Seasonal Psychophysiological Stress of Teachers Related to Age and Aerobic Fitness

Doctoral dissertation

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ABSTRACT

The aims of this study were to investigate teachers' psychophysiological stress responses over one school year and the recovery process after a weekend rest, during the summer holiday and during the perceived low work stress period. The effects of age and aerobic fitness on the psychophysiological stress responses at work and the association between allostatic load indicators i.e. cortisol, BP, plasma lipids, waist-to-hip ratio (WHR) and psychosomatic symptoms during the perceived low and high work-related stress periods were also examined.

The participants were healthy male and female volunteers. The participants in Studies IV and V consisted of female teachers. The perceived stress was recorded using a visual analogue scale (VAS). The neuroendocrine reactivity was assessed by determining the diurnal urine excretion of epinephrine and norepinephrine and cortisol with morning plasma samples. Lipid levels were assessed during the perceived high and low work stress period. BP and heart rate (HR) were measured in a non-ambulatory manner in the field and autonomic nervous function tests were carried out in the laboratory. Aerobic fitness i.e. maximal oxygen uptake (VO₂max) was assessed with a submaximal cycle-ergometer test. Electromyography (EMG) of the trapezius muscle was recorded during working days and also in summer holidays.

The results indicated that teacher psychophysiological stress was at the same level during December, March and October but a significant decrease of psychophysiological stress response was detected during the summer holidays. After the work-week's stress the weekend stress recovery of autonomic nervous system was inadequate. Good aerobic fitness seemed to alleviate muscle tension and HR in the work of teachers. The hypothalamic-pituitary-adrenal axis and sympathetic adrenal medulla systems were activated significantly in the younger female teachers during the perceived high stress period compared to the perceived low stress period, i.e. the allostatic load lowered during the low stress period. In the older teachers, these two stress system responses did not differ between perceived high and low stress periods. In addition, the older teachers exhibited no significant decrease in BP after work in the evening during both periods. The association of allostatic load indicators, age and psychosomatic symptoms with the perceived high stress period may lead to allostatic overload and increased risk of ill-health over the long-term. Therefore adequate recovery from work-related stress and finding appropriate ways of coping are very important health factors for teachers.

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ABBREVIATIONS

ACTH: adrenocorticotropic hormone
ANOVA: analysis of variance
ANCOVA: analysis of covariance
ANS: autonomic nervous system
BP: blood pressure
BMI: body mass index
CRF: corticotropin-releasing factor
CVD: cardiovascular disease
EMG: electromyography
EPI: epinephrine
DBP: diastolic blood pressure
HDL: high density lipoprotein
HF: high frequency
HPA: hypothalamic-pituitary-adrenal
HR: heart rate
HRV: heart rate variability
LF: low frequency
NE: norepinephrine
PNS: parasympathetic nervous system
RMS: root mean square
RRI: R-R interval
SAM: sympathetic-adrenal medullary
SBP: systolic blood pressure
SNS: sympathetic nervous system
TP: total power
VAS: visual analogue scale
VLF: very low frequency
VO₂max: maximal oxygen uptake
WHR: waist-to-hip ratio
LIST OF THE ORIGINAL PUBLICATIONS

This thesis is based on the following original articles, which are referred to in the text by Roman numerals I - V:


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1 INTRODUCTION

In the European Working Conditions Survey published in 2000, work-related stress disorders were found to be the second most common work-related health problem (back pain was more common) in workers in the European Union (Paoli and Merllie 2001). Stress and burnout complaints were reported in occupations with high strain i.e. high workload and low job control (Karasek and Theorell 1990). Work-related stress impacts on worker satisfaction and productivity as well as mental and physical health, absenteeism with the resulting economic implications (Liukkonen et al. 1999). The working environment continues to change with globalisation of world economy and economic rationalisation forcing job restructuring, greater part-time and contract-type working, and greater workload demands (Tennant 2001, Landsbergis 2003).

