ELSEVIER

Applied Ergonomics 37 (2006) 311–318

APPLIED ERGONOMICS

www.elsevier.com/locate/apergo

# Responses of the autonomic nervous system during periods of perceived high and low work stress in younger and older female teachers

Tiina Ritvanen[a,*], Veikko Louhevaara[a], Pertti Helin[a], Sari Väisänen[b], Osmo Hänninen[a]

[a]Department of Physiology, University of Kuopio, P.O. Box 1627, FIN-70211 Kuopio, Finland
[b]Department of Clinical Chemistry, Kuopio University Hospital, P.O. Box 1777, FIN-70211 Kuopio, Finland

Received 18 August 2004; accepted 28 June 2005

**Abstract**

The aim of this study was to examine the response of the autonomic nervous system in younger (mean age 31 yrs, $n = 14$) and older (mean age 54 yrs, $n = 14$) healthy female teachers during work periods of perceived high and low stress. In the younger participants, heart rate, cortisol excretion rate and psychosomatic symptoms were significantly higher during the high work stress period. The older participants experienced no decrease in their heart rate and cortisol excretion during the low stress period and they exhibited no significant decrease in blood pressure after the work in the evening during both periods. It may be concluded that the recovery from the stress in the older teachers was insufficient particularly in view of their elevated diastolic blood pressure during the low work stress period. Ergonomic and individually tailored measures in terms of work time control, specific relaxation techniques, and a part-time retirement may improve the stress management of older teachers.


*Keywords:* Psychophysiological stress; Teachers; Ageing

## 1. Introduction

Teaching is considered to be a stressful occupation since teachers need to cope with many, often conflicting, demands from pupils, parents and managers. In addition, continuous changes to the curriculum and the need to master new information technologies impose pressures, especially for older teachers (e.g., Pithers and Fogarty, 1995; Griffith et al., 1999; Pithers and Soden, 1998). As the population and workforce age, the occupational health of older workers needs to be addressed also with respect to the relationship between work and leisure time to permit adequate recovery of these older workers (Griffiths, 1997). There are both positive and negative factors that characterize differences between older and younger workers. Older workers have decreased physical capabilities and somewhat slower mental processing, but their experience, motivation and competence may compensate for most of their physical and mental deficiencies (Wegman, 1999). The physical and mental workload of older workers may be reduced by applying various aspects of occupational ergonomics (Spirduso, 1995; Ilmarinen, 1999). Wood et al. (2002) have proposed that despite the age-related differences in heart rate variability, the central cardiovascular response, i.e., the response of the autonomic nervous system (ANS) to mental effort in healthy ageing adults, remains intact.

The stress responses are composed of alterations in behaviour, autonomic function and the secretion of several hormones including adrenocorticotropin hormone and cortisol/corticosterone, adrenal catecholamines, oxytoxin, prolactin and renin (Van der Kar and

*Corresponding author. Tel.: +358 17 163102; fax. +358 17 163112.
*E-mail address:* tiina.ritvanen@uku.fi (T. Ritvanen).

0003-6870/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apergo.2005.06.013

Blair, 1999). High work stress has been associated with increased risk of suffering cardiovascular disease (Siegrist et al., 1990; Lynch et al., 1997; Bosma et al., 1998). There is increasing evidence that an inadequate recovery from work predicts premature coronary events rather than activities related to the work (McEwen, 1998). Physiological mediators such us adrenaline, glucocorticoids, and cytokines, produced by the ANS, the hypothalamo–pituitary–adrenal (HPA) axis and the immune system, act on receptors in various tissues and organs to produce effects that are adaptive in the short term but can be harmful if the mediators are not suppressed when no longer needed. This leads to an "allostatic state", such as a chronic elevation of glucocorticoid secretion as a result of long-term stress (McEwen, 1998, 2000). The allostatic overload may lead to metabolic and cardiovascular changes that are associated with obesity, type 2 diabetes and cardiovascular disease (Seeman et al., 1997). Lundberg (2003) also reported that the lack of rest and recovery seems to affect health more than the mental or physical demands occurring during work. He suggested that psychosocial stress is related to pain in the neck and shoulder region by keeping low threshold motor units active also during recovery periods at work and even during leisure time.

The aim of the present study was to examine the responses of the ANS during the perceived high and low work-related stress periods in younger and older female teachers by comparing their blood pressure (BP) and heart rate (HR) between these two periods. Also morning plasma cortisol excretion and recovery HR of the teachers from light physical exercise during the low and high stress periods were examined. In addition, changes of their BP and HR between the working day and evening during both periods were studied and the predictors of BP and HR at work and home were also calculated for the teachers.

