Journal of
PHYSIOLOGICAL
ANTHROPOLOGY

Effects of Daily Walking on Subjective Symptoms, Mood and Autonomic Nervous Function

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Abstract It is well known that moderate exercise is beneficial to health. However, the effects of exercise on subjective symptoms in relation to mood and autonomic nervous function have not yet been fully examined. The purpose of this study was to investigate the effects of daily walking on subjective symptoms as well as on mood and autonomic nervous function in people who take no medication but have some general physical complaints. We assessed their symptoms by the Cornell Medical Index (CMI), and mood states by a profile of mood states (POMS) and a frontal alpha laterality ratio. Autonomic nervous function was evaluated by a supine rest basal level, reactivity to orthostatic challenge (physiological stimulus) and to a self-programmed videogame (psychophysiological stimulus) of heart rate (HR), heart rate variability (HRV), baroreflex sensitivity and blood pressure (BP). Repeated measures analysis of variance showed no significant group (control and walking group) ×time (pre- and post- walking period) interaction of CMI scores. In contrast, the A-H sub-scale (anger and hostility) of POMS and basal HR significantly decreased after a 4-week walking period in a walking group compared to a control group. Negative mood score of POMS reduced, and basal high-frequency component of HRV and reactivity to orthostatic challenge of baroreflex sensitivity increased marginally significantly compared to the control group. Multiple regression analysis revealed a significant contribution of A-H to the physical score of CMI, which showed a marginally significant reduction after the experimental period in the walking group. These results suggest that daily walking can improve mood states and shift autonomic balance to parasympathetic predominance, and may consequently contribute to the reduction of subjective symptoms. *J Physiol Anthropol 25(4): 281–289, 2006* http://www.jstage.jst.go.jp/browse/jpa2
[DOI: 10.2114/jpa2.25.281]

Keywords: daily walking, autonomic function, heart rate variability, CMI, POMS

Introduction

It is well known that moderate exercise contributes to health, and many people take or try to take exercise, not only to promote health, but to prevent or treat lifestyle-related diseases such as simple obesity, type 2 diabetes mellitus, essential hypertension, and coronary heart disease. Exercise usually provides psychological benefits as well as physical fitness, both of which are associated with autonomic nervous function (Rossy et al., 1998; Furlan et al., 1993; Dishman et al., 2000). Nabetani and Tokunaga (2001) reported the acute beneficial effects of short-term running on pleasant mood and anxiety. King et al. (1993) described the chronic beneficial effects of 12 months of exercise on anxiety and depression. Physically fit individuals exhibited a greater vagal control of the heart, which is related to a reduced risk of coronary heart disease (Rossy et al., 1998). Increased physical exercise levels in daily life also improve mortality and prolong a state of independence in the elderly (Oida et al., 2003). However, the effects of exercise on subjective symptoms have not yet been fully examined in relation to mood and autonomic nervous function. Since walking is such a simple, safe and easy exercise, we investigated the effects of daily walking on subjective symptoms as well as mood and autonomic nervous function in people who take no medication but have some general physical complaints whose cause can not be diagnosed.

Subjective symptoms were assessed by the Cornell Medical Index (CMI), which was created to collect a large body of pertinent medical and psychiatric data with minimal expenditure of time. Mood was assessed by a profile of mood states (POMS), which is a useful tool in periodically estimating moods, and by a frontal alpha laterality ratio (FALR), which is thought to be helpful in continuous assessment of emotional states (Field et al., 1998). The autonomic nervous system can be affected by various factors such as the cognitive process, motor activity, postural changes and mental state. Responses to laboratory stimuli may vary depending on the experimental conditions or stimulus modality. Therefore, we evaluated autonomic nervous function by a basal level, reactivity to orthostatic challenge (physiological stimulus) and to a self-programmed videogame task (psychophysiological stimulus) of heart rate (HR), heart rate variability (HRV), baroreflex sensitivity, and blood pressure (BP). The data were taken before and after a 4-week daily walking period, and analyzed in relation to the subject's exercise state.

Methods

Subjects

119 apparently healthy female college students were first screened by the Cornell Medical Index (CMI) questionnaire, and those with total CMI scores higher than the median (median of total CMI score=21) were selected as potential participants. We excluded those who exercised regularly two or more times per week for at least 30 min during the preceding 12 months and those who took medication on a regular basis. Finally, twenty students aged 20 to 22 who agreed to cooperate in this study were determined as subjects and participated in this experiment after providing written informed consent along with data on lifestyle, height, weight and age. All subjects were normotensive non-smokers and were randomly assigned into two groups: a walking group (n=12) and a control group (n=8). Those in the walking group were requested to take a daily rapid walk at a speed of around 6 km/h for 1 h 6 days per week without altering their other habitual activities during the study period. Subjects assigned to the control group were merely requested to maintain their routine physical activities during the study period. To ensure a level of daily activity, all subjects were requested to wear a lifestyle record machine (Lifecorder, Suzuken, Japan) which can record motor activities by acceleration sensors all day except while bathing, from the previous week to the end of the study period.