Generally, stress is defined as responses to severe demands on the body. Selye (1976) defined stress as “the non-specific response of the body to any demand” emphasizing the role of an integrated response of multiple systems. The European Commission has defined work-related stress as a pattern of emotional, cognitive, behavioural and physiological reactions to adverse and noxious aspects of work content, work organisation and work environment. It is a state characterised by high levels of arousal and distress, often accompanied by feelings of not being able to cope.

Prolonged work-related stress is associated with coronary heart disease risk (e.g. Schnall et al. 1994), hypertension (e.g. Schwartz et al. 1996), mental health (e.g. Stansfeld et al. 1995), quality of life (e.g. Lerner et al. 1994), and other outcomes (e.g. van der Doef and Maes 1998). McEwen’s (1998) allostatic load model indicated that it is an inadequate recovery after work that predicts ill-health rather than activities related to the work itself. The allostatic state is benefited in the short term, but if the imbalance of the physiological regulation systems continues then this may have long-term negative effects on health.

Teachers were chosen for the study, since many take premature retirement i.e. the retirement rate doubled in the 1990’s as compared to other occupations in Finland (Kalimo and Toppinen 1997). Mental health problems like burnout are the most common reasons for premature retirement among teachers (Kalimo and Toppinen 1997). In schools there are many stress factors, such as time
demands, environmental and ergonomic shortcomings (i.e. increasing amount of inadequate air conditioning, increasing numbers of pupils per teacher) and precision demands, which are regarded as stressful (Kinnunen and Salo 1994, Kalimo and Toppinen 1997). In addition, continuous changes in the curriculum and the demands to master new information technology, are stressful, especially, among ageing teachers (Ilomäki and Rahikainen 2001).

The present study was carried out since research on teacher stress has mostly been based on cross-sectional surveys, but there have been few objective measurements of their psychophysiological stress responses in the field i.e. during actual work.

Psychophysiological measurements play an important role in the assessment of the interactions between work stress and health (e.g. Frankenhaeuser et al. 1989, Lundberg 1995, Kuiper et al. 1998). Psychophysiology is the relationship between mind and body and therefore psychophysiological stress research provides insights into the basic nature of this complicated phenomenon. The introduction of non-invasive measurement techniques has provided methods for applications of relevant psychophysiological recordings during actual work and they offer facilities to assess the allostatic load. The psychophysiological stress and recovery can be investigated, and thus, it may be possible to identify putative physiological characteristics that are correlated with work related stress responses, for instance, among teachers. The purpose of this study was to investigate a year and week based seasonal work-related psychophysiological stress of healthy younger and older teachers with different levels of aerobic fitness.
2 REVIEW OF THE LITERATURE

2.1 Psychophysiological stress response

The stress responses are composed of alterations in behaviour, autonomic function and the secretion of several hormones (van der Kar and Blair 1999). The stress system coordinates the adaptive response of the organism to real or perceived stressors (Frankenhaeuser 1981, Lazarus 1999). The physiological systems that are critically involved on the stress response are the sympathetic-adrenal medullary (SAM) and the hypothalamic-pituitary-adrenal (HPA) axis systems (Fig. 1). In daily life, these systems respond to stressful events as well as to the diurnal cycle of rest and activity (al'Absi and Arnett 2000).

