Mental Workload under Time Pressure can Trigger Frequent Hot Flashes in Menopausal Women

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Abstract: The aim of this study is to examine the relationship between mental workload and occurrence of hot flashes. Twelve women with moderate to severe menopausal hot flashes participated in the study. Subjects participated in both a mental arithmetic task (Task) and control (Non-task) experiments. We measured heart rate, heart rate variability, blood pressure, near infrared spectroscopy, skin temperature, and skin potential level. The incidence of hot flashes was greater in Task than in Non-task. No significant differences between before, during and after hot flashes emerged for the percentage of correct responses and reaction time. However, the percentage of correct responses for two subjects among the ten who experienced hot flashes in Task substantially declined during hot flashes. Chest skin temperatures increased in both Task and Non-task during hot flashes, and regional oxygen saturation was significantly higher in Non-task than in Task. The present study suggested that mental workload under time pressure might be a risk factor for menopausal hot flashes, and the performance of most people who experienced hot flashes was not affected by hot flashes, however, work-related difficulties due to cognitive disturbance during hot flashes might arise in some people.

Key words: Menopausal hot flash, Mental workload, Female worker

Introduction

According to the report from the Ministry of Health, Labour and Welfare (MHLW) of Japan in 2005, female employees numbered 22.29 million, and the population of working women in their 40s and 50s was higher than for any other age group except the 20s. In particular, the percentage of those in employment by age group has been estimated at 60.8% for ages 40–44, 63.0% for ages 45–49, 56.7% for ages 50–54, and 45.9% for ages 55–59. These rates increased from 5.3 to 7.8% compared with ten years ago. The figures demonstrate that menopausal women are a precious labor resource in an aging society with a falling birthrate. However, they also begin to experience menopausal symptoms such as hot flashes, night sweats, general fatigue, and shoulder stiffness caused by reduced estrogen. Utian (2005)1) has reported that all menopausal symptoms may lead to social impairment and work-related difficulties that significantly decrease overall quality of life.

Hot flashes are the most common symptom of climacteric women. The experience of a hot flash is usually described as sensations of intense heat, sweating, flushing, and chills. Elevated brain noradrenaline activity at central α2-adrenoceptors is involved in the initiation of hot flashes2). According to the report from MHLW of Japan in 2005, there were approximately 9.75 million female employees aged 40 to 59 yr. It is estimated that approximately 2.1–3.8 million female workers may experience work-related difficulties due to hot flashes in the workplace, because the prevalence of mild to severe hot flashes was reported at 22–40% in Japan3, 4). Therefore, it is clear that there will be increasing demand for systematic and effective management to support their health
and safety. For building effective management systems in response to hot flashes, it is necessary to examine the relationship between workload and hot flashes, physiological changes during hot flashes, and workload that is associated with an increased risk of hot flashes. However, most previous studies concerning hot flashes are results of subjects at rest, and there are very few research studies on the relationship between workload and occurrence of hot flashes.

The purpose of this study was to examine the association between occurrence of hot flashes and mental workload, which has attracted attention in the occupational health field. The present study will help efforts to support effective health and safety management of hot flashes of the growing population of middle-aged and elderly female workers.

Methods

Subjects

Twelve women (eight post-menopausal, four perimenopausal) who reported experiencing moderate to severe menopausal hot flashes each day were recruited from Kitakyushu city through advertisements and fliers at community centers. Climacteric symptoms were assessed according to the Kupperman index, a version of the Kupperman index that has been modified for Japanese women (modified 17 symptoms). The subjects were healthy, with a mean age of 52.6 ± 3.1 yr. Their mean height was 155.4 ± 3.5 cm, their mean weight was 55.2 ± 7.9 kg, and their mean BMI was 22.8 ± 2.5. None of the subjects had received hormone replacement therapy, nor were they taking any medication known to affect hot flashes for seven days prior to testing. All subjects gave written informed consent according to procedures approved by the Ethics Committee of the University of Occupational and Environmental Health and were paid for their participation. The subjects wore similar attire such as T-shirts and short pants without brassieres during the experiments.

Measurements and procedures

Previous study showed that peripheral heating and warm ambient temperature can trigger hot flashes. Experiments were carried out in a sitting posture between 13:00–18:00 h in a climatic chamber maintained at 28°C with a relative humidity of 50 ± 10%, which is the standard setting temperature in the workplaces of Japan in summer. We measured physiological responses such as electrocardiography (ECG), blood pressures (BP; Ohmeda, 2300 Finapres), near infrared spectroscopy (NIRS), skin potential level (SPL), and skin temperature.