Experimental procedures

Data were collected twice, i.e., just before and after 4 weeks of daily walking for those in the walking group and on corresponding days for the control group. The two measurements were performed at about the same time on the same day of the week to minimize any circadian rhythm effect (Malliani et al., 1991). All subjects were asked to abstain from eating and drinking for at least 3 h before the measurements, and to retire by no later than midnight of the previous day. They were also requested not to exercise vigorously or to drink excessively the day before the measurements.

On each evaluation day, having previously completed CMI questionnaires to assess their subjective symptoms, subjects were asked to fill out POMS questionnaires to ascertain their mood state during the past week. Each subject sat upright in a reclining chair in front of a notebook computer which provided the videogame task. An occlusion cuff of appropriate size was attached to the left arm with a tonometry sensor on the radial artery at the wrist to measure blood pressure (BP) waveform (Colin, Japan). Then, with subjects fully reclined in the chair, disc electrodes were attached for chest electrocardiograms (ECG) with CM5 leads and for electroencephalograms (EEG) at F3 and F4 of the 10/20 system with corresponding earlobe references. A thermistor for detecting respiration was also attached just under one nostril. ECG, EEG, BP and respiration curves were recorded all during the measurements, along with error signals during the task period. Subjects were asked to remain still with eyes closed without falling asleep, and to avoid any disruptive movements of the head or hands throughout the session, except while performing the task.

After a basal recording was carried out in a supine posture in the reclining chair for 15 min, an orthostatic stimulus was then provided by manually raising the reclining chair from around 20° to 90°, and an upright sitting posture was maintained for 15 min, followed by 10 min of the videogame task. That task consisted of controlling a spaceship to stay within a track displayed on the notebook computer by manipulating a joystick. We set the velocity and direction of the spaceship motion to match those of the joystick movement, thus simplifying the task in order to give all subjects approximately the same mental loads regardless of their personality (Sakuragi and Sugiyama, 2004).

Data were stored on a DAT recorder (TEAC RD-111T, Tokyo, Japan) and on a personal computer equipped with a 12-bit analog-digital converter (ADTM-98, Canopus, Kobe, Japan) for subsequent offline analysis.

Analysis of psychological indices

CMI data were manually scored and summed for physical, mental and C.I.J. symptoms. C (cardiovascular system), I (fatigability), and J (frequency of illness) scores have been found effective to assess neurotic tendencies along with mental symptom scores. POMS scores were added up to generate six sub-scales: T–A (tension and anxiety), D (depression and dejection), A–H (anger and hostility), V (vigor), F (fatigue), and C (confusion). These total raw scores were converted into T-scores for parametric statistical analysis according to the POMS manual (Yokoyama and Araki, 1994). We also calculated the negative mood score (NMS) by averaging T–A, D, A–H, F, and C scores.

EEG data of the last 10 min of a 15-min supine rest period were digitized at a sampling frequency of 200 Hz on the personal computer and spectrally analyzed for 40.96 sec of every minute using fast Fourier transform (FFT) with a Hanning window. The alpha band was defined as 8 to 12 Hz. Relative alpha power was determined as a ratio of alpha power to total EEG power (4 Hz to 30 Hz). FALR was calculated by dividing the difference between right and left frontal relative alpha powers by the sum of these relative powers (F4−F3/F4+F3). FALRs were averaged for the last 10 min of the supine rest period to access the basal mood state. The right cerebral hemisphere is thought to play a major role in processing emotional information (Lang et al., 1990; Spence et al., 1996). Negative emotion was reported to be associated with right-sided activation in the frontal regions that causes a reduction in right frontal alpha power (Davidson et al., 1990). Consequently, FALR is thought to be helpful in assessing the emotional state continuously (Field et al., 1998). A more positive ratio is thought to indicate a more relaxed state, while a more negative one denotes a more stressed state.

Error signals were recorded when the spaceship deviated from the track. Error scores were manually calculated by adding up points when the spaceship deviated; when such a deviation lasted more than a second we added one more point for every second beyond the first. For example, if the spaceship remained deviated for 0.5 sec, we scored it 1 point, with 2 points scored for 1.5 sec, 3 points for 2.5 sec, and so on. Error scores were represented as points/min.

Analysis of autonomic indices

All autonomic variables were analyzed every 5 min. Ten-minute data just prior to the orthostatic challenge were averaged and considered as the basal activity at supine rest (basal level). The response to postural change was calculated by subtracting 5-min data just prior to the orthostatic challenge from 5-min data just after it (Orthostatic Challenge). The response to the videogame task was calculated by subtracting 5-min data just prior to the task from the initial 5-min data of the task period (Reactivity to Task).

