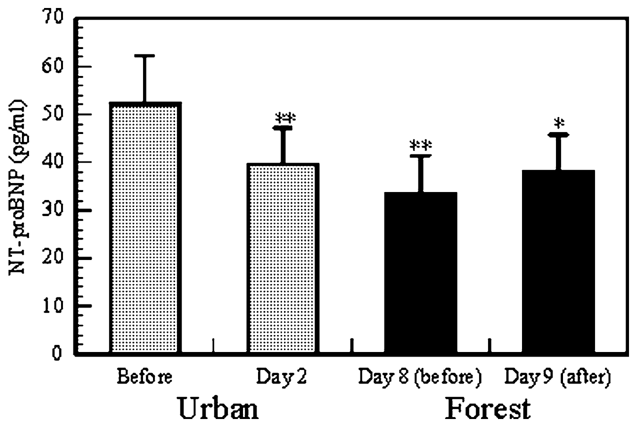


**Fig. 6** Effect of walking on the serum NT-proBNP concentration. Data are presented as the mean + SE ($n = 16$). $^*p < 0.05$, $^{**}p < 0.01$, significantly different from before the walk in the urban area according to the paired *t* test

urban area did not affect the serum level of DHEA-S, suggesting that forest environments may have a beneficial effect on the serum DHEA-S level.

### Effect of walking on serum NT-proBNP

As shown in Fig. 6, walking significantly decreased the serum NT-proBNP level, and this effect lasted for more than 1 week, suggesting that walking exercise has a beneficial effect on the serum NT-proBNP level.

### Effect of walking in the forest park on lipid metabolism and other parameters

As shown in Table 1, neither walking in the forest park nor walking in the urban area affected the levels of triglycerides, total Cho, LDL-Cho, HDL-Cho, RLP-Cho, insulin, or hs-CRP in serum, or blood glucose. Walking also had no effect on the numbers of WBC, RBC, PLT, lymphocytes, granulocytes, or monocytes or the Hb concentration in the peripheral blood.

There were no significant differences in the sleep durations of the subjects between before and after the forest park trip or the urban trip (data not shown).

## Discussion

Because blood pressure shows a circadian rhythm with different levels at different time points during the day; therefore, we could not compare the blood pressure between 8:00 (before walking) and 13:00 (after walking), but could only compare blood pressure after walking in an urban setting

