Influence of high ambient temperatures on the physiological responses and body sway in healthy young adults after quickly standing

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INFLUENCE OF HIGH AMBIENT TEMPERATURES ON THE PHYSIOLOGICAL RESPONSES AND BODY SWAY IN HEALTHY YOUNG ADULTS AFTER QUICKLY STANDING

Running head: INFLUENCE OF HIGH TEMPERATURE AFTER STANDING

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Abstract

This study was aimed to compare the variations in cerebral oxygenation, blood pressure and center-of-foot pressure after standing from sitting and supine positions at normal (22 °C) and high (32 °C) room temperatures. Thirty young adults stood up from a resting posture (sitting or supine position) and kept the static standing posture for 90 sec. Meanwhile, their center-of-foot pressure (COP), blood pressure, and cerebral oxygenation kinetics were measured in continuity. The change of the frequency domain low-to-high frequency (LF/HF) ratio of the R-R interval before and after standing from a supine position was significantly higher than that from a sitting position under both temperature conditions. Blood pressure as well as total and oxygenated hemoglobin levels decreased immediately after standing up and the ratio of blood pressure change when moving from a supine position to standing at high room temperature was the largest as compared with the other conditions. Total hemoglobin (Hb) volume was found to temporarily decrease after standing and required 22-24 sec to recover when the subject started from the sitting position and 33-36 sec when the subject started from the supine position. Cerebral oxygenation kinetics tended to be larger under high, rather than normal, temperature conditions. All COP parameters after standing were significantly larger in the high temperature condition than in the normal temperature condition. Body sway after standing was larger in the high temperature condition than in the normal temperature condition and after standing from a supine position than from a sitting position. In conclusion, cerebral oxygenation kinetics and blood pressure measured after the subject moved to the standing position changed dramatically under high temperature conditions, and variations in this parameter may influence body sway.

Key words: near infrared spectroscopic, electrocardiogram, posture change, body sway

INTRODUCTION

There is a possibility that cerebral symptoms, such as dizziness, lightheadedness, or presyncopy, occur even in healthy people by quickly standing from a sitting or supine posture to a standing position (Mehagnoul-Schipper et al., 2001). These symptoms are caused by a temporary decrease in cerebral blood volume, in spite of the concomitant action of blood pressure regulatory mechanisms (Andre, et al., 1989; Steinberg, 1980; Wieling and Shepherd, 1992).

Halar and Bell (1998) reported that when healthy people quickly stood up from sitting or supine positions, a blood volume of about 500-700 ml moved from the heart to the lower body (i.e. lower limbs or abdomen). Blood pressure is regulated mainly by the baroreceptor reflex, renin-angiotensin system, and aldosterone release. In particular, the blood pressure regulation of various organs by the baroeceptor reflex can response rapidly to prevent orthostatic hypotension and fainting. In this case, heart rate and blood pressure increase temporarily after rapid standing (systolic pressure: over 30 mmHg, diastolic pressure: over 15 mmHg) (Halar and Bell, 1998).

If blood pressure regulation is insufficient, because of a temporal decrease of the systolic pressure and a decrease of circulating blood volume due to pooling of venous blood, cerebral symptoms such as dizziness and lightheadedness may occur (Mehanoul-Schipper et al., 2001). A temporary decrease of oxygen supplied to the cerebrum during orthostatic hypotension may disturb body control while standing.

The degree of orthostatic hypotension can be examined by sympathetic hyperactivity, blood pressure variation, and cerebral blood volume change. When changes in these volumes are large, the influence of orthostatic hypotension will also be large, and lightheadedness when standing may reflect postural sway. These changing volumes will increase with external factors. For example, greater posture changes will cause more changes in blood distribution or increased dilation of blood vessels. For example, standing from a supine position may influence blood distribution more than standing from a sitting position, and high room temperatures may result in peripheral vasodilatation.

As stated above, the symptoms of orthostatic hypotension may be most attributed to a decrease of blood pressure with a temporal decrease of venous return volume. We, therefore, assumed that a temporary reduction in cerebral perfusion immediately after standing becomes larger because of peripheral vasodilatation and increases in precapillary circulation in the higher room temperature condition.