## 2. Study participants and methods

### 2.1. Participants

Twenty-eight (28) female teachers volunteered to participate in this study. All study participants were healthy and free of cardiovascular diseases as assessed by medical history. Two of them were smokers. Five of the participants were receiving postmenopausal hormone replacement therapy, and seven of them were taking oral contraceptives. The participants were divided into two age groups ($p = 0.002$) representing younger (range 26–35 yrs, mean age 31 yrs, $n = 14$), and older (range 50–57 yrs, mean age 54 yrs, $n = 14$) female teachers. The study protocol was approved by the Ethics Committee of Kuopio University Hospital. Each participant provided full informed consent.

### 2.2. Methods

The study was carried out over two periods when the participants had experienced high and low work stress during the past two weeks according to a visual analogue scale (VAS) (Price et al., 1983) modified to assess perceived stress. The results of each VAS were reported in millimetres (scale 0–100 mm, with the end points of no stress and extremely high stress). Work stress was classified as high when VAS $>60$ mm and low when VAS $<30$ mm.

The body mass index (BMI) of the participants was calculated as weight in kilograms divided by height in metres squared (Bray, 1992). Their waist circumference and hip circumference were measured at the mid point between the lowest rib and the iliac crest, and at the level of the great trochanters (WHO, 1995), respectively. Their waist–hip ratio (WHR) was calculated. The various psychosomatic symptoms were inquired with the scale of 0–5, where "never" = 0 and "every working day" = 5. The registered symptoms were headache, tiredness, anxiety, tenseness, nervousness, depressed mood, stomach pain, mild fever, indisposition, sleeping disorder and exhaustion. The theoretical range of the sum-scale was 0–55. The sum-scale was modified from that of Pohjonen (2001). The Cronbach's alpha value of the scale was 0.78.

A step test was carried out at the work site at the same place and time of the day during the high and low stress periods. Before the test, the participants rested in a seated position for 5 min, and were then asked to step up and down on a bench at a constant rate of 50 steps per minute for 6 min. The height of the bench was 25 cm. After the test, the participants sat and rested for 5 min. HR was recorded with the cardiac monitor of Polar S810 (Polar Electro Ltd., Kempele, Finland) at 1-s intervals. The lowest resting HR was used as the baseline HR. The recordings of HR were visually inspected to exclude possible artefacts. The HR recovery was defined as the decrease in HR during the first and second minute after the termination of the step test.

The venous blood samples were taken in the morning between 8 and 9 a.m. from the forearm with the participants seated after a 12 h fast for the cortisol and lipoprotein lipid assays. The samples were transferred into chilled tubes, and plasma was separated by centrifugation at 4 °C. Plasma cholesterol (CHOD-PAP method, Thermo Electron Co., Vantaa, Finland) and triglycerides (GPO-PAP method, Thermo Electron Co.) were analysed using enzymatic photometric assays. Direct enzymatic colorimetric methods were used for HDL (Konelab HDL-CHOLESTEROL, Thermo Electron Co.) and LDL cholesterol (Konelab LDL-CHOLESTEROL, Thermo Electron Co.) analyses. The Konelab 60i clinical chemistry analyzer (Labsystems CLD, Konelab, Finland) was used for all analyses.

Between-run coefficients of variation for cholesterol, triglycerides, HDL and LDL cholesterol assays were 1.2%, 2.0%, 3.3% and 1.8%, respectively.

The plasma fractions were frozen and stored at −80 °C until the cortisol level was assayed. The Immulite 2000 Cortisol method based on the EIA principle with chemiluminescense detection was used to quantitate cortisol levels (Diagnostic Products Corporation, Los Angeles, CA, USA).

The participants measured their BP and HR with an automatic device (Omron M4, Matsusaka Co., Ltd., Japan). They were instructed to perform measurements by sitting comfortably in a chair and to relax for 5 min before each recording. They refrained from drinking coffee or tea, smoking or doing any sporting activities for at least 1 h before the measurements. BP and HR were measured three times at intervals of 1 min in the morning immediately after awakening, in the afternoon at the worksite and in the evening at home. The average of the three measurements was used in the analysis of the data.

### 2.3. Statistical analysis

Means and standard deviations were used to describe the data. The Student's *t*-test was used to examine group differences in physical characteristics and physical activity levels. Differences between the low and high stress periods within the groups were calculated using the Student's *t*-test with paired samples. Analyses of variance (ANOVA) was used to examine the HR responses during recovery after the step test. A Bonferroni test was used to isolate specific differences between the groups in the HR responses during recovery. Relations of hips to age were determined by linear regression analyses with the calculation of Pearson Product correlation coefficients. Multiple backward regression analyses were used to determine the independent predictors of BP and HR at work. Statistical significance was denoted by $p<0.05$.

## 3. Results

### 3.1. Comparison of the physiological parameters in the younger and older participants

Waist circumference and WHR were significantly ($p<0.05$) greater in the older participants. Other differences in physiological characteristics were insignificant between the groups (Table 1).

