

White-collar workers' hemodynamic responses during working hours

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Abstract: In the present study, two investigations were conducted at a communication center, to examine white-collar workers' hemodynamic responses during working hours. In investigation I, hemodynamic responses were measured on a working day; and in investigation II, cardiovascular responses were verified on both working and non-working days. In investigation I, blood pressure, cardiac output, heart rate, stroke volume, and total peripheral resistance were measured in 15 workers during working hours (from 9:00 am to 18:00 pm) on one working day. Another 40 workers from the same workplace participated in investigation II, in which blood pressure and heart rate were measured between the time workers arose in the morning until they went to bed on 5 working days and 2 non-working days. The results showed that blood pressure increased and remained at the same level during working hours. The underlying hemodynamics of maintaining blood pressure, however, changed between the morning and the afternoon on working days. Cardiac responses increased in the afternoon, suggesting that cardiac burdens increase in the afternoon on working days. The present study suggested that taking underlying hemodynamic response into consideration is important for managing the work-related cardiovascular burden of white-collar workers.

Key words: Hemodynamics, White-collar worker, Blood pressure, Cardiac output, Total peripheral resistance

Introduction

Previous studies have suggested that work-related factors, such as long working hours and cumulative exposure to work-related stress, increase cardiovascular morbidity and mortality risks for white-collar workers^{1–6}. In Japan, periodic health examinations of workers also show that the ratios of cardiovascular morbidity have increased continuously⁷. In addition, approximately 3,000 workmen's accidents owing to cerebrovascular/cardiovascular diseases in the past decade have been considered cases related to excessively heavy workloads, and most of them were white-collar workers⁸. It is known that excessive increases

in cardiovascular responses to work, such as increases in systolic blood pressure, are considered long-term predictors of cardiovascular disorders^{3–6}. Previous studies have reported that white-collar workers have higher average blood pressure levels during working days compared with non-working days, and blood pressure during working hours (from 9:00 am to 18:00 pm) is higher than at other times, such as when workers are at home^{9, 10}. Lundberg *et al.*¹¹ compared white-collar workers working in an office, working at home (teleworkers), and relaxing at home, and found that their blood pressure was significantly higher during working hours at the office than during times of relaxation at home. These studies suggest that increased blood pressure during working hours is owing to work itself. Therefore, preventing excessive increases in blood pressure during working hours is important, but effective methods for achieving this have not yet been found.

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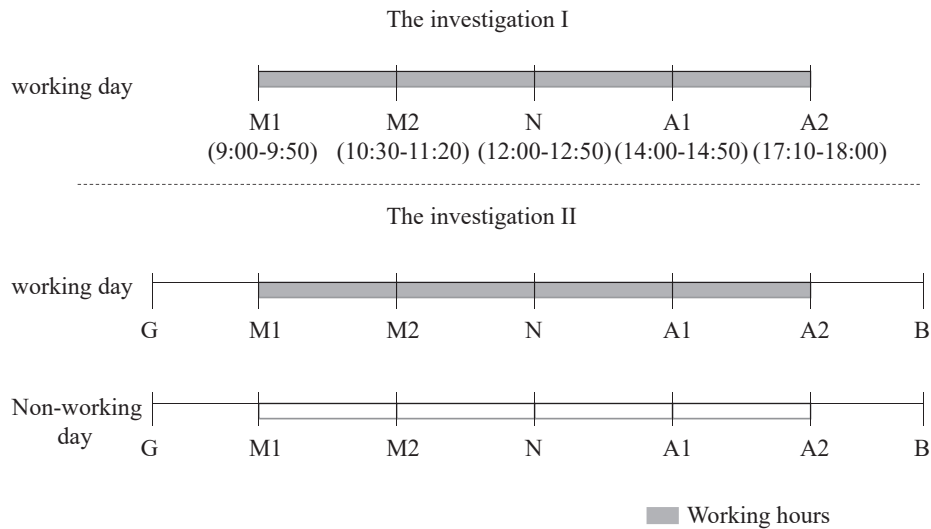


Fig. 1. Measurement schedule of investigations.