From the ECG (LEG-1000, NIHON KOHDEN, Japan) data with a sampling frequency of 1 KHz, heart rate (HR) and heart rate variability (HRV) were derived. Previous studies have reported the reliability of HRV as a non-invasive index of autonomic nervous activity. Spectral analysis of HRV (DADISP, DSP Development Corporation) was applied to the time series data of R-R intervals for every 2 min, by Fast Fourier Transformation (FFT). The LF and HF components were integrated from 0.05 to 0.15 Hz and 0.15 to 0.40 Hz of the power spectra, respectively.

NIRS is a non-invasive method to measure regional oxygen saturation (rSO_2), which is based upon the principles of light absorption and transmission in oxygenated and deoxygenated hemoglobin in cerebral vessels. A dual sensor NIRS system (TOS-96, TOSTEC, Japan) was attached to the subject’s forehead to monitor the rSO_2 in the bilateral frontal lobes at a depth of approximately 30 mm beneath the skin. The distance between the light source and the photo detector was 40 mm. NIRS was used to evaluate the prefrontal cortex activity during hot flashes.

SPL was recorded via DC amplification (Skinos-Giken, Japan) by setting an exploring electrode on the hypothenar and the reference electrode on the upper third of the inside of the forearm, and then the changes in voltage, positive or negative, which occurred during a 1 s interval, were analyzed. SPL was used as a main parameter to predict hot flashes.

Skin temperature was recorded on a personal computer (mate NX, NEC) through an analog digital converter (Remote Scanner DE1200, NEC) using thermocouples placed on the forehead, chest, forearm, hand, thigh, leg, foot and finger. Mean skin temperature was calculated using the formula of Hardy-DuBois. Furthermore, NIRS, SPL, and skin temperature were continuously recorded at 1 s intervals.

The subjects participated in both a mental arithmetic task (Task) and control (Non-task) experiments. During Non-task, they were instructed to read freely a book about garden design that we had prepared in advance. The experimental procedure is conducted in Rest1 (15 min) - Task1 or Non-task1 (30 min) - Rest2 (10 min) - Task2 or Non-task2 (30 min) - Rest3 (10 min). The Task and Non-task conditions were counterbalanced across subjects in each group. Mental arithmetic tasks were performed with Task1 first followed by Task2.

Mental arithmetic task

A mental arithmetic task was presented on a computer screen. The subjects were instructed to give the last digit of the sum after adding two single-digit numbers. The Task questions were shown for 0.5 s, followed by equal sign (=) shown for 0.5 s. The answers were divided into...
the three groups of [0,3,6], [1,4,7], [2,5,8]. The subjects then had to click the mouse button as quickly as possible within 2 s after selecting the answer from among the three groups. The answer numbers from each group were adjusted to appear evenly at 5-min intervals. The percentage of correct responses and the reaction time were expressed as the mean for 5 min. The viewing distance between the subject’s eyes and the computer screen was approximately 70 cm. The subjects were instructed to place the screen work area slightly below the horizontal plane, adjust the seat height so that their feet rested on the floor, adjust the backrest of their chairs to push the lower back forward slightly, and to keep their thighs parallel to the floor.

Subjective and objective hot flashes
The subjects were required to fill out frequency and intensity (0–10) of hot flashes after each task. However, separate self-report measures of symptom frequency and severity may be influenced by memory and recall biases. Freedman (2005) has reported that increased sternal skin conductance, an electrical measure of sweating, is the best objective marker of menopausal hot flashes. Skin conductance rises sharply from baseline at the onset of a hot flash, and then slowly returns to baseline. In this study, SPL was used instead of skin conductance level. Maximum levels of SPL vary among individuals depending on the degree of the sympathetic sweating on the palm. Hot flash occurrence was chiefly predicted by remarkably increased SPL, and secondly by subjective self-reported hot flashes and increased rSO2 or chest skin temperature that was measured at 1 s intervals.