### 3.2. Lipid levels and cortisol excretion during the high and low stress periods

Psychosomatic symptoms were significantly more common during the high stress work periods both in younger ($p<0.001$) and older participants ($p<0.05$). Cortisol excretion was significantly greater during the high stress periods in the younger participants ($p<0.05$). Total cholesterol concentration was significantly lower in the younger participants compared to the older ones during both high and low stress periods ($p<0.05$) and these individuals had also significantly lower serum triglyceride levels during the low stress periods compared to their older colleagues ($p<0.05$) (Table 2).

### 3.3. HR responses to the step test during the high and low stress periods

The resting HR of the younger participants was, on average, 7 beats/min higher during the high stress period compared to the periods of low stress ($p = 0.045$). Their HR was, on average, 9, 10 and 11 beats/min higher during the sixth minute of stepping ($p = 0.025$), and during the first ($p = 0.004$), and second ($p = 0.009$) minute of recovery, respectively, during the high stress period compared to the corresponding values taken during low stress. These kinds of differences were not observed in the older participants. The average HR response of the younger participants in the step test was 16 beats/min higher during the high than low stress

Table 1
Characteristics of the younger (age 26–35 yrs) and older (age 50–57 yrs) participants

| Variables | Younger ($n = 14$) | Older ($n = 14$) | $P$ |
|---|---|---|---|
| Height (cm) | 166 (5) | 165 (5) | NS |
| Weight (kg) | 62 (6) | 66 (9) | NS |
| BMI (kg/m$^2$) | 22.4 (3.7) | 24.3 (3.5) | NS |
| Hip circumference (cm) | 99.8 (6.7) | 104 (9.0) | NS |
| Waist circumference (cm) | 76.1 (9.0) | 84.9 (11.0) | 0.023 |
| WHR[a] | 0.77 (0.06) | 0.81 (0.06) | 0.035 |
| Absenteeism (days/year) | 2.9 (3.2) | 1.8 (2.3) | NS |
| Exercise activity[b] | 3.0 (1.6) | 3 (1.2) | NS |

The values are means (standard deviations).
[a]Waist–hip ratio.
[b]Time/week at least 30 min.

Table 2
Symptoms, lipids and cortisol of the younger and older participants during the low and high stress periods

| Variables | Younger ($n = 14$) | | Older ($n = 14$) | |
|---|---|---|---|---|
| | Low | High | Low | High |
| Psychosomatic symptoms | 15 (7) | 22 (10)*** | 11 (7) | 17 (7)* |
| Triglycerides (mmol/l) | 0.98 (0.70)# | 0.85 (0.71) | 1.10 (0.43) | 0.93 (0.27) |
| Cholesterol, total (mmol) | 4.65 (0.68)# | 4.50 (0.59)# | 5.33 (0.75) | 5.22 (0.65) |
| Cholesterol, LDL (mmol) | 2.53 (0.59) | 2.45 (0.44) | 2.98 (0.82) | 2.81 (0.70) |
| Cholesterol, HDL (mmol/l) | 1.59 (0.29) | 1.53 (0.33) | 1.61 (0.44) | 1.76 (0.51) |
| Cortisol (mmol/l) | 323 (161) | 355 (168)* | 362 (109) | 356 (120) |

The values are means (standard deviations).
Significance between the low and high stress periods within the groups, *$p<0.05$, ***$p<0.001$, #$p<0.05$ between groups.

period ($p = 0.008$). No significant differences in their recovery HR values were observed during periods of low and high stress. Compared to the older participants, the HR responses of the younger participants during the sixth minute of stepping averaged 10 beats/min higher ($p<0.05$) during the high stress period, but there were no significant differences in the recovery HR values between the younger and older participants. In the younger participants, the resting HR values were, on average, 6 beats/min higher ($p<0.05$) during the high stress period compared to those of the older participants (Fig. 1).

### 3.4. BP and HR during the high and low stress periods

Diastolic and systolic BP values measured in the morning were equal during both the low and high work stress periods in the younger and older participants. In the younger participants, morning HR was significantly higher ($p<0.01$) during the high stress period. In the older participants, systolic ($p<0.01$) and diastolic ($p<0.001$) BP were significantly higher at work at 12.00–14.00 and in the evening at home at 18.00–20.00 ($p>0.01$) during the high stress period. In the younger participants, HR was significantly higher at home ($p<0.01$) during the high stress period. The systolic and diastolic BP values were, on average, 8 mmHg ($p<0.001$) lower in the younger participants when their values obtained at work and in the evening were compared during the periods of both low and high stress. In the older participants, the corresponding differences in the systolic and diastolic BP were insignificant (Table 3).