ECG data were digitized at a sampling frequency of 1 kHz on a personal computer. After detecting every R-wave peak, consecutive R–R intervals on the ECG were calculated, excluding ectopic beats and abrupt discharges in R–R intervals. Spectral analysis was applied to the time series data of R–R intervals for each 5 min, using the maximum-entropy method (MemCalc Version 2.5, Suwa Trust) (Ohtomo et al., 1994). After calculating the power-spectral density, the magnitude of the power for HRV was obtained by measuring areas under the spectral density curves. The values were divided into two major bands, a low-frequency component (LF; 0.04–0.15 Hz) and a high-frequency component (HF; 0.15–0.4 Hz). The amplitude of each frequency band was obtained as twice the power magnitude and the square root thereof. We considered HF amplitude as an index of parasympathetic nervous function, and the ratio of LF to HF amplitude (LF/HF ratio) as a marker of sympathovagal balance (Malliani et al., 1991; Pagani et al., 1986). Mean heart rate (HR) was also calculated for every 5 min.

BP wave forms were also digitized at a sampling frequency of 1 kHz on a personal computer. Beat-to-beat systolic and diastolic peaks of the BP wave were detected and stored as time series data of systolic (SBP) and diastolic blood pressure (DBP), respectively. Spectral analysis was applied to the time series data of SBP for each 5 min, then LF and HF amplitudes of SBP variability were obtained in the same way as the spectral analysis of HRV. Thereafter, baroreflex sensitivity was calculated as the ratio of LF amplitude of HRV to that of SBP variability. Mean SBP and DBP were also calculated for every 5 min.

Body mass index (BMI) was calculated by dividing weight in kilograms by squared height in meters. The exercise level was presented as kcal per body surface area (in square meters) per day. Exercise levels at 0 week and at 4 weeks represent the average value of the week prior to the initial evaluation (0 week) and that of the 4 weeks of the study period (4 weeeks), respectively.

Statistical analysis

To compare the fundamental characteristics of the both groups, the student's *t*-test was applied to the psycho-physiological variables obtained at the beginning (week 0). Repeated measures analysis of variance (ANOVA) was applied to the variables obtained before and after the 4-week experimental period in the two groups to clarify interactions of group (walking and control)×time (pre and post-walking period) on subjective symptoms, mood state, and autonomic nervous function. The student's *t*-test and paired *t*-test were also applied to elucidate the main effect of time and group separately. Furthermore, we carried out multiple regression analysis based on a stepwise forward selection method in order to elucidate individual and/or cumulative contributors to A–H, NMS, basal HR, basal HF and baroreflex sensitivity response (ΔBaro) to orthostatic challenge, since they showed significant or marginally significant group×time interactions and were considered to be affected by daily walking. Factors contributing to the CMI physical scores were also analyzed since they were the main target of the present study, and the change in physical score was marginally significant in the walking group. BMI, alcohol consumption, and sleeping time were included in explanatory variables as lifestyle-related factors, since they might have made some contribution to the indices mentioned above. Consequently, POMS subscales, lifestyle-related factors (total energy consumption/kg, total energy consumption/m^2, amount of exercise/kg, amount of exercise/m^2, BMI, alcohol consumption, and sleeping time) and autonomic factors (basal level, response to orthostatic challenge, and reactivity to task of HF, LF/HF, and baroreflex sensitivity, and basal HR, DBP and SBP) were taken as candidate explanatory variables. POMS subscales were excluded from candidate explanatory variables when A–H and NMS were adopted as the dependent variables, and basal level, response to orthostatic challenge, and reactivity to task of HF, LF/HF were excluded from candidate explanatory variables when basal HF was adopted as the dependent variable. The F value of stepwise forward selection was set at 4.0 at each step. Statistical analysis was performed on a personal computer using Statview Ver. 5.0 (HULINKS), and differences with a probability value of less than 0.05 were considered significant.

Results

Fundamental characteristics

Rapid walking would correspond to activity of at least 0.07 kcal/kg (body weight)/min, and ordinary activities would correspond to that of about 0.03 to 0.05 kcal/kg/min. Sixty min

Table 1 Fundamental characteristics of the two groups

	Control group (n=7)		Walking group (n=8)		p-value
	Mean	SD	Mean	SD	
Age (years)	20.1	1.2	19.4	1.4	0.282
Height (cm)	159.0	6.2	158.0	5.2	0.740
Weight (kg) at 0 week	52.6	6.8	53.3	7.3	0.851
Weight (kg) at 4 weeks	52.5	6.8	53.7	7.2	0.746
BMI(kg/m^2) at 0 week	20.8	1.8	21.4	3.0	0.651
BMI(kg/m^2) at 4 weeks	20.7	1.9	21.5	3.0	0.552
Alcohol consumption (g/day) around 0 week	1.4	1.8	0.9	1.3	0.583
Alcohol consumption (g/day) around 4 weeks	2.0	3.5	2.9	3.4	0.607
Sleeping time (hours/day) around 0 week	6.1	1.0	6.6	0.6	0.223
Sleeping time (hours/day) around 4 weeks	5.7	0.7	6.6	0.8	0.035†
Basal Heart Rate (bpm) at 0 week	64.0	6.5	65.5 ┐	6.3	0.667
Basal Heart Rate (bpm) at 4 weeks	63.9	6.2	61.2 ┘*	6.7	0.437
Amount of exercise (kcal/m^2/day) around 0 week	121.6	52.4	113.6 ┐	43.6	0.754
Amount of exercise (kcal/m^2/day) during 4 weeks	122.5	39.5	197.6 ┘*	41.3	0.003††