G: after getting up; M1: the first measurement in the morning (9:00–9:50); M2: the second measurement in the morning (10:30–11:20); N: at noon (12:00–12:50); A1: the first measurement in the afternoon (14:00–14:50); A2: the second measurement in the afternoon (17:10–18:00); B: before going to bed.

In addition to increased blood pressure, the underlying hemodynamics in increasing blood pressure is also considered a risk factor for cardiovascular disorders^{6, 12, 13}. Underlying hemodynamics in increasing blood pressure refers to that mean arterial pressure (MAP) that is elevated by cardiac output (CO) and/or total peripheral resistance (TPR) ($MAP = CO \times TPR$), and CO that is changed by heart rate (HR) and/or stroke volume (SV) ($CO = HR \times SV$). Laboratory studies suggest that the underlying hemodynamics in increasing blood pressure sometimes changes and that blood pressure can even remain at the same level while performing mental tasks^{14–16}. However, the manner in which underlying hemodynamics change during working hours in an actual workplace are unknown. It has been shown that some factors mainly influence cardiac responses while others mainly influence vascular responses^{17–23}. The elucidation of underlying hemodynamics in increasing blood pressure could provide specific information that is useful in the investigation of effective methods for managing work-related cardiovascular responses among white-collar workers.

In recent years, the information service industry has increased steadily in Japan and workman's accident also increases^{8, 24}. In the present study, we conducted two investigations at a communication center, where mainly sells goods and provide technical support to clients over the telephone, to examine cardiovascular responses of white-collar workers. In investigation I, we aimed to examine the underlying hemodynamics during working hours on a

workday; investigation II was conducted to compare workers' cardiovascular responses between working days and non-working days over a 1-week period, to verify whether the cardiovascular responses were related to work.

Methods

Participants and measurement

A total of 15 healthy male workers at a communication center in East Japan (mean age 37.07 ± 5.39 years) participated in investigation I. Participants arrived at an appointed location in a meeting room for hemodynamic measurement using a specialized equipment (Portapress Model-2; Finapres Medical Systems, Inc., Netherlands). This monitor measures beat-to-beat arterial pressure and heart rate (HR) with a cuff worn on the fingers and computes stroke volume (SV) from the arterial pressure according to the model flow method. Then, cardiac output (CO) was calculated using SV and HR, and total peripheral resistance (TPR) was predicted from the mean pressure and model mean flow²⁵. Systolic and diastolic blood pressure (SBP and DBP), mean arterial pressure (MAP), CO, HR, SV, and TPR were measured continuously for 5 minutes during each measurement, and 5 measurements were conducted on 1 working day. The working hours were from 9:00 am to 18:00 pm, and the lunch break was for 1 hour. The measurement schedules is shown in Fig. 1 and included measurement times at work initiation in the morning (M1: 9:00–9:50), during work in the morn-

ing (M2: 10:30–11:20), at noon (N: 12:00–12:50), during work in the afternoon (A1: 14:00–14:50), and work termination in the afternoon (A2: 17:10–18:00). The measurement at noon was conducted before lunch, and A1 was measured 1–2 hours after lunch.

Another 40 healthy workers (14 men and 26 women; mean age 36.62 ± 9.80 years) from the same communication center participated in investigation II. Participants were asked to measure their SBP, DBP, and HR between getting up in the morning and going to bed at night on 5 working days and 2 non-working days within a 1-week period, using a home sphygmomanometer (CH-463E; Citizen Systems Japan Co. Ltd., Japan). Female participants measured their cardiovascular indices during the follicular phase (approximately 10 days after menstruation). The measurement schedule is shown in Fig. 1, and measurement times at work (or during the day on non-working days) were nearly the same as those in investigation I. The working hours were also from 9:00 am to 18:00 pm, and the lunch break was 1 hour on working days. The measurement schedules on working days included after getting up (G), upon initiating work in the morning (M1), during work in the morning (M2), at noon (N), during work in the afternoon (A1), upon terminating work in the afternoon (A2), and before going to bed (B) on working days. On non-working days, participants measured these indices at nearly the same times as on working days, including after getting up (G), two times in the morning (M1 and M2), at noon (N), two times in the afternoon (A1 and A2), and before going to bed (B).