In addition, sympathetic nerve activity will become hyperactive to control the blood pressure. Cerebral blood volume is insusceptible to the influence of slightly decreasing blood pressure. However, Halar and Bell (1998) reported that it decreased when systolic pressure decreased temporarily over 20-30 mmHg.

The variation in cerebral oxygenation and blood pressure while changing posture has been examined by many researchers (Harms et al., 2000; Kawaguchi et al., 2001; van Lieshout et al., 2001) with an emphasis on people with orthostatic symptoms and the elderly. A phenomenon similar to that described above also occurs in young healthy adults, and the variation in cerebral oxygenation affect body posture control just after standing up (Mehagnoul-Schipper et al., 2000; Kawaguchi et al., 2001). Few have examined the effects of change on postural sway in previous studies. Therefore, it will be necessary to examine whether or not quick changes in posture and differences in room temperature affect physiological responses and reflect body sway.

This study was aimed to compare the variation in autonomic activity, blood pressure, and cerebral oxygenation and the center-of-foot pressure after active standing from the sitting and supine positions in both normal and high room temperatures using healthy young Japanese adults.

METHODS

Subjects

The subjects were thirty healthy young adults (15 males, age: 20.9 ± 2.3 years, height: 171.6 ± 5.2 cm, weight: 68.2 ± 6.6 kg, 15 females, age: 20.9 ± 1.6 years, height: 162.3 ± 7.0 cm, weight: 53.9 ± 5.5

kg) not habitually using medicines, such as depressors. Written informed consent was obtained from all subjects after a full explanation of the experimental purpose and protocol. This experimental protocol was approved by the Ethics Committee (Kanazawa University Health and Science Ethics Committee).

Materials

1) Stabilimeter

An Anima's stabilimeter (G5500, Japan) was used for the measurement of the center-of-foot pressure. This instrument can calculate the COP of vertical loads from values of three vertical load sensors that are put on the peak of an isosceles triangle on a level surface. Data were recorded at a sampling frequency of 20 Hz.

2) Cerebral tissue oxygenation monitor

NIRS instruments (PSA-IIIN, Biomedical Science, Japan) can evaluate cerebral tissue oxygenation while changing posture (du Plessis, 1995). The NIR instruments consist of a probe and a computerized control system (Nagashima et al., 2000). The probe contains a light source filtered at 700, 750 and 830 nm. Two optical detectors were placed at 15 and 25 mm from the light source. The transmitted light from the probe was then either absorbed or scattered within the tissue. The scattered light was delivered via two fiber-optic light detectors to a photomultiplier every 0.1 sec. The mean depth of the measurement in the tissue has been confirmed as half the distance between the light source and the detector (Hamaoka et al., 1996; Hamaoka et al., 2003). According to this hypothesis, the measured mean depth of the PSA-IIIN was approximately 7.5 mm. The PSA-IIIN used three wavelengths and two optical detectors to analyze the absorbance of the three wavelengths based on the Beer-Lambert Law and to measure tissue oxygen saturation (StO_2) and total tissue hemoglobin (Total Hb) (Nagashima et al., 2000). Nagashima et al. (2000) confirmed the validity and the trial-to-trial reliability of tissue oxygenation measured by PSA-IIIN,

and many researchers have measured tissue oxygenation kinetics using this NIRS instrument (du Plessis, 1995). Data were recorded at a sampling frequency of 10 Hz.

3) Heart rate monitor

A heart rate monitor (MINATO, Japan) was used for the measurement of the ECG data (R-R interval) to evaluate the autonomic nerve system change. The signal from 12 bipolar leads was measured continuously during the experiment, converted from analog to digital data, and recorded on a digital recorder (DRF-1, TEAC, Japan) at a sampling frequency of 100 Hz.

4) Blood pressure

Arterial pressure of the finger was measured with the volume-compensation method (Radia press RBP-100, KANDS, Japan). Averages of systolic and diastolic blood pressure values measured by noninvasive continuous blood pressure monitoring devices were calculated every second. The measurement principle of this device is almost the same as the commonly used Portapres (Finapres Medical System) although the algorithms of pressure correction are different.