BMI=body mass index; bpm=beats per minute
All fundamental characteristics were not significantly different between the two groups at the beginning of the experiment (at 0 week).
Sleeping time (hours/day) at 4 weeks and Amount of exercise (kcal/m^2/day) during the experimental period was significantly greater in walking group than in control group. $*=p<0.05$, $**=p<0.01$ based on paired t-test (0 week vs 4 weeks), $\dagger=p<0.05$, $\dagger\dagger=p<0.01$ based on t-test (control vs walking).

daily walking would consequently increase the amount of exercise by at least 1.2 (0.02×60) kcal/kg/day. Therefore, we did not consider subjects to have done enough daily walking throughout the experimental period whose average amount of exercise calculated from the lifecorder data did not increase by more than 1.2 kcal/kg/day. Finally, five subjects (four from walking and one from the control group) out of 20 were excluded for the statistical analysis because three subjects in the walking group did not meet the criteria mentioned above and the other two had caught cold and took medications during the experimental period.

Table 1 shows the fundamental characteristics of the walking and control groups. The two groups did not differ in age, height, weight or BMI either at the beginning or end of the study. Lifestyle factors such as alcohol consumption, sleeping time, and amount of exercise were not significantly different at the beginning of the study, while the average amount of exercise during the study period was, of course, significantly higher in the walking group. Sleeping time at the end of the study period was significantly different between the two groups, although there was no significant change from 0 week to 4 weeks in both groups. Psychological indices such as CMI, POMS scores, and FALR, as well as physiological indices such as HR, HRV, baroreflex sensitivity, and BP, including their reactivity to given stimuli, were not significantly different at the beginning of the study. We asked about their menstrual phase at week 0 and at week 4 since menstrual cycle is said to have some influence on mood or autonomic nervous function. Eleven out of 15 subjects were in the same phase at the two measurements. The other 4 were in various phases as follows: 1 was in the luteal phase at week 0 and menstrual phase at week 4; 1 was in the menstrual phase at week 0 and luteal phase at week 4 in the walking group; 1 was in the follicular phase at week 0 and luteal phase at week 4; and 1 was in the luteal phase at week 0 and follicular phase at week 4 in the control group. Therefore, we considered the influence of menstrual cycle would be limited and negligible.

Effects of walking on psychological indices

POMS score, FALR, CMI and Error score obtained at the beginning (0 week) and at the end (4 weeks) of the experimental period are shown in Fig. 1. Repeated measures ANOVA showed significant group×time interaction in A–H ($F(1,13)=4.704$, $p=0.0492$) and marginally significant group×time interaction in NMS ($F(1,13)=3.429$, $p=0.0869$). The student's t-test showed no significant difference at the beginning of the study but showed significant difference between the two groups after the 4-week period in T–A ($p=0.0324$) and D ($p=0.044$). In the control group, a paired t-test showed no significant difference between that at 0 week and that at 4 weeks, while in the walking group, T–A ($p=0.0415$), D ($p=0.0127$), A–H ($p=0.0129$) and NMS ($p=0.0057$) of POMS significantly decreased after 4 weeks of daily walking. FALR showed no significant inter- and intra-group difference. A marginally significant decrease of the physical score of CMI after 4 weeks of daily walking was observed ($p=0.0533$) in walking but not in the control group, though repeated measures ANOVA showed no significant group×time interaction. Mental and C.I.J. score showed no significant inter- and intra-group difference. Error scores significantly decreased at week 4 compared to those at week 0 in both groups ($p=0.0016$ in control, and $p=0.0090$ in walking group), but the changes of the scores were not significantly different between the two groups.