**Table 1** Results of blood analysis (mean ± SD)

| | Urban ($n$ = 16) | Forest ($n$ = 16) | *P* value[#] |
|---|---|---|---|
| T-Cho (mg/dl) | | | |
| Before | 211.25 ± 37.00 | 210.00 ± 38.53 | 0.704 |
| After | 211.63 ± 36.62 | 207.69 ± 33.55 | 0.171 |
| HDL-Cho (mg/dl) | | | |
| Before | 59.06 ± 13.26 | 59.50 ± 13.29 | 0.639 |
| After | 58.44 ± 13.33 | 58.50 ± 13.89 | 0.947 |
| LDL-Cho (mg/dl) | | | |
| Before | 125.13 ± 28.58 | 130.19 ± 32.16 | 0.198 |
| After | 126.75 ± 29.00 | 128.69 ± 29.40 | 0.558 |
| TG (mg/dl) | | | |
| Before | 117.75 ± 63.95 | 105.56 ± 60.48 | 0.428 |
| After | 115.44 ± 54.71 | 117.38 ± 61.78 | 0.798 |
| RLP-Cho (mg/dl) | | | |
| Before | 7.56 ± 5.25 | 6.44 ± 4.97 | 0.459 |
| After | 6.26 ± 3.63 | 7.01 ± 4.61 | 0.204 |
| hs-CRP (mg/dl) | | | |
| Before | 0.07 ± 0.05 | 0.09 ± 0.12 | 0.441 |
| After | 0.06 ± 0.04 | 0.11 ± 0.12 | 0.126 |
| Glucose (mg/dl) | | | |
| Before | 100.56 ± 11.30 | 99.56 ± 13.68 | 0.656 |
| After | 96.75 ± 12.85 | 99.00 ± 11.08 | 0.274 |
| Insulin (μU/ml) | | | |
| Before | 6.86 ± 4.29 | 6.62 ± 3.50 | 0.710 |
| After | 6.15 ± 3.41 | 6.86 ± 4.02 | 0.059 |
| WBC/μl | | | |
| Before | 6,075 ± 1,329 | 6,150 ± 1,306 | 0.711 |
| After | 6,165 ± 1,436 | 6,829 ± 1,723 | 0.191 |
| Lymphocytes/μl | | | |
| Before | 1,642 ± 530 | 1,707 ± 635 | 0.258 |
| After | 1,786 ± 570 | 1,771 ± 731 | 0.857 |
| Granulocytes/μl | | | |
| Before | 3,954 ± 860 | 3,980 ± 7,912 | 0.887 |
| After | 3,885 ± 881 | 4,562 ± 1,469 | 0.151 |
| Monocytes/μl | | | |
| Before | 479 ± 171 | 463 ± 133 | 0.608 |
| After | 491 ± 204 | 496 ± 233 | 0.913 |
| RBC ($\times 10^6$/μl) | | | |
| Before | 4.70 ± 0.42 | 4.70 ± 0.37 | 0.409 |
| After | 4.73 ± 0.46 | 4.69 ± 0.42 | 0.775 |
| Hb (g/dl) | | | |
| Before | 14.88 ± 0.95 | 14.91 ± 0.80 | 0.368 |
| After | 14.97 ± 1.02 | 14.98 ± 0.95 | 0.531 |
| PLT ($\times 10^3$/μl) | | | |
| Before | 223 ± 39.6 | 223 ± 36.5 | 0.618 |
| After | 221 ± 41.2 | 219 ± 41.6 | 0.288 |

[#] *p* values indicate the differences between the urban and forest trips according to the paired *t* test with that after walking in forest environments at the same time point; i.e. urban versus forest at 13:00 (after walking). In the present study, we found that walking in a forest park, but not in an urban area significantly reduced both systolic and diastolic blood pressure in male middle-aged subjects. It has been reported that habitual walking exercise for 4–58 weeks and physical activity have beneficial effects on lowering blood pressure (Bravata et al. 2007; Vogel et al. 2009; Lee et al. 2010). However, there was no significant difference in physical activity between the walk in the forest park and that in the urban area, suggesting that the difference in blood pressure between the two trips was not due to physical activity. These findings suggest that habitual walking in forest environments has beneficial effects on lowering blood pressure. Park et al. (2010) also reported that in young male students, walking in forest environments for about 20 min induced small, but significant decreases in both systolic and diastolic blood pressure compared to walking in urban areas, supporting our findings. However, there are many differences between our study and that by Park et al. (2010). First, the subjects were different: middle-aged subjects (36–77 years, mean $\pm$ SD 57.4 $\pm$ 11.6) in our paper versus young male students (mean age $\pm$ SD 21.7 $\pm$ 1.5 years) in the study by Park et al. (2010). We consider that studying the effect of walking in forest environments on blood pressure in middle-aged subjects is more important than that in young male students. Second, the blood pressure levels of the subjects were different: higher levels of blood pressure (SBP: 141 $\pm$ 19 and DBP: 87 $\pm$ 11 mmHg) in our study versus lower levels of blood pressure (SBP: about 120–130 and DBP: about 60–70 mmHg) in the study by Park et al. (2010). It is generally accepted that studying the effect of walking in forest environments on blood pressure in subjects with a higher blood pressure is more important than that in those with a lower blood pressure. Finally, the reduction in blood pressure after walking in a forest environment was greater in our subjects (mean SBP: from 141 to 134 mmHg, mean DBP: from 86 to 79 mmHg) than in those studied by Park et al. (2010) (the changes were very small).