This device determines absolute values of arterial blood pressure from light volume variation corrected by calibration values, which are the ratio of the pressure pulse wave (standard values) to the photoelectric volume pulse wave. After measuring blood pressure at the upper arm during rest by the oscillometric method, this device detects variations of blood hemoglobin with blood flow volume by optical wavelength irradiation (640nm) to the skin from an emission sensor attached to the ear lobule while providing light pressure (about 100 mmHg). Emission sensors consist of a photoelectronic sensor and a body motion sensor. The former detects reflected light volume variation in the blood vessel from optical wavelength irradiation (640nm), and the latter detects it on a surface via a photoelectronic sensor. It is designed to eliminate measurement errors that result from changes in the photoelectric volume pulse wave

by body motion. Nakata et al. (2008) reported a high trial-to-trial reliability of blood pressure measured by this device and close agreement with the Portapres during exercise.

Experimental procedure

The experimental design was a within-subject design whereby the subjects participated in all experimental conditions (room temperature: normal, 22°C and high, 32°C; body position during rest: sitting and supine). Each subject was measured during the same day with an interval of 30 min resting at 22°C between trials, and the trials were performed using counter balance in terms of the order of the conditions. The humidity was kept at 30% in all conditions.

A NIRS probe was attached to the center of the subject's forehead, and the 12 lead bipolar electrode was attached to the subject's chest. Cerebral oxygenation was measured for 1 min in a sitting position in a normal temperature room. The NIRS probe was left attached until the end of all experimental conditions. In any condition, the mean value of cerebral oxygenation in a sitting position in a normal temperature room was set as the criterion value (100%). The changes in continuous blood pressure were measured at the ear lobule with the Radia press RBP-100. During active standing with the measurement of COP, cerebral oxygenation was continually measured.

The subjects entered the environmental chamber kept at a normal or high temperature and remained resting in either a sitting or a supine position for 10 min in order to adapt to the room environment. Then, they stood up and their COP was measured in an upright posture for 90 sec. They were instructed to respire naturally, not to do a Valsalva maneuver, and to stabilize their body posture. Moreover, to reduce the influence of the muscle pump, they stood up so as not to overstrain their muscles. Following this procedure, each experimental condition (room temperature and body position during resting conditions) was repeated three times. After the measurements in all body position conditions finished in one environmental chamber, the subject was moved to another environment.

A switch was set to the lateral region of the thigh. A sensor was switched when the subject stood vertically on the floor, and the COP was then measured. Event signals were also entered into the NIRS recorder at the same time.

COP, cerebral oxygenation, and heart rate parameters

A total of eleven COP parameters with high trial-to-trial and day-to-day reliabilities were selected from the following four domains: distance (2 parameters), velocity (3 parameters), area (2 parameters), and the amplitude distribution (4 parameters). The details of these parameters are shown in Table 1. The cerebral oxygenation parameter selected in this study was Total Hb.

The autonomic nervous functions in each condition were estimated by spectral analysis for the variability of R-R intervals from the ECG after standing. Frequency components of the R-R interval time series were divided into high frequency (frequency band: 0.15-0.45 Hz) and low frequency (frequency band: 0.05-0.15 Hz) components. The spectral density was calculated by fast fourier transform for R-R intervals time series filtering hamming window function. LF/HF ratio was calculated from the spectral density area in each frequency band for HF and LF.

********* Table 1 near here *********

Data analysis

The cerebral oxygenation of each subject was converted into a relative value based on the mean during resting for each condition. The trial-to-trial reliabilities of the COP and the change ratio of the cerebral oxygenation before and after standing up were examined by using an intra-class correlation coefficient (ICC). The reliability of the time-series change of the cerebral oxygenation was examined by the cross correlation coefficient. The mean differences in the COP after standing up, the variation of the

cerebral oxygenation while standing and changing of LF/HF ratio before and after standing between conditions (room temperatures and body positions during rest) were examined by using two-way ANOVA. Tukey's HSD test was used for the multiple comparisons. The recovery time of the Total Hb decrease after standing up was calculated in each condition. A probability level of 0.05 was considered as indicative of statistical significance.

RESULTS

The ICC of the COP and LF/HF ratio between trials was over 0.75 (ICC = 0.76 - 0.83) in all conditions. The ICC of the change ratio of the cerebral oxygenation before and after standing up was over 0.70 (ICC = 0.72 - 0.78) in all conditions. There were insignificant trial-to-trial differences in the COP and the change ratio of the cerebral oxygenation in all conditions. Moreover, the cross-correlation coefficient of the time-series change of the cerebral oxygenation and blood pressure was over 0.8 (r_{xy} = 0.82 - 0.93). Therefore, the data of the third trial, which was exposed for a long time, was used in the subsequent analysis.