2.1.1 The autonomic nervous system and cardiovascular stress response

The autonomic nervous system (ANS) provides a rapidly available mechanism to provide a response mechanism to control a wide range of functions (Tsigos and Chrousos 1994). Cardiovascular, respiratory, gastrointestinal, renal, endocrine and other systems are regulated by the sympathetic nervous system (SNS) or the parasympathetic nervous system (PNS), or both (Gilbey and Spyer 1993). The ANS is an essential part of the integrated cardiovascular regulatory system (Barron and Chokroverty 1993). Both psychological (Pagani et al. 1991, Karemaker and Lie 2000) and physiological (Theorell 1986, Zotti et al. 1991) stress can affect cardiovascular functioning i.e. blood pressure (BP) and heart rate (HR) intervals and their variability. The fluctuations in the circulatory parameters reflect the rapid and long-term adaptation to the stressors (Specchia et al. 1991).
The SNS controls the activity of smooth and cardiac muscles. The cardiovascular center in the medulla receives sensory input from peripheral receptors in blood vessels, joints, and muscles. Stimuli these mechanical and chemical receptors that monitor the state of active muscle modify either vagal or sympathetic outflow to bring about the appropriate cardiovascular response (Herd 1991). Receptors, so-called baroreceptors in the aortic arch and carotid sinus respond to changes in arterial blood vessels and evoke a reflex slowing of
the HR, as well as a compensatory dilatation of the peripheral vasculature. This causes BP to decrease towards more normal levels (Cowley 1992, Rowell 1994).

The adrenal medulla receives a sympathetic innervation via preganglionic fibers directly from the spinal cord, causing the adrenal medulla to release epinephrine (EPI) and norepinephrine (NE) at the same time (Ganong 1999), but the effects of NE in the circulation on tissues are limited (Lovallo 1997). Instead, EPI can affect the heart, blood vessels, and glands and its effects in the heart are essentially the same as direct stimulation of the sympathetic cardioaccelerator nerves i.e. depolarization of the sinus node that makes the heart beat faster. Acetylcholine, the neurotransmitter of parasympathetic nervous system, retards the rate of sinus discharge and slows the heart. This effect is largely mediated through the action of the vagus nerves whose cell bodies originate in the cardioinhibitory center in medulla (Guyton and Hall 1994).

2.1.2 The hormonal stress response

A common endocrine feature of the stress response is the activation of the HPA axis, leading to increases in plasma cortisol (DeRijk et al. 2002). Psychological or physical stress induces the hypothalamus to secrete corticotropin-releasing factor (CRF) and arginine vasopressin that stimulate the anterior pituitary to releases adrenocorticotropic hormone (ACTH). In turn, ACTH causes the adrenal cortex to release cortisol into the circulation (DeRijk et al. 2002). The overall activity of the HPA system is regulated by the hippocampus, a limbic brain structure involved in behavioural adaptation, through its binary glucocorticoid and mineralocorticoid receptors (Heuser and Lammers 2003). Whereas catecholamines facilitate the availability of energy to vital organs, glucocorticoids from the adrenals function as “antistress” hormones, helping to shut down the neural defensive reactions that have been activated by stress (Munck et al. 1984, McEwen 1998).

The typical neuroendocrine response occurs within seconds and initially, involves the increased secretion of EPI and NE from the SAM system, involving both central and peripheral compartments, the release of CRF and vasopressin into the portal circulation and increased secretion of oxytocin, and 5-10 s later, the secretion of pituitary ACTH (van der Kar and Blair 1999, Sapolsky et al. 2000). CRF plays a prominent role in mediating the effect of stressors on the
HPA axis, and in coordinating the endocrine, autonomic, behavioural and immune responses to stress (Vale et al. 1981, Dunn and Berridge 1990, De Souza 1995, De Kloet et al. 1998, van der Kar and Blair 1999, Stout et al. 2002). There is clear evidence that individuals can be classified as either high or low HPA axis responders (Kirschbaum et al. 1995, Gerra et al. 2001, Schommer et al. 2003), whereas the habituation of catecholamine responses seems to exhibit a different temporal profile (Schommer et al. 2003).

2.2 Aerobic fitness and psychophysiological stress responses

The maximal oxygen uptake (VO$_2$ max) is a commonly used determinant of aerobic (cardiovascular or cardiorespiratory) fitness. VO$_2$ max means the maximum capacity for oxygen consumption by the body during maximum exertion with the maximum amount of active muscle mass. That is also known as aerobic power or maximal oxygen consumption. VO$_2$ max (units are l/min or ml/min/kg) relates to how well the cardiovascular system works to transport and utilize oxygen in body muscles. VO$_2$ max is significantly related to age, gender, exercise habits, heredity, and the clinical status of the cardiorespiratory system (Fletcher et al. 1995, Erikssen 2001). Overall, good health is one of the most important factors in determining an individual's fitness for work. In sedentary jobs, less dynamic muscular work is needed than in those occupations requiring standing and walking (Ilmarinen et al. 1991, Ilmarinen 1992a, b). In contrast, for instance, fire-fighters need to have a good VO$_2$ max (Lusa et al. 1993).