Statistical analysis
All data were expressed as the mean value ± standard deviation (SD). ECG and BP data were analyzed at 2-min intervals in pre, hot flash, post1, and post2 (before, during and after) hot flashes. The value for the hot flash is data from 30 s before onset of a hot flash to 90 s after onset. Physiological parameters were analyzed using two-way repeated measures ANOVA (Huynh-Feldt correction applied) with condition and time course factors to compare differences during hot flashes between Task and Non-task. Post-hoc comparisons of the mean values were performed using Bonferroni. The number of subjects who experienced hot flashes during Task and Non-task were compared using a non-parametrical McNemar test. Total frequency of hot flashes between Task and Non-task was analyzed using a non-parametrical test (Wilcoxon signed rank test). The percentage of correct responses and reaction time between before, during and after hot flashes were analyzed using a non-parametrical Friedman test. p<0.05 was considered significant (SPSS 11.5J, SPSS Japan Inc.).

Results
As illustrated in Table 1, the number of subjects who experienced hot flashes was 10 in Task, which was greater than the 5 in Non-task, but there was no significant difference between the two conditions (p=0.125). The total frequency of hot flashes was observed as 26 during Task as compared with 11 during Non-task (p=0.079).

Differences in physiological change between Task and Non-task during hot flashes were examined using the data of four subjects who experienced hot flashes during both Task and Non-task. Fig. 1 shows the comparisons between conditions of chest and finger skin temperature, and left rSO2 for four subjects who experienced hot flashes during both Task and Non-task. A significant main effects of time course emerged for the chest skin temperature (p<0.05). It showed an increased tendency at 1 min after hot flashes compared to that at the onset of hot flashes. A significant main effect of condition was observed in the finger skin temperature (p<0.05), which indicated a significant increase in Task compared with in Non-task. A significant condition × time course interaction (p<0.01) was indicated in the left rSO2. Left rSO2 was significantly higher in Non-task than in Task at 3 and 4 min after hot flashes. In addition, a significant main effect of time course was observed in the leg skin temperature (p<0.05), which indicated a significant decrease at 2 min after hot flashes compared to that at 3 min before hot flashes. No significant differences between the two con-

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<th>Task</th>
<th>Non-task</th>
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<td></td>
<td>Number of subjects</td>
<td>Total frequency of hot flashes</td>
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<tr>
<td>Objective hot flashes</td>
<td>10</td>
<td>26</td>
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<td>Subjective hot flashes</td>
<td>9</td>
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Objective hot flash was chiefly predicted by sharply increased skin potential level, and secondly by subjective self-reported hot flashes and increased regional oxygen saturation or chest skin temperature. Subjects were asked to recall frequency and severity of hot flashes after each task.
ditions emerged for other skin temperatures, SPL, right rSO2, HR, HRV, and BP.

To examine the influence on performance by hot flashes, the percentage of correct responses and reaction time were compared before, during, and after hot flashes for ten subjects who experienced hot flashes in Task. However, performance data of two subjects for which data could not be obtained before, during, and after hot flashes due to the time of hot flash occurrence was excluded from the analysis. Since the percentage of correct responses and the reaction time were expressed as the mean for 5 min, 6 data sets are obtained when a mental arithmetic task is performed for 30 min (for example, T5, T10, T15, T20, T25, and T30). For example, when a hot flash occurred at 12 min after starting the task, the values T10, T15, and T20 are obtained for the performance data for before, during, and after hot flashes, respectively. From these results, the percentage of correct responses for before, during, and after hot flashes was 94.66 ± 6.06, 92.78 ± 8.51, and 94.63 ± 5.68, respectively. Both the percentage of correct responses and reaction time were not affected by hot flashes.

This study is not a case report of patients, but we examined the performance data of the subjects that presented significant changes in performance during a hot flash, because safety is the most important problem in the Occupational Health field. As illustrated in Fig. 2A, the percentage of correct responses for two subjects (S08, S09) among the ten who experienced hot flashes substantially declined during hot flashes in Task. During a hot flash, the percentage of correct responses decreased drastically by 78% in S08, and by 52% in S09. The former had a longer reaction time during the hot flash than before the hot flash, and the latter had a shorter reaction time (Fig. 2B).

As illustrated in Table 2, 11 out of the 26 hot flashes occurring after onset of Task were observed within 10 min, and four occurred immediately after finishing Task.