Figure 1 shows the changing ratio of the LF/HF ratio before and after standing up in all conditions. There were significant differences between the body rest positions, and the changing ratio of LF/HF after standing up from a supine position was significantly higher than that from a sitting position.

********* Figure 1 near here *********

Figure 2 shows the average time series change of all subjects in the frontal total, oxygenated, and deoxygenated hemoglobin in each body position and at room temperatures. The cerebral oxygenation by NIRS was measured based on the mean value in the sitting position in a normal temperature room. All parameters decreased more temporarily after standing up from the supine position under high room

temperature compared with the other conditions.

In both temperature rooms, the recovery of Total Hb and Oxy-Hb after standing up from a sitting position took about 25 sec (normal temperature: 22.0 ± 10.3 sec, high temperature: 23.6 ± 11.9 sec) but took about 35 sec from a supine position (normal temperature: 33.4 ± 13.2 sec, and high temperature: 35.2 ± 12.2 sec).

********* Figure 2 near here *********

Figure 3 shows the results of two-way ANOVA (room temperature × body position during rest) for the average values of the standard deviation in total Hb while standing (90 sec) among conditions. They were significantly larger in the high temperature room than in the normal temperature room (normal temperature: sitting position; 5.6 ± 3.2 %, supine position; 7.6 ± 4.2 %, high temperature: sitting position; 13.3 ± 5.4 %, supine position; 13.8 ± 6. 5%).

********* Figure 3 near here *********

Figure 4 shows the average time series change of all subjects in blood pressure and heart rate in each body position and at room temperatures. Heart rate increased after standing up in all conditions, and the response speed tended to be faster in rising from sitting as compared with from the supine position. Blood pressure decreased temporarily after standing up in all conditions but tended to be larger in rising from the supine position than from the sitting position.

********* Figure 4 near here *********

Table 2 shows the results of the two-way ANOVA (room temperature × body position during rest) for the COP parameters after standing up. There were significant differences in the room temperature factor in all parameters. All COP parameters after standing up significantly changed more at high room temperature than at normal room temperature. The COP parameters, except for the root mean square, standard deviation of the Y-axis, and two area parameters, were significantly larger when standing from a supine than from a sitting position.

********** Table 2 near here **********

DISCUSSION

The COP, cerebral oxygenation, ECG, and blood pressure during rest and after standing up were measured, and the measurements were repeated three times for two room temperatures and two body positions during rest. According to Currier (1990), an ICC of over 0.70 is judged to be highly reliable. The trial-to-trial reliability of parameters is, therefore, considered to be high. Moreover, although it took over 30 min to finish the three trials, there was an insignificant difference in the COP parameters and cerebral oxygenation between the first and third trials. Because the subjects adapted to the condition (room temperature and body positions) during rest from the above, the experimental setting in this study is judged to have been valid.

The physiological mechanism of orthostatic hypotension has been explained by many researchers. The blood pressure decreases temporarily with the decrease of stroke volume, because the venous return volume decreases due to the movement of circulating blood to the lower body after standing up (Halar and Bell, 1998). Healthy people do not have a large stagger of body posture or syncope, because blood pressure regulation for them acts normally (Steinberg, 1980). However, even healthy people often feel cerebral symptoms such as dizziness, lightheadedness, or presyncopy caused by a temporary decrease of blood pressure (Mehagnoul-Schipper et al., 2001). When the outside air temperature is high, vasodilation

controlled by the thermoregulation system occurs and peripheral blood flow volume, including skin blood flow, increases. We, therefore, hypothesized that the cerebral circulation volume temporarily decreases as a result of gravity after standing up. Moreover, this symptom may occur more readily when standing up from a supine position than from a sitting position.