Why do forest environments reduce blood pressure? To answer this question, we measured the levels of urinary adrenaline and noradrenaline in the present study and found that the urinary noradrenaline level after walking in the forest park was significantly decreased compared with that before the trip. In addition, the urinary adrenaline level also tended to decrease after walking in the forest park. It is well known that the sympathetic and parasympathetic nerve systems play a pivotal role in the regulation of blood pressure and that sympathetic nerve activity increases blood pressure, whereas parasympathetic nerve activity reduces blood pressure (Mena-Martín et al. 2006). Sympathetic nerve activity can be determined by measuring the levels of urinary adrenaline and/or noradrenaline (Frankenhaeuser 1975), and there are significant correlations between blood pressure and urinary adrenaline and noradrenaline levels (Mena-Martín et al. 2006). We previously found that walking in forest environments, but not urban environments reduced the urinary levels of adrenaline and/or noradrenaline in both male and female subjects (Li et al. 2008a, b, 2010). In addition, Park et al. (2010) reported that forest viewing and walking significantly reduced sympathetic nerve activity and increased parasympathetic nerve activity compared to performing the same activities in an urban environment, supporting our findings. Taken together, walking in forest environments may reduce blood pressure by lowering the activity of the sympathetic nerve and increasing the activity of the parasympathetic nerve.

Why factors in forest environments reduce blood pressure? We speculated that phytoncides (wood essential oils) from trees may have beneficial effects on blood pressure. Dayawansa et al. (2003) reported that cedrol (cedar wood oil) inhalation induced significant reductions in systolic and diastolic blood pressure compared to blank air together with an increase in parasympathetic activity and a reduction in sympathetic activity in humans. We previously found that exposure to a tree-derived phytoncide (Chamaecyparis obtusa stem oil) by inhalation significantly reduced the concentrations of urinary adrenaline and noradrenaline in males (Li et al. 2009). In fact, phytoncides, such as alpha-pinene, beta-pinene, tricyclene, camphene, and limonene were detected in higher concentrations in the forest park, but were not detected in the urban area of Tokyo (Li et al. 2010). Taken together, the above findings suggest that the natural fragrance of trees (phytoncides) partially contributed to the reduction in blood pressure observed during walking in the forest park in the present study.

Adiponectin (also called ARCP30 and AdipoQ) is a serum protein hormone that is specifically produced by adipose tissue. Studies have shown that lower than normal blood adiponectin concentrations are associated with several metabolic disorders, including obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome (Simpson and Singh 2008). In the present study, we found that walking in a forest park, but not an urban area significantly increased the level of blood adiponectin, suggesting that habitual walking in forest environments may have a beneficial effect on blood adiponectin levels. Previous studies on the effects of acute exercise on adiponectin levels have shown discrepancies. A systematic review of the effects of exercise on adiponectin level identified seven acute exposure exercise studies with conflicting findings (Simpson and Singh 2008). Some studies have shown no effect of acute exercise on adiponectin levels in normal or overweight individuals (Ferguson et al. 2004; Kraemer et al. 2003; Numao et al. 2008), but other studies have observed significant changes in adiponectin levels (Jürimäe et al. 2005, 2006). Chang et al. (2011) found that 60-min Yang's style Tai Chi exercise significantly increased the blood adiponectin levels of the middle-aged subjects (mean age 60.2 years). In the present study, there was no significant difference in physical activity between the walk in the forest park and that in the urban area suggesting that the differences in blood adiponectin levels between the two trips were not due to physical activity. Taken together, the above findings suggest that both walking (exercise) and the forest environment contributed to the increase in blood adiponectin seen in this study. However, further studies are necessary to explore why the forest environment increased the level of blood adiponectin.