All participants in both investigations were requested to refrain from exercise and alcohol intake during the measurement periods and were prohibited from drinking caffeinated beverages or smoking during the 1-hour period immediately preceding the measurements. After details of the study were explained, participants were asked to sign a written consent form before participating in the study. This study was approved by the Research Ethics Committee of the National Institute of Occupational Safety and Health of Japan.

Data analyses

The data were analyzed using mixed-model analysis of variance (ANOVA) because the mixed-model can properly account for correlation between repeated measurements in the same participant, and has greater flexibility to model time effects, which makes the mixed-model more appropriate for the analysis of repeated measures data²⁶. In investigation I, 5-minute data of all cardiovascular indi-

ces were averaged and used to conduct repeated one-way ANOVA. In investigation II, values on working days and non-working days were averaged and used to conduct repeated two-way mixed-model ANOVA (Day [2] × Time [7]). The covariance structures were compared among compound symmetry, heterogeneous compound symmetry, and first-order autoregressive according to the Akaike Information Criterion (AIC), and compound symmetry was chosen according to the minimum AIC. Multiple comparisons (Bonferroni) were conducted to further examine the significant results. The level of significance was set at 0.05. Statistical analysis was carried out using IBM SPSS Statistics 19 (IBM Corp., Armonk, NY, USA).

Results

Investigation I

The mean value and standard deviation of each index and the results of multiple comparisons are shown in Fig. 2. The results showed that the differences among measurement periods were not significant for SBP ($F(4, 56)=0.57$, $p=0.68$), DBP ($F(4, 56)=2.46$, $p=0.06$), and MAP ($F(4, 56)=1.40$, $p=0.25$). Differences among measurement periods were significant for HR ($F(4, 56)=3.64$, $p<0.01$), SV ($F(4, 56)=6.98$, $p<0.01$), CO ($F(4, 56)=8.55$, $p<0.01$), and TPR ($F(4, 56)=5.65$, $p<0.01$).

The results of multiple comparisons showed that HR, SV, and CO increased in the afternoon compared with the morning (HR: A1 and A2 > M2, $p<0.05$; SV: A1 > M1 and M2, $p<0.01$; CO: A1 and A2 > M2, $p<0.01$). In contrast, TPR decreased in the afternoon compared with the morning (A1 and A2 < M2, $p<0.05$).

Investigation II

The mean value and standard deviation of SBP, DBP, and HR and the results of multiple comparisons, are shown in Fig. 3. The main effect of the day of measurement was significant for SBP ($F(1, 507)=17.93$, $p<0.01$), DBP ($F(1, 507)=16.54$, $p<0.01$), and HR ($F(1, 507)=25.71$, $p<0.01$). The main effect of the time of measurement was significant for SBP ($F(6, 507)=12.41$, $p<0.01$), DBP ($F(6, 507)=10.11$, $p<0.01$), and HR ($F(6, 507)=24.15$, $p<0.01$). The interaction between factors was significant for SBP ($F(6, 507)=3.55$, $p<0.01$), DBP ($F(6, 507)=5.64$, $p<0.01$), and HR ($F(6, 507)=8.37$, $p<0.01$).

The results of further analysis showed that on working days, SBP and DBP increased during working hours compared with after getting up (SBP: M1, M2, N, A1, and A2 > G, $p<0.01$; DBP: M1, M2, N, and A2 > G, $p<0.05$).