### 3.5. Associations between cardiovascular response and age during the high and low stress periods

Age correlated positively significantly with the diastolic BP at work at 12.00–14.00 ($r = 0.50$, $p = 0.005$)

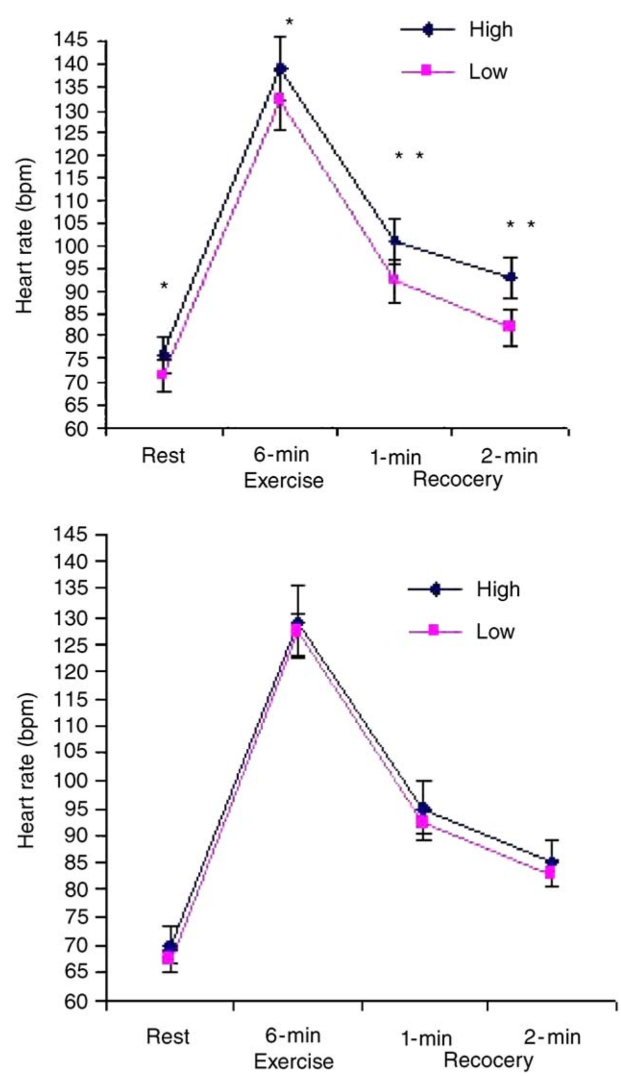


Fig. 1. The rest and submaximal exercise (the sixth minute) and recovery (the first and second minute) heart rate responses (bpm = beats/min) during the high and low stress periods in the younger (upper panel) and older (lower panel) participants. The values are means. *$p<0.05$ and **$p<0.01$ significance differences between the high and low stress periods in the two age groups.

Table 3
Systolic (SBP) and diastolic blood pressures (DBP) and heart rate (HR) of the younger and older participants during the low and high stress periods

| Periods | Groups | Stress | SBP (mmHg) | DBP (mmHg) | HR (bpm) |
|---|---|---|---|---|---|
| At home | | | | | |
| 7.00 | Younger | Low | 108 (13) | 70 (8) | 62 (12)** |
| | | High | 109 (14) | 70 (8) | 69 (10) |
| | Older | Low | 117 (15) | 75 (8) | 63 (8) |
| | | High | 116 (19) | 76 (10) | 65 (8) |
| At work | | | | | |
| 14.00 | Younger | Low | 121 (11)$^{\#}$ | 78 (9)$^{\#}$ | 63 (7)* |
| | | High | 124 (10)$^{\#}$ | 77 (9)$^{\#}$ | 68 (11) |
| | Older | Low | 125 (17)** | 78 (6)*** | 65 (9) |
| | | High | 134 (23) | 87 (8) | 68 (11) |
| At home | | | | | |
| 20.00 | Younger | Low | 111 (11) | 70 (7) | 59 (7)** |
| | | High | 117 (14) | 72 (9) | 69 (11) |
| | Older | Low | 116 (13)* | 75 (8)* | 63 (7) |
| | | High | 124 (17) | 80 (7) | 66 (9) |

The values are means (standard deviations).
Significance between the low and high stress periods within the groups *$p<0.05$, **$p<0.01$, ***$p<0.001$, between the working day and evening within the groups $^{\#}p<0.05$, paired samples $t$-test.

Table 4
Multiple regression models of diastolic blood pressure (DBP) during the high and low work stress periods

| Dependent variable | $r^2$ | $p$ | Independent[a] variable | $\beta$ | $p$ |
|---|---|---|---|---|---|
| *High work stress* | | | | | |
| DBP at work | 0.23 | 0.005 | Age | 0.41 | 0.011 |
| | | | Cortisol | 0.40 | 0.013 |
| | | | LDL | 0.36 | 0.031 |
| DBP in the evening | 0.34 | 0.002 | Age | 0.61 | 0.001 |
| | | | HDL | −0.34 | 0.043 |
| *Low work stress* | | | | | |
| DBP at work | 0.20 | 0.020 | WHR | 0.53 | 0.007 |
| DBP in the evening | 0.43 | 0.001 | WHR | 0.50 | 0.006 |
| | | | Age | 0.39 | 0.018 |

[a]Age, WHR (waist–hip ratio), cortisol, total cholesterol, HDL, LDL, triglycerides.