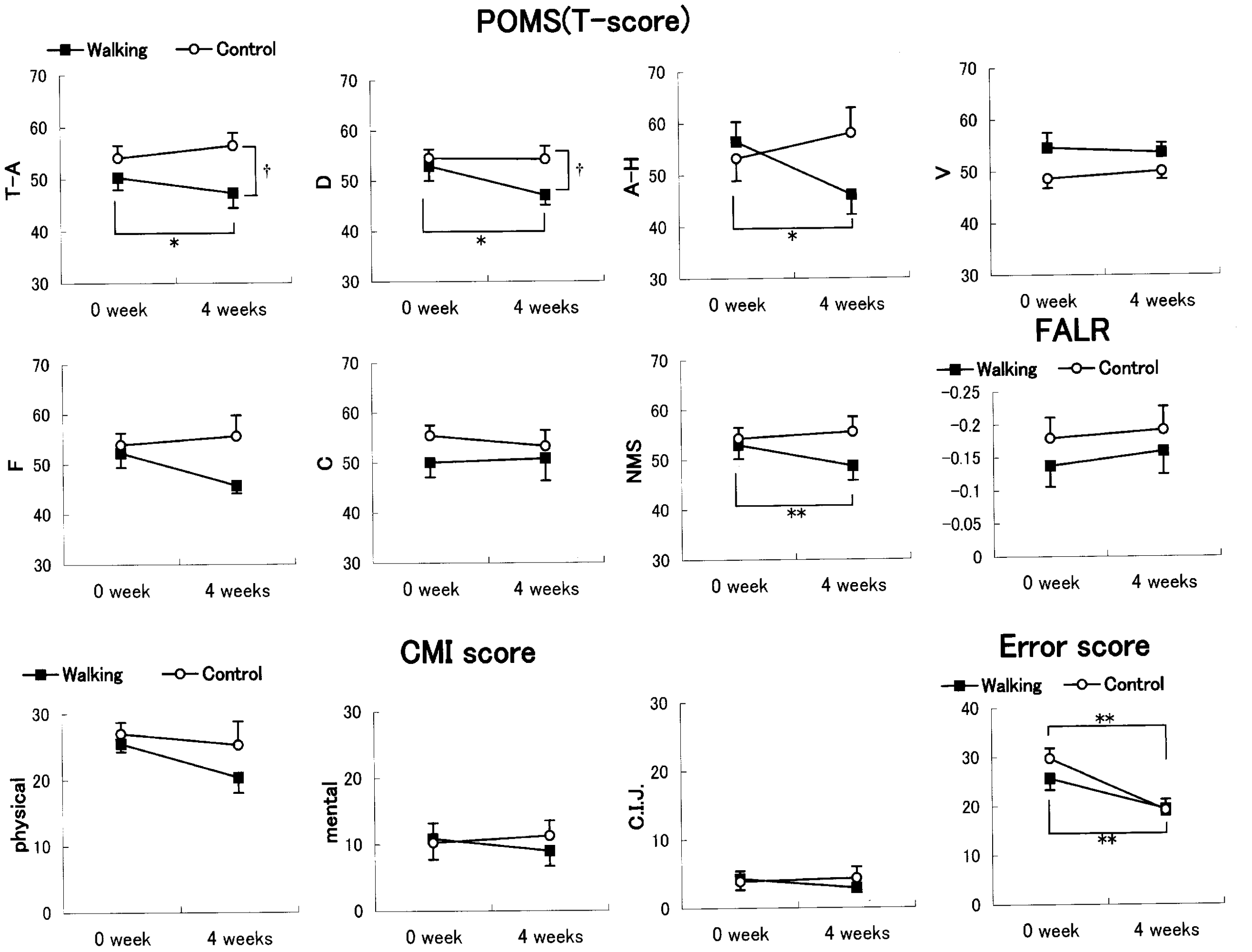

Fig. 1 POMS scores, FALR, CMI scores and Error scores at 0 week and at 4 weeks of the two groups. All values are represented as mean +/− S.E. ($n=7$ for control and $n=8$ for walking group). * and ** denote significant difference between 0 week and 4 weeks ($p<0.05$ and $p<0.01$, respectively). † denotes significant difference between control and walking group ($p<0.05$).

Effects of walking on autonomic indices

Figure 2 shows the supine rest basal level (Basal Level), the response to orthostastic challenge (Orthostatic Challenge), and the response to the videogame task (Reactivity to Task) of HR, HRV indices (LF, HF, LF/HF), Baroreflex sensitivity, and BP (SBP and DBP). Repeated measures ANOVA showed significant group×time interaction in basal HR (F(1,13)=5.781, $p=0.0318$) and marginally significant group×time interaction in basal HF (F(1,13)=4.169, $p=0.062$) and in baroreflex sensitivity response (ΔBaro) to orthostatic challenge (F(1,13)=3.367, $p=0.0895$). The student's *t*-test showed no significant difference at the beginning and at the end of the 4-week period between the groups. In the control group, a paired *t*-test showed no significant difference between 0 week and 4 weeks, while in the walking group, basal level HR significantly decreased, and the HR response to orthostatic challenge (ΔHR) and LF/HF reactivity to the task (ΔLF/HF) significantly increased after the walking period.