The LF/HF ratio was found to increase after rapid transition from a sitting or supine position to an upright position. In addition, the changing ratio of LF/HF before and after standing was significantly greater after standing from a supine position than from a sitting position. This means that the power spectrum component in the LF band, which reflects sympathetic hyperactivity, increased after standing, and this tendency was larger after standing from the supine position than from the sitting position. It is inferred that the increasing LF/HF ratio after standing results from the actions of the blood pressure regulation system (Boulos et al., 1996). The LF/HF ratio after standing up from the supine position is larger than from sitting position because blood pressure regulation depends on the amplitude of bodily transition. However, there was no significant difference between room temperature conditions. If according to the above hypothesis, blood pressure experienced a greater decrease temporarily at high temperatures. But the result may not accept the hypothesis, and blood pressure regulation may not act appropriately for increasing room temperature.

The present results suggested that body sway (COP) after standing up is larger at high temperatures than at normal temperatures and in standing up from a supine position rather than from a sitting position. That is, the findings supported the above hypothesis. Many previous studies have examined variations in cerebral oxygenation and blood pressure while changing posture, especially using people with orthostatic symptoms or the elderly (Harms et al., 2000; Kawaguchi et al., 2001; Kusano et al., 2000). However, few studies have examined the influence of the temporal decline in cerebral blood volume on bodily sway after changing posture to the standing position.

The findings in previous studies regarding the physiological responses of the cerebral

oxygenation available after changing posture may be summarized as follows: after standing up, the blood pressure and heart rate increase and the oxygenated hemoglobin and Total Hb decrease, whereas deoxygenated hemoglobin increases (Colier et al., 1997; Kawaguchi et al., 2001; Mehagnoul-Schipper et al., 2000; Tanaka et al., 2003). Moreover, because oxygenated hemoglobin decreases just after standing up, the auto-control of the cerebral blood circulation has difficulty compensating for the rapid posture change. Therefore, the imbalances in the supply and demand for oxygen may produce cerebral symptoms, such as dizziness or lightheadedness.

The present results regarding the change in the total Hb just after standing up agreed with those in previous studies (Colier, et al., 1997; Kawaguchi, et al., 2001; Kusano, et al., 2000; Madsen et al., 1998; Tanaka, et al., 2003). The temporary decrease of total Hb immediately following standing up was larger at high temperatures as compared with normal temperatures, but this decrease in volume was influenced more heavily by the initial resting position before standing rather than the temperature conditions. It was reported that the decrease of blood pressure by rapid standing recovers to a fixed level after approximately 20-30 sec by the blood pressure regulation system in healthy people (van Lieshout, et al., 2001). Although the continuous change of blood pressure was not measured in this study, the total Hb in the cerebral blood supply recovered after approximately 20-30 sec following the temporary pressure decrease induced by standing up. This recovery is believed to correspond to a recovery in blood pressure regulation. A significant difference was found between recovery times from a temporary decrease, and it was found to be significantly longer in a supine position than in a sitting position. Regarding the change in cerebral oxygenation, it is easy for us to explain the differences in body sway (COP) as compared between resting positions, but it is difficult to explain an increase in body sway at high room temperatures. The variation of total Hb while standing (90 sec) was larger at high temperatures than at normal temperatures. Tanaka et al. (2003) reported that a patient with orthostatic intolerance had unstable total-Hb and Oxy-Hb in their cerebral blood after standing up. In addition, it was suggested that the delay in the recovery of the cerebral

oxygenation kinetics relates closely to chronic fatigue. The temporary deficiency in blood supply by the delay of blood pressure regulation may influence body sway. This unstable blood supply may occur because of the difference in the outside air temperature rather than the resting position (sitting and supine positions).

Moreover, it is possible that heat stimulation by the high room temperature affects the somatosensory and respiratory centers and interferes with the postural control system. This possibility should be examined in further studies. Because orthostatic hypotension becomes more obvious with age even in healthy people, it may represent a risk factor for falling for the elderly with inferior lower limb strength. Hence, further studies may be necessary to prevent the blood pressure regulation delay that causes an increase of body sway.

A typical time-series diagram of a COP change suggests that the body sways largely forward just after standing up from the supine position. Great interest should be paid to the change of the time series data of body sway after standing up.

In conclusion, cerebral oxygenation kinetics and blood pressure after standing changed largely under high temperature conditions, and changed largely after standing from a supine position as compared with standing from a sitting position. Body sway just after standing up is also more pronounced at high room temperatures than at normal room temperatures and in standing up from a supine position rather than from a sitting position. Therefore, it is suggested that the variation of cerebral oxygenation and blood pressure after standing up may affect body sway.