and at home in the evening ($r = 0.53$, $p = 0.001$) during the high stress period and also during the low stress period in the evening ($r = 0.54$, $p = 0.002$). The regression analyses (independent variables; age, WHR, total cholesterol HDL, LDL, triglycerides and morning cortisol excretion) revealed that age ($\beta = 0.41$, $p = 0.011$), morning cortisol excretion ($\beta = 0.40$, $p = 0.013$) and LDL ($\beta = 0.36$, $p = 0.031$) predicted the higher diastolic BP at work during the high stress period, and accounted for 23% of the total variation ($p = 0.005$). Correspondingly, in the evening at home, age ($\beta = 0.61$, $p = 0.001$) and HDL ($\beta = -0.34$, $p = 0.043$) predicted 34% of the total variation of the diastolic BP ($p = 0.002$). Furthermore, during the low stress period, the higher diastolic BP at work was significantly associated with WHR ($r^2 = 0.20$, $p = 0.020$, $\beta = 0.53$, $p = 0.007$). At home in the evening, WHR ($\beta = 0.50$, $p = 0.006$) and age ($\beta = 0.39$, $p = 0.018$) predicted 43% of the total variation of the diastolic BP ($p = 0.001$). No corresponding associations were observed with the systolic BP or HR (Table 4).

## 4. Discussion

In the present study, the higher BP and HR values of the samples of older and younger female teachers during the perceived high stress periods reflected the shift to a relative predominance of sympathetic nervous system activity. These results are consistent with many previous studies e.g., Lundberg and Frankenhaeuser (1980) and Theorell et al. (1991). In principal, cardiac autonomic control varies as a function of self-reported stress (Sloan et al., 1994).

The present elevated HR and BP values at work were consistent with other non-ambulatory studies (Frankenhaeuser et al., 1989; Stoney, 1992; Ritvanen et al., 2003) and ambulatory studies (Goldstein et al., 1999; Steptoe et al., 2000) as cardiovascular responses usually increase at work and decrease after work at home (Steptoe, 1997). According to the allostatic load model (McEwen, 2000) ANS contributes to the physiological adaptive process in the short run but may be damaging if the release of the mediators such as adrenaline from the adrenal medulla is not terminated when no longer needed. In the present study, the younger teachers seem to recover after the working day at home and their BP and HR values were also significantly lower during the low work stress period. In contrast, the systolic and diastolic BP of the older teachers failed to decrease in the evening during both the high and low stress periods. The results revealed that age predicted the increased BP reactivity with or without perceived stress. The greater BP reactivity of older individuals is considered to be due to an age-related increase in both cardiac output and total peripheral resistance occurring during daily activities (Whelton, 1994). In the present multivariate analysis, age predicted elevated diastolic BP during the high stress period, whereas during the low work stress period, WHR was the main predictor of elevated diastolic BP. Similar contradictory results have been reported previously based on both ambulatory (Blumenthal et al., 1995; Cesana et al., 1996) and non-ambulatory studies (Albright et al., 1992; Light and Turner, 1992) since the assessment of occupational stress generally relies on often subjectively biased self-reporting (Theorell, 1990; Muneta et al., 1997).

To minimize potential individual factors that may result in bias, this study was conducted in normotensive participants to quantify the association between work stress and BP. It is probable that BP and HR are higher during stressful periods because individuals are more active both at work and home. These various confounding factors were controlled during the BP and HR measurements by performing the measurements in the same position after the same resting time for each recording. To fully exclude this kind of bias, long-term ambulatory BP recordings during work and leisure time could be undertaken in future studies.

In the older teachers, the present study failed to detect differences in HR responses between the low and high stress periods at work and in the step test. This might indicate that age decreases the HR variability during high stress (Wood et al., 2002). The ANS contributes to the physiological adaptive process involving the stress factors and ageing attenuates the regulatory capacity. The persistent sympathetic drive and reduced vagal tone attenuate the capacity to recover after stress (Fukusaki et al., 2000). Good ergonomics such appropriate work–rest regimens, physical activity and relaxation techniques may help protect against these age-related processes that reduce the capacity of the ANS.

In the step test, the younger teachers experienced a higher HR response during the high stress period because their resting HR was already elevated. Thus, it seems that the sympathetic nervous system of younger teachers had been activated during the high stress period. On the other hand, their exercise and recovery responses in the step test were similar during both the high and low stress periods. There were slight differences between the younger and older teachers in HR responses in the step test. Healthy individuals seem to react differently to psychological and physical stress as suggested by Schwartz et al. (2003), Shannon et al. (1997) and Wood et al. (2002). Singh et al. (1999) reported that men who were highly responsive to physical stress were also highly responsive to psychological stress.