Results of regression analysis

Table 2 shows the results of multiple regression analysis based on the stepwise forward method. In the multiple regression analysis, the main contributor to A–H was the amount of exercise/kg (standard regression coefficient=−0.425, $p=0.0191$), while the main contributor to NMS was total energy consumption/kg (standard regression coefficient=−0.497, $p=0.0052$). The main contributors to basal HR were basal HF and basal baroreflex sensitivity (standard regression coefficient=−0.366, $p=0.0160$ for the former, and standard regression coefficient=−0.508, $p=0.0014$ for the latter) and the main contributor to basal HF was the amount of exercise/m^2 (standard regression coefficient=0.438, $p=0.0154$). The main contributor to the baroreflex sensitivity response (ΔBaro) to orthostatic challenge was basal baroreflex sensitivity (standard regression coefficient=−0.870, $p<0.0001$). The main contributor to the physical scores of CMI was A–H (standard regression coefficient=0.593, $p=0.0006$). BMI, alcohol consumption, and sleeping time were not selected as possibly significant explanatory variables by the stepwise forward method.

Respiratory frequencies

Respiratory frequencies of all subjects exceeded 10 cycles per min (cpm) (i.e., over 0.15 Hz) throughout the experiments.

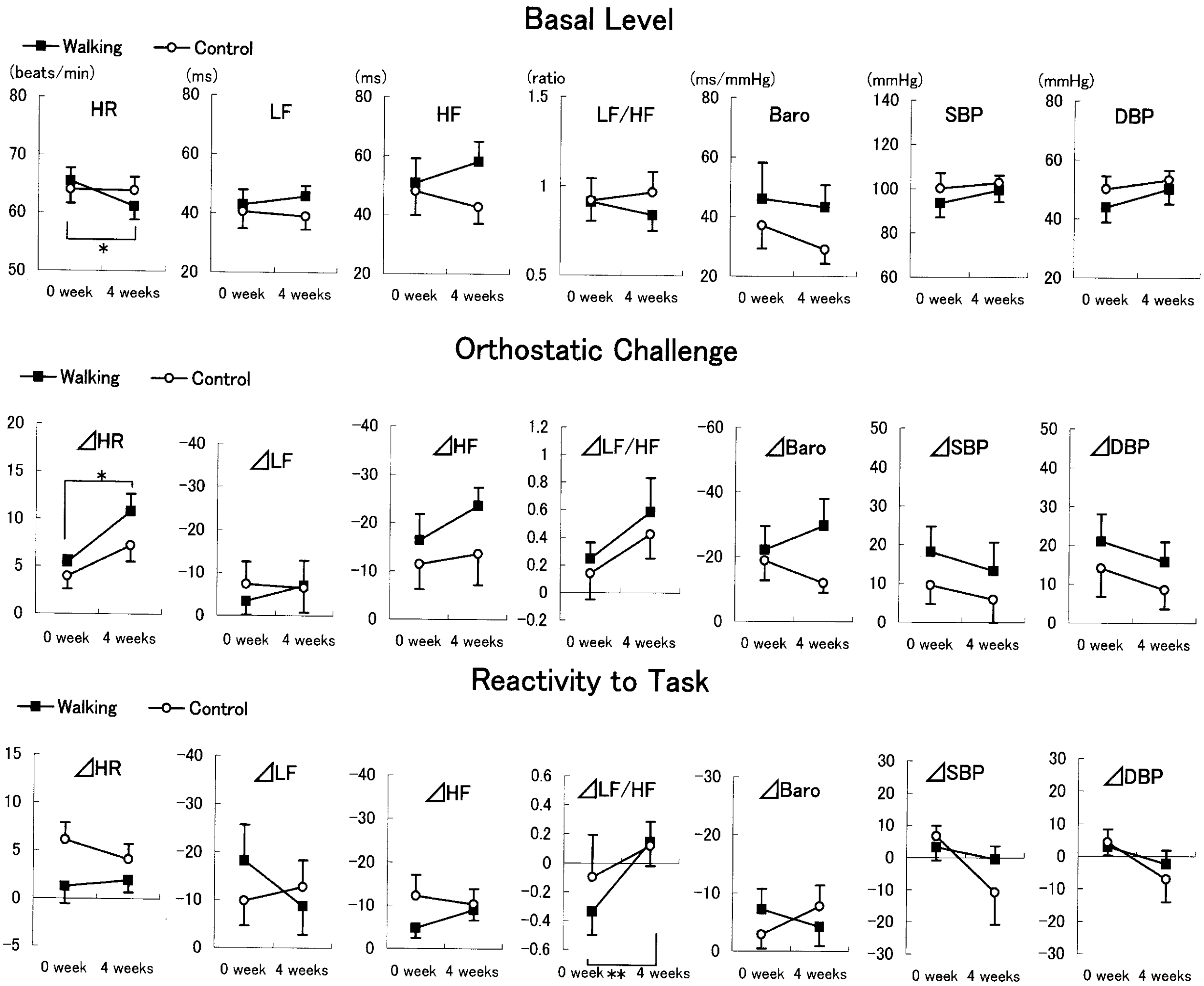

Fig. 2 Supine rest basal level (Basal level), response to orthostatic challenge (Orthostatic Challenge) and reactivity to videogame task (Reactivity to Task) of: heart rate (HR), low-frequency component (LF), high-frequency component (HF), ratio of LF amplitude to HF amplitude (LF/HF) of heart rate variability (HRV), baroreflex sensitivity (Baro), systolic and diastolic blood pressure (SBP and DBP) at 0 week and at 4 weeks of the two groups. All values are represented as mean +/− S.E. ($n=7$ for control and $n=8$ for walking group). * and ** denote significant difference between 0 week and 4 weeks ($p<0.05$ and $p<0.01$, respectively).