The levels of DHEA and DHEA-S, the major secretory products of the adrenal gland, decline dramatically with age, concurrent with the onset of degenerative changes and chronic diseases associated with aging (Bjørnerem et al. 2004; Tsai et al. 2006). Epidemiological evidence in humans suggests that DHEA-S has cardioprotective, anti-obesity, and antidiabetic properties (Bjørnerem et al. 2004). In the present study, we found that walking in a forest park significantly increased the blood level of DHEA-S. Although walking in an urban area also increased the blood level of DHEA-S the increase was not significant, suggesting that habitual walking in forest environments has beneficial effects on blood DHEA-S. In males, it has been shown that acute exercise induces an increase in circulating DHEA-S level. Such changes are directly related to the type of exercise, its intensity and duration, and to the subject's training status (Tremblay et al. 2004). On the other hand, Tsai et al. (2006) reported that resistance exercise induced a significant decrease at post-48 h and post-72 h. In the present study, there was no significant difference in physical activity between walk in the forest park and that in the urban area suggesting that the difference in serum DHEA-S between the two trips was not due to physical activity. Antoni (2003) reported that a cognitive behavioral stress management intervention induced a reduction in urinary noradrenaline level (and reduced anxiety) and an increase in serum DHEA-S levels (and a reduced incidence of depressed moods). We also found that the increase in blood DHEA-S levels observed after the walk in the forest park was accompanied by a reduction in urinary noradrenaline levels in the present study. Moreover, Brzoza et al. (2008) reported that the DHEA-S concentration is negatively correlated with the level of anxiety and the level of depression in chronic urticaria patients and that the DHEA-S reductions observed in chronic urticaria patients might be a phenomenon secondary to psychological disturbance. Taken together, the above findings suggest that stress status affects the serum level of DHEA-S.

Measurements of the circulating concentration of NT-proBNP, a cardiac biomarker, are used to diagnose heart failure and left ventricular dysfunction (Seino et al. 2004). Increased NT-proBNP levels are independently associated with an increased risk of death and heart failure progression in several disorders, including chronic heart failure, acute coronary syndromes, and processes involving the right ventricle (de Lemos et al. 2003). In the present study, on the day before the urban area trip, the mean number of steps taken by the subjects was $5,951 \pm 3,341$, whereas on the walking day, it was $17,156 \pm 2,074$, which was significantly greater than that before the walking day. The serum NT-proBNP level after the walking ($39.6 \pm 29.3$ pg/ml, day 2) was significantly decreased compared with that before the walking ($52.1 \pm 39.4$ pg/ml), and this effect lasted for more than 1 week ($33.6 \pm 30.0$ pg/ml on day 8 and $38.0 \pm 30.0$ pg/ml on day 9 after the walking), suggesting that habitual walking exercise has beneficial effects on the circulating concentration of NT-proBNP. On the other hand, there was no significant difference in blood pressure between before ($142 \pm 20/88 \pm 13$ mmHg) and after ($141 \pm 19/87 \pm 11$ mmHg) the walking, suggesting that the change in the serum NT-proBNP level was independent of the change in blood pressure. Berent et al. (2009) reported that 4 weeks of moderate exercise reduced the NT-proBNP level, independent of the left ventricular ejection fraction, and improved physical fitness and blood lipid profiles. Physical training of moderate intensity significantly improves exercise capacity and reduces the serum level of NT pro-BNP in patients with chronic heart failure (Maria Sarullo et al. 2006). In addition, the blood NT-proBNP level of athletes was significantly lower than that of sedentary controls (Lippi et al. 2006). On the other hand, intense exercises such as running a marathon significantly increased the blood NT-pro-BNP concentration (Frassl et al. 2008; Scott et al. 2009), suggesting that the intensity of exercise affects the serum level of NT-pro-BNP.

As a limitation, the present study only showed the acute effects of walking in forest environments; therefore, a further study is necessary to investigate the chronic effects of walking in forest environments with longer-term and repeat studies.

In conclusion, habitual walking in forest environments may lower blood pressure by reducing sympathetic nerve activity (reducing urinary noradrenaline levels) and increasing parasympathetic nerve activity. In addition, habitual walking in forest environments may have beneficial effects on blood adiponectin and DHEA-S levels, and habitual walking exercise may have beneficial effects on blood NT-proBNP levels.

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**Conflict of interest** None declared.

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