One explanation for lower HR levels of the older teachers may be that because of their long work history in teaching, they have learned the skills needed for coping with the many stress evoking problems at work. Those individuals with coping failures may leave the teaching profession after a few years. It is also possible that teachers still rate their jobs as stressful, even though they experience no periods of acute stress during the routine working day. Another explanation is that the older teachers in some way had limited their activities during the measurement day. Costa et al. (1999) reported that energy expenditure was lower on the day of ambulatory monitoring than on the subsequent day. The multiple activities that women may have to do in the evening should also be noted. In addition, Crews and Landers (1987) showed in their meta-analysis that individuals who were physically active or fit had lower cardiovascular responses to psychosocial stress factors. This may also have affected the present results.

Cortisol is widely regarded as an objective marker of changes in psychological stress (Kirschbaum et al., 1995), and cortisol levels have been shown to increase during periods of both acute (Al'Apsi et al., 1997) and chronic (Vedhara et al., 1999) stress. In the present study, younger teachers exhibited significantly greater cortisol excretion during the high stress period. This seems to indicate that the HPA axis does 'shut off' when it is no longer needed during the low work stress period. No significant differences in cortisol excretion were found among the older teachers between the low and high stress work periods. Nevertheless, the morning cortisol with LDL concentration and age was related to diastolic BP. The morning cortisol levels were assessed at 8:00–9:00 when the teachers arrived at school during both the low and high stress periods. The weakness in this test design is that cortisol (plasma) concentration increases markedly in the first 30–45 min after arousal in the morning and then begins to decline (Schulz et al., 1998). Since cortisol levels decline very rapidly after the waking up, the difference between the wake up time between the low and high stress periods may have affected the cortisol levels, due to the normal diurnal variation. The observed higher plasma concentrations of total cholesterol and triglycerides in the older teachers are in agreement with earlier studies showing that ageing increases cholesterol levels (Despres et al., 1988; Ericsson et al., 1991; Lemieux et al., 1995; Ryan et al., 1996; Williams and Krauss, 1997; Nicklas et al., 1999). No differences in lipid levels were observed between the low and high stress periods.

The timing of the cardiovascular sampling in relation to the menstrual cycle could be important, since differences are claimed to be most pronounced among women in the luteal phase (days 21–25 of the menstrual cycle) (Kirschbaum et al., 1999). In the present study, the female teachers were not tested at the same phase of the menstrual cycle. However, in a discussion on variables encountered in non-ambulatory studies, Stoney (1992) concluded that the interaction of cardiovascular variables and the menstrual cycle phase was minor and inconsistent when used in a between-subjects design. Moreover, usually no effect of the menstrual cycle phase has been detected on the cardiovascular stress responses in studies utilizing a within-subjects design. Komesaroff et al. (1999) reported that estrogen supplementation in perimenopausal women could attenuate BP, glucocorticoid, and catecholamine responses to psychological stress. However, estrogen appeared to have no effect on HR.

Some limitations of the present study need to be noted. The results cannot be generalized to all teachers due to the relatively small sample size and the fact that only female teachers were examined. It is not known whether the nature of the environmental and other events have initiated perceived high stress during the working period. Nevertheless, the current analyses suggest that stress can provoke cardiovascular activation. The ANS of the younger teachers seems to recover after work during both low and high work stress periods. This recovery was not clearly observed in the older teachers. The increase in the diastolic BP of teachers associated with ageing should receive special attention. Individually tailored ergonomics including appropriate work–rest regimens must be arranged when the curriculum is planned and time scheduling measures may also help to improve stress management. Teachers need to have access to a special silent room where they can relax and recover during the stressful work periods. In conclusion, ergonomic and individual measures in terms of work time control, specific relaxing techniques and a partial retirement may improve the stress management for older teachers.

## References


Al'Apsi, M., Bongard, S., Buchanan, T., Pincomb, GA., Licinio, J., Lovallo, WR., 1997. Cardiovascular and neuroendocrine adjustment to public speaking and mental arithmetic stressors. Psychophysiology 34, 266–275.

Albright, CL., Winkleby, MA., Ragland, DR., Fisher, J., Syme, SL., 1992. Job strain and prevalence of hypertension in a biracial population of urban bus drivers. Am. J. Public Health 82 (7), 984–989.

Blumenthal, JA., Thyrum, ET., Siegel, WC., 1995. Contribution of job strain, job status and marital status to laboratory and ambulatory blood pressure in patients with mild hypertension. J. Psychosom. Res. 39, 133–144.

Bosma, H., Peter, R., Siegrist, J., Marmot, M., 1998. Two alternative job stress models and the risk of coronary heart disease. Am. J. Public Health 88, 68–74.

Bray, G.A., 1992. An approach to the classification and evaluation of obesity. In: Björntorp, P., Brodoff, B.N. (Eds.), Obesity. JB Lippincott, Philadelphia, pp. 294–308.

Cesana, G., Ferrario, M., Sega, R., Milesi, C., De Vito, G., Mancia, G., Zanchetti, A., 1996. Job strain and ambulatory blood pressure levels in a population-based employed sample of men from northern Italy. Scand. J. Work Environ. Health 22, 294–305.