REFERENCES

André JL, Petit JC, Gueguen R, Spyckerelle Y, Deschamps JP (1989) Blood pressure variations from clinostatism to orthostatism. *Arch. Mal. Coeur. Vaiss.*, **82**: 1027-1032.

Boulos M, Barron S, Nicolski E, Markiewicz W (1996) Power spectral analysis of heart rate variability during upright tilt test: a comparison of patients with syncope and normal subjects. Cardiology, **87**: 28-32.

Colier WN, Binkhorst RA, Hopman MT, Oeseburg B (1997) Cerebral and circulatory haemodynamics before vasovagal syncope induced by orthostatic stress. *Clin. Physiol.*, **17**: 83-94.

Currier DP (1990) Elements of research in physical therapy. 3rd edn. Williams & Wilkins, Baltimore, 150-171.

Du Plessis AJ (1995) Near-infrared spectroscopy for the in vivo study of cerebral hemodynamics and oxygenation. *Curr. Opin. Pediatr.*, **7**: 632-639.

Halar EM, Bell KR (1998) Contracture and other deleterious effects of immobility. In: DeLisa JA (ed) Rehabilitation medicine, Principles and Practice, 3rd edn. Lippincott-Raven, Philadelphia, 23-37.

Hamaoka T, Iwane H, Shimomitsu T, Katsumura T, Murase N, Nishio S, Osada T, Kurosawa Y, Chance B (1996) Noninvasive measures of oxidative metabolism on working human muscles by near-infrared spectroscopy. *J. Appl. Physiol.*, **81**: 1410-1417.

Hamaoka T, Katsumura T, Murase N, Sako T, Higuchi H, Murakami M, Esaki K, Kime R, Homma T, Sugeta A, Kurosawa Y, Shimomitsu T, Chance B (2003) Muscle oxygen consumption at onset of exercise by near infrared spectroscopy in humans. *Adv. Exp. Med. Biol.*, **530**: 475-483.

Harms MP, Colier WN, Wieling W, Lenders JW, Secher NH, van Lieshout JJ (2000) Orthostatic tolerance, cerebral oxygenation, and blood velocity in humans with sympathetic failure. *Stroke*, **31**: 1608-1614.

Kawaguchi T, Uyama O, Konishi M, Nishiyama T, Iida T (2001) Orthostatic hypotension in elderly persons during passive standing: a comparison with young persons. *J. Gerontol. A. Biol. Sci. Med. Sci.*, **56**:

M273-80.

Kusano E, Yorifuji S, Okuno M, Nakanishi F, Imaoka H, Matsuno Y, Abe k, Hayakawa K (2000) Skin hemodynamics during change from supine to lateral position. *J. Neurosci. Nurs.*, **32**: 164-168.

Madsen P, Pott F, Olsen SB, Nielsen HB, Burcev I, Secher NH (1998) Near-infrared spectrophotometry determined brain oxygenation during fainting. *Acta. Physiol. Scand.*, **162**: 501-507.

Mehagnoul-Schipper DJ, Colier WN, Jansen RW (2001) Reproducibility of orthostatic changes in cerebral oxygenation in healthy subjects aged 70 years or older. *Clin. Phsiol.*, **21**: 77-84.

Mehagnoul-Schipper DJ, Vloet LC, Colier WN, Hoefnagels WH, Jansen RW (2000) Cerebral oxygenation declines in healthy elderly subjects in response to assuming the upright position. *Stroke*, **31**: 1615-1620.

Nagashima Y, Yada Y, Hattori M, Sakai A (2000) Development of a new instrument to measure oxygen saturation and total hemoglobin volume in local skin by near-infrared spectroscopy and its clinical application. *Int. J. Biometeorol.*, **44**: 11-19.

Nakada M, Demura S, Yamaji S, Kondou S (2008) Blood pressure during intermittent progressive workload exercise: Comparison of two noninvasive continuous blood pressure monitoring devices. *J. Edu. Health Sci.*, **53**: 286-292.

Steinberg FU (1980) The immobilized patient-functional pathology and management. Plenum Medical Book Co, New York, 11-23.