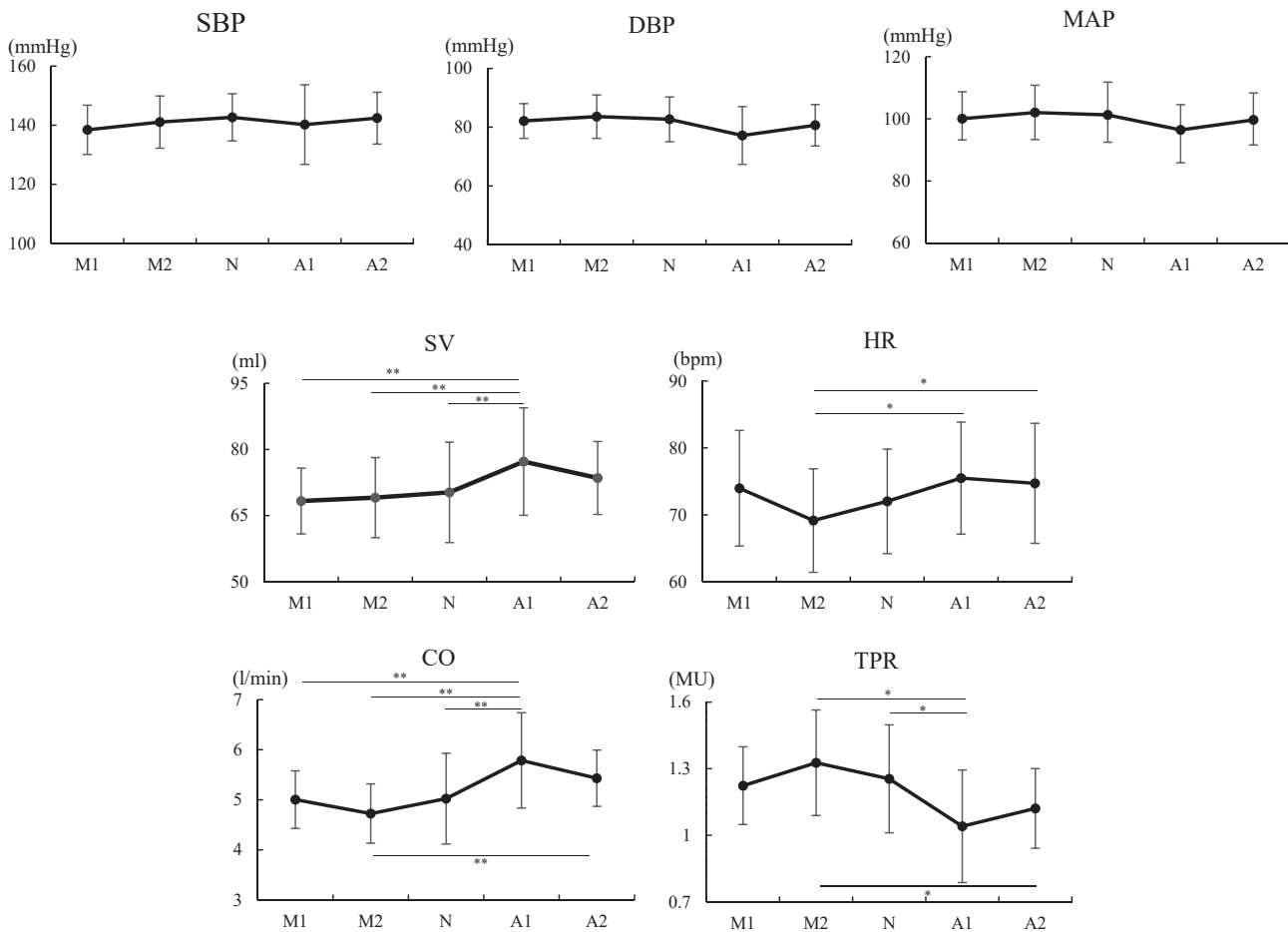


Fig. 2. Hemodynamic responses on 1 working day.

Values are means and standard deviation (SD), $n=15$. M1: the first measurement in the morning (9:00–9:50); M2: the second measurement in the morning (10:30–11:20); N: at noon (12:00–12:50); A1: the first measurement in the afternoon (14:00–14:50); A2: the second measurement in the afternoon (17:10–18:00); SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; HR: heart rate; CO: cardiac output; SV: stroke volume; TPR: total peripheral resistance. * $p < 0.05$; ** $p < 0.01$.

SBP and DBP during working hours were not different. HR increased during working hours (M1, M2, N, A1, and A2 $> G$, $p < 0.01$) and HR in the afternoon was higher than in the morning (A1 $> M2$, $p < 0.1$). The highest HR was detected at the time of work initiation in the morning. On non-working days, however, no significant differences across days were found for SBP and DBP. HR increased during the daytime (M1, M2, N, A1, and A2 $> G$, $p < 0.05$) but did not differ between the morning and the afternoon.