**Discussion**

No significant difference between Task and Non-task emerged for the number of subjects who experienced hot flashes. However, the incidence of hot flashes was observed more frequently during Task compared with Non-task ($p=0.079$). This suggests that the frequency of menopausal hot flashes may be at least associated with mental workload. Our result is supported by Freedman (2005)2). He has reported that hot flashes are triggered by small elevations in core body temperature acting within a reduced thermoneutral zone due to elevated brain...
noradrenaline in symptomatic menopausal women. Core body temperature was not measured in this study, but its elevation can be inferred from elevated chest and finger skin temperatures indicating heat dissipation. Previous studies showed that mental arithmetic tasks lead to activation of the central sympathetic nervous system\(^{12, 13}\)). This suggests that the mental workload that activates the central sympathetic nervous system may be a risk factor for hot flashes.

Interestingly, although in this experiment hot flashes were generated easily by mental workload that elevated brain norepinephrine, there were two subjects who did not experience hot flashes during Task. All subjects who participated in the experiment were women with self-reported moderate to severe hot flashes. Our study chiefly focused on severity, and did not emphasize frequency such as \(\geq 10/d\) or \(\geq 5/d\)\(^{9, 14}\). Therefore, the subjects may have included women with lesser frequency of hot flashes per day even with moderate to severe symptoms, which may affect our result. Temperature homeostasis is a complex intercommunicative function requiring coordination between internal core body temperature, the central nervous system and peripheral vasculature. Hot flashes are due to thermoregulatory dysfunction or a disruption in communication between these mechanisms\(^{15}\). We do not know the amount of variation of brain norepinephrine in the subjects during the mental task because we did not measure a physiological index to examine central sympathetic nervous activity. However, this task might have not been sufficient to activate the central sympathetic nervous system in the two subjects who did not experience hot flashes, and other factors also might have affected them. Interestingly, one of the two women who did not have hot flashes during mental workload experienced one hot flash during Non-task. These results suggest that the hot flash-triggering mechanism cannot be explained only by elevated brain noradrenaline acting at central \(\alpha\)-adrenoceptors, but that a more complex mechanism is involved.

Menopausal hot flashes were frequently triggered in Task compared with in Non-task, although physiological differences between two conditions were quite small. Chest skin temperature increased in both Task and Non-task during hot flashes, and there was no significant difference between two conditions. Cutaneous vasodilation is a classic mechanism of heat loss that is activated during a hot flash. Finger skin temperature was significantly higher in Task than in Non-task during hot flashes due to the influence of the mental arithmetic task (Fig. 1). Our results during hot flashes are consistent with Freedman (1998)\(^{16}\) and Kronenberg (1990)\(^{17}\). However, our results showed a smaller increase in skin temperature than did these previous studies. Freedman (1998)\(^{16}\) showed that core body temperature and mean skin temperature increased approximately 0.05˚C and 0.25–0.3˚C during hot flashes, respectively. Kronenberg (1990)\(^{17}\) has reported that finger temperature typically increases at least 1˚C during a hot flash. In contrast, the chest skin temperatures in Task and Non-task increased approximately 0.25˚C and 0.1˚C during hot flashes, respectively. Finger skin temperature showed increases of 0.1˚C under both conditions during hot flashes. The magnitude of the skin temperature response is influenced by several factors including ambient temperature, vascular responsiveness of the individual, clothing, and workload. Warm ambient temperature (28˚C with a relative humidity of 50 ± 10% artificial climate chamber), vasodilation induced by performing mental arithmetic tasks, and the inclusion of women with moderate hot flashes are cited as the main cause of small physiological response during hot flashes in this study. Although our results showed small elevations in the skin temperatures, they clearly differ between before and after hot flashes. Therefore, it is unlikely that small elevations in skin temperatures were influenced by measurement errors due to sensor and position mismatches, or other environmental factors.

Additionally, \(\text{rSO}_2\) increased significantly in Non-task compared with in Task during hot flashes. This increase was caused by activation in the prefrontal cortex by...
vasodilation for hot flashes. Interestingly, an increase in rSO2 was not observed in mental arithmetic tasks. We can estimate the reason for this from the results of previous studies that show that brain activation related to arithmetic tasks was observed in both the prefrontal and parietal cortices\(^ {16-18}\). It might be that brain activations in the prefrontal and parietal areas had already increased during the mental tasks; thus, there was no further activation associated with the occurrence of hot flash in the prefrontal cortex. These results suggest that rSO2 provides a good marker of hot flash occurrence, particularly at rest, but is not an effective objective marker for mental workload under time pressure.