Table 2 Results of multiple regression analysis

Dependent variables	R^2	R^2 adjusted for the degrees of freedom	explanatory variables	standard regression coefficient	p-value
A-H subscale of POMS	0.181	0.152	Amount of exercise/kg	−0.425	0.0191
NMS of POMS	0.247	0.220	Total energy consumption/kg	−0.497	0.0052
Basal heart rate	0.496	0.458	Basal HF amplitude	−0.366	0.0160
			Basal baroreflex sensitivity	−0.508	0.0014
Basal HF amplitude of HRV	0.192	0.163	Amount of exercise/m^2	0.438	0.0154
Baroreflex sensitivity response to orthostatic challenge	0.756	0.748	Basal baroreflex sensitivity	−0.870	<0.0001
Physical score of CMI	0.351	0.328	A-H subscale	0.593	0.0006

Abbreviations; A-H, anger-hostility; POMS, profile of mood states; NMS, negative mood score; HF, high frequency; HRV, heart rate variability; CMI, Cornell medical index. Explanatory variables were selected by stepwise forward method.

Therefore, respiratory frequencies did not overlap with the frequency domains of the LF component. Those frequencies significantly increased during the task period compared to the basal level in both groups at week 0 and at week 4 (14.6±3.1 at basal and 19.5±2.1 during the task in the control, 14.6±2.9 and 18.5±2.0 in the walking group at week 0, and 15.6±2.4 at basal and 19.4±2.9 during the task in the control, 15.1±2.3 and 17.5±3.0 in the walking group at week 4; represented as mean (cpm)±SD). Respiratory frequencies during the task at week 4 were not significantly different from those at week 0 in both groups.

Discussion

Repeated measures ANOVA showed significant group (control and walking group)×time (pre- and post-walking period) interaction in A–H and marginally significant group×time interaction in NMS; that is, the change from A–H at the beginning to that at the end of the study was significantly different between walking and control groups, and the change of NMS was possibly different between the two groups. The paired *t*-test showed a significant reduction of T–A, D, A–H and NMS after 4 weeks of daily walking in the walking group. Comprehensively, mood is considered to be improved by 4 weeks of daily walking (consistent with previous findings: Moses et al., 1989; King et al., 1993; Nabetani and Tokunaga, 2001). Moses et al. (1989) reported that positive psychological effects such as a reduction in tension/anxiety were observed in subjects who exercised moderately, but not in those with strenuous exercise or attention-placebo. In this respect, our walking program would be suitable for the improvement of mood states. In the present study, repeated measures ANOVA showed no significant group×time interaction in CMI scores, that is, changes from subjective symptoms at the beginning to those at the end of the study were not significantly different between the walking and control group, though the paired *t*-test showed a marginally significant decline of physical symptoms assessed by a CMI questionnaire after 4 weeks of daily walking in the walking group. The regression analysis revealed A–H as a significant contributor to the physical score of CMI, and A–H was significantly decreased after 4 weeks of daily walking. Therefore, subjective physical symptoms would be consequently reduced by adequate daily physical activity, but the period in this study might not have been long enough to reduce subjective symptoms. The factors underlying subjective physical symptoms are diverse and have major individual differences, which might have confounded the analysis.

There was no significant improvement of FALR in either group, despite the fact that POMS indicated a significant improvement in mood. FALR might not have been suitable to assess the persistent effect on mood since it was primarily designed to assess momentary mood states, whereas POMS could evaluate mood states over a period of days.

Autonomic nervous function was evaluated using a spectral analysis of HRV and baroreflex sensitivity as well as HR and BP. HRV spectral analysis is a useful tool in evaluating autonomic nervous function non-invasively (Akselrod et al., 1985; Langewitz et al., 1991; Montano et al., 1994; Pagani et al., 1986; Pagani et al., 1991; Pomeranz et al., 1985). HRV can be divided into two main components by spectral analysis, i.e., HF which corresponds to respiratory sinus arrhythmia (RSA) and reflects parasympathetic nerve activity, and LF which corresponds to Mayer wave-related sinus arrhythmia and relates to both sympathetic and parasympathetic nerve activities (Akselrod et al., 1985; Berger et al., 1989; Pomeranz et al., 1985; Pagani et al., 1986; Montano et al., 1994). Baroreflex sensitivity is also considered to be an index of autonomic nervous function and is known to decrease under stress (Steptoe et al., 1989; Conway et al., 1983). The autonomic nervous system can be modulated by various factors, such as postural change, limb immersion in cold water, cognitive processes, motor activity and mental state. To examine not only autonomic balance but also reactivity, we loaded two types of stimulus, physiological (orthostatic challenge) and psychophysiological (videogame task), and evaluated reactivity to both stimuli as well as basal level.