Tanaka H, Matsushima R, Tamai H, Kajimoto Y (2003) Impaired postural cerebral hemodynamics in young patients with chronic fatigue with and without orthostatic intolerance. *J. Pediatr.*, **140**: 412-417.

van Lieshout JJ, Pott F, Madsen PL, van Goudoever J, Secher NH (2001) Muscle tensing during standing: effects on cerebral tissue oxygenation and cerebral artery blood velocity. *Stroke*, **32**: 1546-1551.

Wieling W, Shepherd JT (1992) Initial and delayed circulatory responses to orthostatic stress in normal humans and in subjects with orthostatic intolerance. *Int. Angiol.*, **11**: 69-82.

Figure captions

Figure 1　Changing rario of LF/HF between rest and after the standing in each condition [(after standing - rest) / rest × 100].

Note. There were significant differences between the body rest positions (*p < 0.05).

Figure 2　Average changes in frontal Total, Oxy- and Deoxy hemoglobin in each body position and room temperature. Values are expressed as mean every sampling time.

Note. All values was calculated the relative value based on the rest for sitting position on 22℃ The time series data was the average every sampling time in all subjects. Total Hb: total hemoglobin, Oxy-Hb: oxygenated hemoglobin, Deoxy-Hb: deoxygenated hemoglobin.

Figure 3　Two-way ANOVA of the average values of the standard deviations for total hemoglobin while standing (90 sec) among the experimental conditions.

Note. There were significantly differences between room temperatures (*p < 0.05).

Figure 4　Average changes in systolic and diastolic blood pressure and heart rate in each body position and room temperature.

Note. The time series data was the average every sampling time in all subjects. SBP: systolic blood pressure, DBP: diastolic blood pressure, HR: heart rate.

Table 2. The results of two way ANOVA (temperature × body position during rest) and post-hoc for each COP parameter.

Temperature		Normal temperature		High temperature		ANOVA			Post-hoc	
Body position		Sitting	Supine	Sitting	Supine	Temperature	Body position	Interaction	Temperature	Body position
COP parameters	Unit	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F	F	F		
Mean path length	(cm/s)	0.97 (0.21)	1.05 (0.26)	1.13 (0.29)	1.25 (0.40)	21.19 *	13.89 *	1.40	Nor<High	Sit<Sup
Root mean square	(cm)	0.80 (0.19)	0.80 (0.20)	0.89 (0.26)	0.97 (0.24)	14.01 *	1.78	2.25	Nor<High	
Standard deviation of X-axis	(cm)	0.44 (0.10)	0.49 (0.14)	0.49 (0.13)	0.55 (0.15)	10.14 *	8.38 *	0.33	Nor<High	Sit<Sup
Standard deviation of Y-axis	(cm)	0.65 (0.20)	0.62 (0.18)	0.73 (0.25)	0.79 (0.23)	11.15 *	0.21	2.28	Nor<High	
Standard deviation of X-axis velocity	(cm/s)	1.00 (0.25)	1.07 (0.32)	1.16 (0.32)	1.28 (0.45)	16.85 *	5.76 *	2.76	Nor<High	Sit<Sup
Standard deviation of Y-axis velocity	(cm/s)	0.94 (0.20)	1.04 (0.24)	1.14 (0.29)	1.27 (0.35)	23.75 *	23.31 *	0.34	Nor<High	Sit<Sup
Area surrounding mean path length	(1/cm)	22.00 (7.56)	21.93 (9.47)	19.87 (8.77)	16.79 (4.86)	7.86 *	2.14	3.86	Nor<High	
Area surrounding maximal amplitude	(cm^2)	11.17 (5.98)	11.90 (5.89)	16.03 (10.58)	17.88 (8.21)	14.06 *	1.68	0.45	Nor<High	
Mean velocity of X-axis	(cm/s)	0.58 (0.15)	0.63 (0.20)	0.67 (0.20)	0.75 (0.28)	13.80 *	6.70 *	1.36	Nor<High	Sit<Sup
Mean velocity of Y-axis	(cm/s)	0.54 (0.11)	0.60 (0.14)	0.64 (0.15)	0.73 (0.21)	25.35 *	28.64 *	0.92	Nor<High	Sit<Sup
Root mean square of sway velocity	(cm/s)	1.38 (0.31)	1.50 (0.36)	1.63 (0.41)	1.82 (0.53)	23.63 *	17.98 *	1.04	Nor<High	Sit<Sup