Discussion

The results of our investigations showed that blood pressure increased and was maintained at the same level during working hours on workdays. To maintain blood pressure, however, the underlying hemodynamics changed between the morning and the afternoon. Compared with the morn-

ing, cardiac responses (HR, SV, and CO) increased, but vascular responses (TPR) decreased in the afternoon. Previous studies^{9–11,27} have reported that blood pressure increases during working hours, and the present study supported these results. In addition, the most important result of our study is that the underlying hemodynamics in increasing blood pressure was different between the morning and afternoon. Cardiac responses increased significantly in the afternoon although blood pressure was not different compared with the morning. To verify whether the difference in underlying hemodynamics between morning and afternoon was owing to the circadian rhythm, we compared cardiovascular responses between working and non-working days. We found that HR increased in the afternoon only on working days; on non-working days, HR did not differ between the morning and afternoon. These results suggest that the increases in cardiac responses in

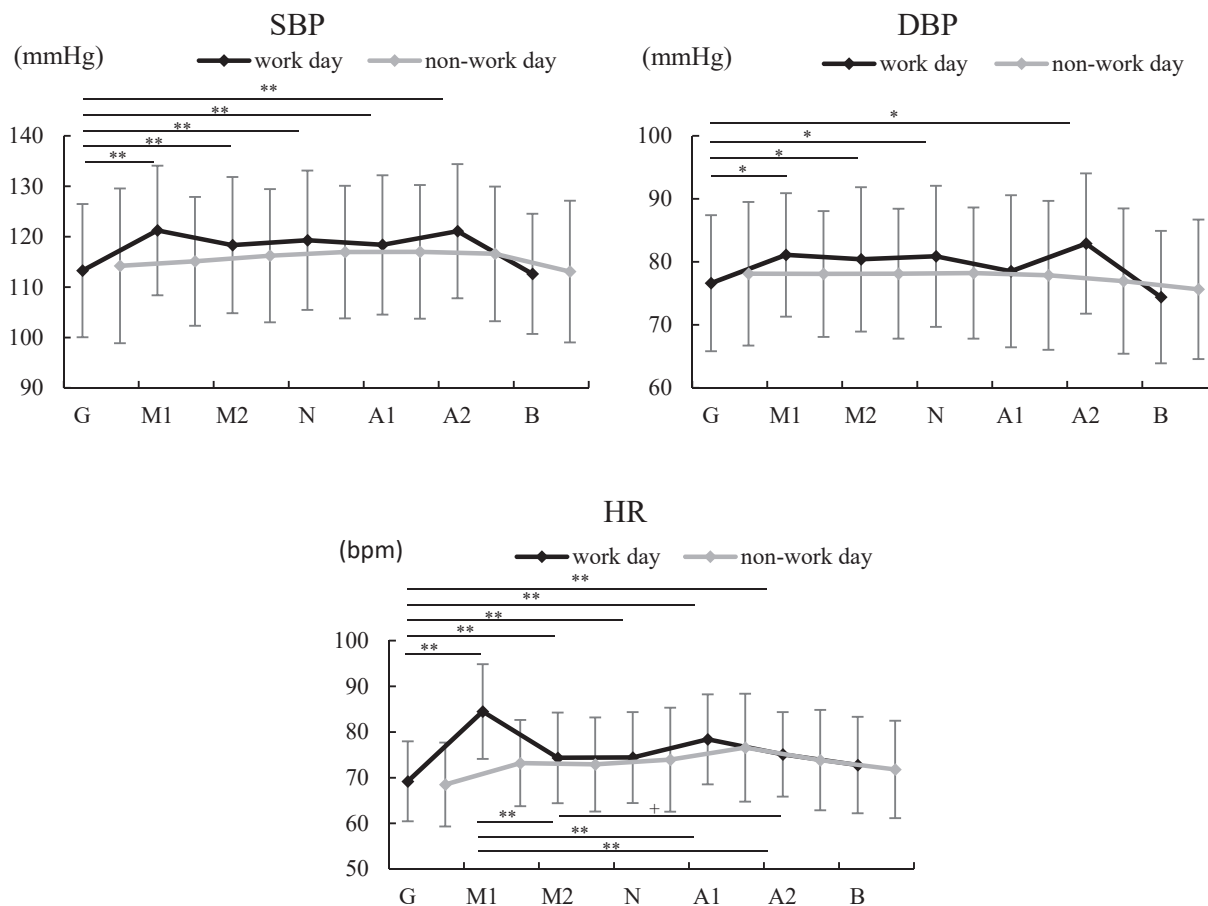


Fig. 3. Blood pressure and heart rate on the working day and the non-working day.