The results of the repeated measures ANOVA suggest that the changes from basal HR at week 0 to those at week 4 were significantly different between the walking and control groups, and the changes in basal HF were possibly different between the two groups. The regression analysis study revealed that basal HF and basal baroreflex sensitivity were the significant main contributors to basal HR. Amount of exercise /m^2 was supposed to be a main contributor to basal HF elevation, which is consistent with previous findings (Rossy et al., 1998; Furlan et al., 1993). Thus, 4 weeks of daily walking possibly shifted the autonomic balance to parasympathetic predominance. Previous reports described a negative correlation between HF and the risk of ischemic heart diseases, i.e., the higher the HF, the lower the risk. From this aspect, daily walking may be effective in enhancing health but a period of 4 weeks may not be enough.

An orthostatic challenge is known to induce parasympathetic withdrawal with simultaneous sympathetic activation, which would be reflected as an HF reduction and an LF/HF augmentation, respectively. Repeated measures ANOVA showed marginally significant group×time interaction in baroreflex sensitivity response (ΔBaro) to orthostatic challenge, that is, the change from baroreflex sensitivity response to orthostatic challenge at week 0 to that at week 4 was possibly different between the two groups. In the control group, The paired *t*-test showed no significant difference between those at week 0 and those at week 4, while in the walking group, HR response to orthostatic challenge (ΔHR) significantly changed. These findings may indicate some improvement of autonomic reactivity to physiological stimuli.

The videogame task is known to induce parasympathetic withdrawal and/or sympathetic activation, which would be reflected as an HF reduction and/or an LF/HF augmentation, respectively. Repeated measures ANOVA showed no significant group×time interaction. In contrast, the paired *t*-test showed the significantly increased reactivity of LF/HF amplitude to the task after 4 weeks of daily walking. Error scores significantly reduced after the 4-week period of study in both groups, and the change was not significantly different between the groups. This error score reduction would possibly be due to an adaptation effect. Therefore, we suspected that the result of repeated measures ANOVA may be confounded by the adaptation effect. Hence, these findings may indicate some improvement of autonomic reactivity to psychophysiological stimuli. We previously reported that a videogame task would require a cognitive process and motor activity which would influence the autonomic nervous system considerably more than the mental state (Sakuragi and Sugiyama, 2004), i.e., reactivity to the task would reflect autonomic reactivity rather than mental stress induced by the task. Consequently, sympathetic activation, which corresponds to an LF/HF increase, may reflect the appropriate autonomic reaction to perform the task more adequately. Such increased reactivity may lead to improved reactions to the naturally occurring events of daily life, which in turn may consequently contribute to a reduction in subjective symptoms.

Although 4 weeks of daily walking possibly shifted the autonomic balance to parasympathetic predominance, no autonomic indices showed a significant contribution to A–H, NMS or physical scores of CMI. Correspondingly, the daily walking improved the mood state, but mood indices showed no significant contribution to the autonomic indices which were supposed to be affected by the daily walking. The autonomic function and mood may each be affected through a separate pathway in a different manner by daily physical activity. Subjective physical symptoms assessed by CMI as well as mood state are related to a variety of psychological and/or physiological factors. Unmeasured influences on cardiovascular responses may vary appreciably between individuals (Manuck et al., 1990). Thus, various factors may confound the correlation between psychological indices and cardiovascular autonomic indices, i.e., there may exist multiple dimensions of individual differences in both psychological and cardiovascular reactivity.

Conclusion

We examined the effects of 4 weeks of daily walking on subjective symptoms in relation to mood and autonomic nervous function. A–H evaluated by a POMS questionnaire significantly decreased after 4 weeks of daily walking and A–H score significantly contributed to physical symptoms assessed by a CMI questionnaire, though the change of physical score was not proved to be significantly different between the groups. The autonomic cardiovascular indices indicated a shift of autonomic balance to parasympathetic predominance and possibly increased reactivity, and the amount of exercise/m^2 contributed to the elevation of basal HF, which reflects parasympathetic activity. The autonomic indices showed no significant contribution to A–H, NMS and physical scores. Thus, we concluded that exercise shifts the autonomic balance to parasympathetic predominance and improves the mood state differently, both of which may make some contribution to the reduction of subjective general physical symptoms. Further investigation is needed to clarify the mechanism underlying the improvement of mood and autonomic function by habitual walking exercises.

Acknowledgments We are grateful to our students, C. Ogasawara, N. Kotake, H. Hasegawa, and S. Makino, for their valuable cooperation in the study.

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Received: December 16, 2005
Accepted: June 13, 2006

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