Note) * $p<.05$, Nor: Normal room temperature, High: High room temperature,
Sit: Sitting position during rest, Sup: Supine position during rest

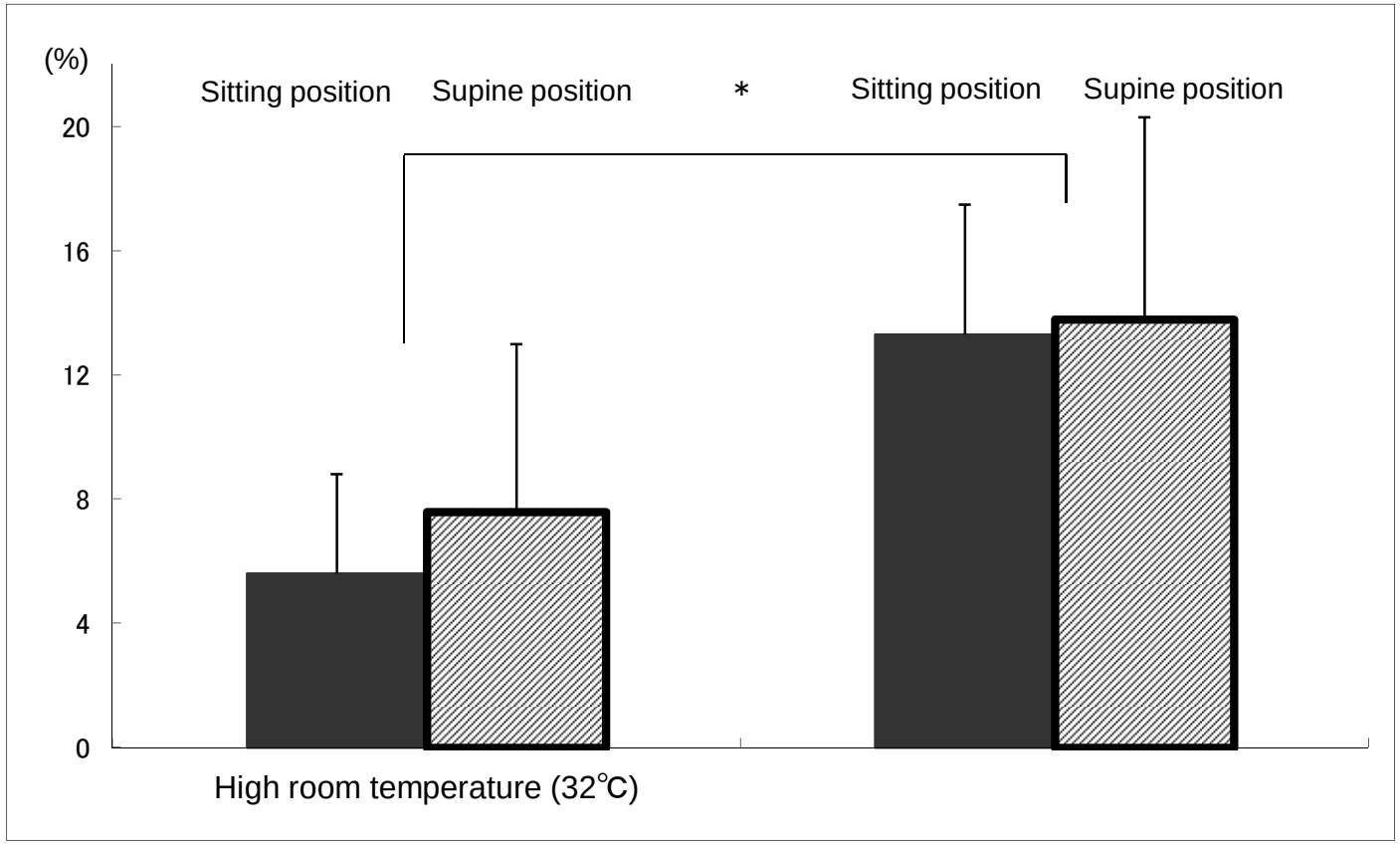

Fig.4. Two-way ANOVA of the average values of the standard deviations for total Hb while standing (90 sec) among the experimental conditions. *: P<0.05