Previous studies showed that HR increases within a few minutes of the onset of a hot flash\(^ {19, 20}\), whereas HR and BP did not increase during hot flashes in this study. This was because there was no significant increase in the cardiovascular system during a hot flash since HR and BP had already increased during the mental arithmetic task\(^ {21, 22}\). In this study, comparisons of physiological change between Task and Non-task during hot flashes were analyzed using the data of only four subjects who experienced hot flashes during both Task and Non-task. There is concern that the results may lead to problems such as the reliability of the results and reproducibility due to the small sample size. Therefore, it is necessary to do further research on a larger sample to enhance the reliability of the results. In the present study, differences in the physiological change between Task and Non-task during hot flashes were compared, but the results obtained through only noninvasive indices were insufficient to examine the reasons why hot flashes are frequently triggered during mental workload. Therefore, to clarify the association between frequent hot flashes and mental workload, further research that compares the differences in physiological response between at rest and Task during hot flashes using an index of central sympathetic nervous activity is required. The physiological changes associated with hot flashes often result in increased anxiety and stress caused by mood swings and unpredictable hot flashes\(^ {15}\). Therefore, psychological strain may be greater in women with frequent hot flashes than in asymptomatic women.

### Table 2. Time of hot flash occurrence during Task and Non-task in twelve subjects. (+) represents hot flash occurrence

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<tr>
<th>Subject</th>
<th>Task1</th>
<th>Non-task1</th>
<th>Task2</th>
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Industrial Health 2008, 46, 261–268
menopausal women in a work-related situation.

Shepherd (2001)\textsuperscript{23} has reported that cerebral blood flow during hot flashes decreased in the hippocampus, a center for memory and cognition. The performance was not affected by hot flashes in the present study. However, that of two subjects among ten who experienced hot flashes decreased markedly in terms of percentage of correct responses. This drop may result from memory and cognition impairment caused by a decrease of cerebral blood flow during hot flashes. In particular, one of the two women had a short reaction time together with a drop in the percentage of correct responses for the longer duration of 10 min (Fig. 2). It is likely that she felt psychological strain, such a surge of panic and anxiety, due to hot flashes\textsuperscript{1).} In addition, psychological strain might have been aggravated by time pressure, which is associated with a short time to carry out the task. Because Greiner \textit{et al.} (1998)\textsuperscript{24} have reported that stressor dimensions include work barriers that interfere with task performance due to time pressure, and time binding, there were thus elevated risks for work accidents for high time pressure operators. Thus, a rise in calculation errors in some people may be associated with time pressure. The above results indicate that performance in most people is not affected by hot flashes, but a hot flash may directly affect the safety of workers depending on the kind of work because decreases of performance were marked in some people.

Therefore, effective management of hot flashes is extremely important to protect the health and the safety of female workers. Based on the results of this study, we can suggest several ways to support occupational health and safety for female workers who experience hot flashes during mental workload. First, in the 2 to 3 min before a hot flash occurs, chest skin temperature began to increase (Fig. 1). Previous study has reported that skin temperature, cutaneous blood flow, and heart rate begin to increase before a hot flash occurs\textsuperscript{23).} Accordingly, temporarily stopping work at the worker’s discretion or taking a short rest are recommended when physiological changes such as rising skin temperature that is predictive of hot flash are felt. Second, relaxing of time pressure as a stressor may help prevent hot flashes, because greater psychological strain may be promoted by time pressure. For instance, measures such as adjusting work speed if necessary or limiting mental workload under high time pressure for pacing work may reduce the occurrence of hot flashes. Finally, 11 out of 26 hot flashes were observed within 10 min after onset of Task (Table 2), and then the frequency of hot flashes decreased gradually. This shows that for mental workload under time pressure, it may be more effective to start at a slow pace and gradually return to the normal pace instead of keeping to a uniform time distribution from beginning to end. These results suggest that frequent hot flashes may lead to workplace safety problems, reducing quality of life, and adversely affecting performance in some people, but effective management should help to protect the health and safety of middle-aged and elderly female worker with menopausal hot flashes in the workplace. These are really novel results for an occupational health investigation. Practical research is required to examine effective measures for the prevention of hot flashes in the future.

\section*{Conclusion}

The present study suggested that mental workload under time pressure might be a risk factor for menopausal hot flashes, and the performance of most people who experienced hot flashes was not affected by hot flashes, however, work-related difficulties due to cognitive disturbance during hot flashes might arise in some people. In addition, it could be inferred that appropriate preventive measures will help to protect the health and safety of female workers with menopausal hot flashes during mental workload.

\section*{Acknowledgements}

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\section*{References}