Values are means and standard deviation (SD), $n=40$. G: after getting up; M1: the first measurement in the morning (at work initiation); M2: the second measurement in the morning; N: at noon; A1: the first measurement in the afternoon; A2: the second measurement in the afternoon (at work termination); B: before going to bed; SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate. * $p<0.05$; ** $p<0.01$; + $p<0.1$.

the afternoon on working days were not owing to the circadian rhythm. We think that the highest HR at work initiation in the morning on working days are mainly because of influences of commuting.

Some reasons can be considered to explain the change in the trend of cardiac responses on working days. It is known that physical activities are associated with HR responses during working hours^{27, 28}. A previous study²⁷ compared physical activity between white-collar and blue-collar workers and showed that white-collar workers sat more (66%), and stood (23%) and walked (9%) less at work, compared with blue-collar workers who sat less (43%), and stood (34%) and walked (17%) more. Steptoe *et al.*²⁸ reported that HR among firefighters remained at nearly the same level on working days and suggested that this effect was owing to posture and the high-level physical activity of these workers. We believe that increases in

cardiac responses in the afternoon for workers at the communication center were also partly owing to low-level physical activities because such workers must maintain sedentary postures for long periods at work. In addition, fatigue was also considered an important factor for changing underlying hemodynamics in the afternoon. Previous studies have suggested that high HR reactivity as well as high blood pressure at work among white-collar workers were related to low vagal activity; decreased vagal activity and increased sympathetic activity are associated with fatigue, especially mental fatigue^{9, 27, 29}. In the present study, cardiac responses increased in the afternoon on working days possibly also owing to increased mental fatigue as most workers must communicate with clients or colleagues for long periods during working hours. In any case, the increases in the cardiac responses of workers in the afternoon on working days were related to their work.

The results of the present study showed that the underlying hemodynamics in increasing blood pressure changed between the morning and the afternoon, suggesting that cardiac burden may increase in the afternoon on working days. As mentioned above, some factors mainly influence cardiac responses and some mainly influence vascular responses^{17–23}. For example, diet (e.g., carbohydrate meals) and sleep quality could influence vascular responses and relaxation could influence cardiac responses^{17–19}. Negative emotions (e.g., anger, depression) enhance vascular responses but positive emotions (e.g., contentment, amusement) promote faster recovery of increased HR^{20–23}. We believe that the elucidation of underlying hemodynamics in increasing blood pressure could provide helpful information for managing work-related cardiovascular responses. For white-collar workers, changing postures frequently (e.g., stretching), consciously increasing vagal activities (e.g., relaxation), and inducing positive emotions in the afternoon may be useful to inhibit excessive increases in cardiac responses during work. Of course, further investigation in the future is necessary.

There are some limitations in the present study. First, the characteristics of the communication center (such as telephone communication with clients and others) may affect the results because the type of work also influences underlying hemodynamic responses^{15, 16}; additional, occupations should be examined in the future. Second, only male workers participated in investigation I; female workers should also be included in the future studies. Third, the lifestyle of participants, including habitual smoking and drinking, was not considered, although participants were instructed to refrain from alcohol intake during measurement periods and were prohibited from smoking during the 1-hour period preceding the measurements. Finally, participants in investigation I had to temporarily interrupt their work and walk to the measurement area, the influence of which is unknown.

In conclusion, the underlying hemodynamics in maintaining blood pressure during working hours changed between the morning and the afternoon in this study. Cardiac responses increased, but vascular responses decreased in the afternoon on working days; this change may occur only on working days. The results of the present study suggest that cardiac burden increases in the afternoon on working days and that taking underlying hemodynamic responses into consideration is important to manage the work-related cardiovascular burden of white-collar workers.

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