Costa, M., Steptoe, A., Cropley, M., Griffith, J., 1999. Ambulatory blood pressure monitoring is associated with reduced physical activity during everyday life. Psychosom. Med. 61, 806–811.

Crews, DJ., Landers, DM., 1987. A meta-analytic review of aerobic fitness and reactivity to psychosocial stressors. Med. Sci. Sports Exerc. 19, 114–120.

Despres, JP., Trenmblay, A., Leblanc, C., Bouchard, C., 1988. Effect of the amount of body fat on the age-associated increase in serum cholesterol. Prev. Med. 17, 423–431.

Ericsson, S., Erikssom, M., Vitols, S., Einarsson, K., Berglund, L., Angelin, B., 1991. Influence of age on the metabolism of plasma low density lipoproteins in healthy males. J. Clin. Invest. 87, 591–596.

Frankenhaeuser, M., Lundberg, U., Fredrikson, M., Melin, B., Tuomisto, M., Myrsten, AL., Hedman, M., Bergman-Losman, B., Wallin, L., 1989. Stress on and off the job as related to sex and occupational status in white-collar workers. J. Organ. Behav. 10, 321–346.

Fukusaki, C., Kawakubo, K., Yamamoto, Y., 2000. Assessment of the primary effect of aging on heart rate variability in humans. Clin. Auton. Res. 10 (3), 123–130.

Goldstein, IB., Shapiro, D., Chicz-DeMet, A., Guthrie, D., 1999. Ambulatory blood pressure, heart rate, and neuroendocrine responses in women nurses during work and off work days. Psychosom. Med. 61, 387–396.

Griffith, J., Steptoe, A., Cropley, M., 1999. An investigation of coping strategies associated with job stress in teachers. Br. J. Educ. Psychol. 69, 517–531.

Griffiths, A., 1997. Ageing, health and productivity: a challenge for the new millennium. Work Stress 11, 197–214.

Ilmarinen, J., 1999. Ageing Workers in the European Union—Status and Promotion of Work Ability, Employability and Employment. Finnish Institute of Occupational Health, Ministry of Social Affairs and Health, Ministry of Labour, Helsinki.

Kirschbaum, C., Kudielka, B.M., Gaab, J., Schommer, N.C., Hellhammer, D.H., 1999. Impact of gender, menstrual cycle phase, and oral contraceptives on the activity of the hypothalamus–pituitary–adrenal axis. Psychosom. Med. 6, 154–162.

Kirschbaum, S., Prussner, JC., Stone, AA., Federenko, I., Gaab, J., Lintz, D., Schommer, N., Hellhammer, D.H., 1995. Persistent high cortisol responses to repeated psychological stress in a subpopulation of healthy men. Psychosom. Med. 57, 468–474.

Komesaroff, P.A., Esler, M.D., Sudhir, K., 1999. Estrogen supplementation attenuates glucocorticoid and catecholamine responses to mental stress in perimenopausal women. J. Clin. Endocrinol. Metab. 84, 606–610.

Lemieux, S., Prud'homme, D., Moorjani, S., Tremblay, A., Bouchard, C., Lupien, P.J., Despres, J.-P., 1995. Do elevated levels of abdominal visceral adipose tissue contribute to age-related differences in plasma lipoprotein concentrations in men? Atherosclerosis 118, 155–164.

Light, K., Turner, J.R., 1992. Job strain and ambulatory work blood pressure in healthy young men and women. Hypertension 20, 214–218.

Lundberg, U., 2003. Psychological stress and musculoskeletal disorders: psychobiological mechanisms. Lack of rest and recovery greater problem than workload. Lakartidningen 22, 1992–1995.

Lundberg, U., Frankenhaeuser, M., 1980. Pituitary–adrenal and sympathetic–adrenal correlates of distress and effort. J. Psychosom. Res. 24 (3–4), 125–130.

Lynch, J., Krause, N., Kaplan, GA., Salonen, R., Salonen, JT., 1997. Workplace demands, economic reward, and progression of carotid atherosclerosis. Circulation 96, 302–307.

McEwen, B.S., 1998. Protective and damaging effects of stress mediators. N. Engl. J. Med. 338, 171–179.

McEwen, B.S., 2000. Allostasis and allostatic load: implications for neuropsychopharmacology. Neuropsychopharmacology 22, 108–124.

Muneta, S., Kobayashi, T., Matsumoto, I., 1997. Personality characteristics of patients with "white coat" hypertension. Hypertension Res. 22, 99–104.

Nicklas, B.J., Ryan, A.S., Katzel, L.I., 1999. Lipoprotein subfractions in women athletes: effects of age, visceral obesity and aerobic fitness. Int. J. Obesity 23, 41–47.

Pithers, R.T., Fogarty, G.J., 1995. Occupational stress among vocational teachers. Br. J. Educ. Psychol. 65, 3–14.

Pithers, R.T., Soden, R., 1998. Scottish and Australian teacher stress and strain: a comparative study. Br. J. Educ. Psychol. 68, 269–279.

Pohjonen, T., 2001. Perceived work ability of home care workers in relation to individual and work-related factors in different age groups. Occup. Med. 51, 209–217.

Price, D., McGrath, P.A., Rafii, A., Buckinham, B., 1983. The validation of visual analogue scale as ratio scale measure for chronic and experimental pain. Pain 17, 45–56.

Ritvanen, T., Louhevaara, V., Helin, P., Halonen, T., Hänninen, O., 2003. Psychophysiological stress in high school teachers. Internat. J. Occup. Environ. Health 16, 255–264.

Ryan, A.S., Nicklas, B.J., Elahi, D., 1996. A cross-sectional study on body composition and energy expenditure in women athletes during aging. Am. J. Physiol. 271, E916–E921.

Schulz, P., Kirschbaum, C., Pruessner, J.C., Hellhammer, D.H., 1998. Increased free cortisol secretion after awakening in chronically stressed individuals due to work overload. Stress Med. 14, 91–97.

Schwartz, J.B., Gibb, W.J., Tran, T., 2003. Aging effects on heart rate variation. J. Gerontol. 46, M99–M106.

Seeman, T.E., Singer, B.H., Rowe, J.W., Horwitz, R.I., McEwen, B.S., 1997. Price of adaptation—allostatic load and its health consequences. MacArthur studies of successful aging. Arch. Intern. Med. 27, 2259–2268.

Shannon, D.C., Carley, D.W., Benson, H., 1997. Aging modulation of heart rate. Am. J. Physiol. 253, H874–H877.

Siegrist, J., Peter, R., Junge, A., Cremer, P., Seidel, D., 1990. Low status control, high effort at work and ischemic heart disease: prospective evidence from blue-collar men. Soc. Sci. Med. 31, 1127–1134.

Singh, A., Petrides, J.S., Gold, P.W., Chorousos, G.P., Deuster, P., 1999. Differential hypothalamic–pituitary–adrenal axis reactivity to psychological and physical stress. J. Clin. Endocrinol. Metab. 84, 1944–1948.

Sloan, R.P., Shapiro, P.A., Bagiella, E., Boni, S.M., Paik, M., Bigger, J.T., Gorman, J.M., 1994. Effect of mental stress throughout the day on cardiac autonomic control. Biol. Psychol. 37, 89–99.

Spirduso, W.W., 1995. Physical Dimensions of Ageing. Human Kinetics, Champaign, IL.

Steptoe, A., 1997. Behavior and blood pressure: implications for hypertension. In: Zanchetti, A., Mancia, G. (Eds.), Handbook of Hypertension—Pathophysiology of Hypertension. Elsevier Science, Amsterdam.

Steptoe, A., Lundwall, K., Cropley, M., 2000. Gender, family structure and cardiovascular activity during the working day and evening. Soc. Sci. Med. 50, 531–539.

Stoney, C.M., 1992. The role of reproductive hormones in cardiovascular and neuroendocrine function during behavioural stress. In: Turner, J.R., Sherwood, A., Light, K.C. (Eds.), Individual Differences in Cardiovascular Response to Stress. Plenum Press, New York, pp. 147–163.

Theorell, T., 1990. Family history of hypertension—an individual trait interacting with spontaneously occurring job stressors. Scand. J. Work Environ. Health 16, 74–79.

Theorell, T., Harms-Ringdahl, K., Ahlberg-Hulten, G., Westin, B., 1991. Psychosocial job factors and symptoms from the locomotor system—a multicausal analysis. Scand. J. Rehabil. Med. 23 (3), 165–173.

Van der Kar, L.D., Blair, M.L., 1999. Forebrain pathways mediating stress induced hormone secretion. Front. Neuroendocrinol. 20, 1–48.

Vedhara, K., Cox, N.K.M., Wilcock, G.K., Perks, P., Hunt, M., Anderson, S., Lightman, S.L., Shanks, N.M., 1999. Chronic stress in elderly care of dementia patients and antibody response to influenza vaccination. Lancet 353, 627–631.

Wegman, D.H., 1999. Older workers. Occup. Med. 14, 537–557.

Whelton, P.K., 1994. Epidemiology of hypertension. Lancet 344, 101–106.

WHO Expert Committee on Physical Status, 1995. The Use and Interpretation of Anthropometry: Report of a WHO Expert Committee. WHO, Geneva.

Williams, P.T., Krauss, R.M., 1997. Associations of age, adiposity, menopause and alcohol intake with low-density lipoprotein subclasses. Arterioscler. Thromb. Vasc. Biol. 17, 1082–1090.

Wood, R., Maraj, B., Lee, C.M., Reyes, R., 2002. Short-term heart rate variability during a cognitive challenge in young and older adults. Age Aging 31, 131–135.