There was only meagre scientific evidence on the effectiveness of physical activity programs at worksites for absenteeism and even less evidence for other occupational parameters e.g. job satisfaction, job stress and employee turnover, it is claimed to have absolutely no impact on productivity (Proper et al. 2002). On the other hand, several studies have shown that worksite physical exercise intervention can improve physical fitness and perceived health status and also prevent an early decline in work ability in the employees performing physically demanding work over a long-term period (Shephard 1996, Dishman et al. 1998, Pohjonen and Ranta 2001). The aerobic fitness and training status are associated with altered autonomic functions, e.g. a decrease in sympathetic activity and an increase in parasympathetic activity (Dixon et al. 1992, Sacknoff et al. 1994, Macor et al. 1996).

Plasma cortisol levels increase less in trained individuals compared with sedentary subjects in response to the same moderate exercise performance.
Some of this difference may be due to the elevated psychological stress experienced by the untrained persons during the testing. The NE and EPI hormones fall dramatically during the first few weeks of training (Herd 1991). Helin et al. (1988) reported that the stress experienced in shooters during a shooting competition seems to provoke mental tension above a suitable level e.g. by measurements of urinary biogenic amines, without any signs of overstimulation.

The decrease of HR and the smaller rise in BP during submaximal exercise is most likely a reflection of the result of sympathetic adrenal response. This kind of adaptation to training is a favourable response since it contributes to a lowering of myocardial oxygen demands both at rest and during submaximal exercise. This is the foundation for the belief that aerobic fitness might also reduce the physiological activation during psychological stress. However, there is no consensus that aerobic fitness can protect against the kind of stress that is related to lifestyle or occupation (Scully et al. 1998, Dishman and Jackson 2000). Several studies have attempted to investigate the effects of physical fitness on physiological stress responses in simulated mentally demanding tasks in the laboratory (e.g. Szabo et al. 1993, Choi and Salmon 1995, Boutcher et al. 1998, DiLorenzo et al. 1999, Summers et al. 1999) but only a few have been performed under field conditions (e.g. Brooke and Long 1987, Wittels et al. 1994).

Aerobic fitness seems to dampen stress responses and to improve an individual's capacity for stress coping (Brandon et al. 1991, Choi and Salmon 1995, DiLorenzo et al. 1999). Rejeski et al. (1992) reported that physical exercise acutely reduces the reactivity of the BP to psychosocial stress. Boutcher and Nugent (1993) reported that the absolute response of HR during and after repeated exposures to psychological stress factors is lower for aerobically fit compared to unfit individuals. Furthermore, Boutcher et al. (1998) suggested that the greater heart rate variability (HRV) at rest and the smaller decline of the HRV during and after a mental challenge could be influenced by both good aerobic fitness and genetic inheritance. In the study of Szapo et al. (1993), the reactivity of HR while the subjects did a mental arithmetic task was independent of the level of aerobic fitness.

Some studies have indicated that regular exercise provides no resistance to stress-related disease i.e. it does not alter psychological make-up or acute psychophysiological reactivity (e.g. De Geus et al. 1993, Summers et al. 1999). On the other hand, several studies suggest that aerobic fitness or regular
physical activity can act as a buffer against stress (Tucker et al. 1986, Brandon et al. 1991, Labbate et al. 1995, Aldana et al. 1996, Carmack et al. 1999). Dishman et al. (2002) found that fitter individuals had a greater increase in cardiac pace while performing mental arithmetic, which was thought to be a reflection of a decreased cardiac-vagal component of HRV, and a greater compensatory reduction in stroke volume. Therefore, aerobic fitness seemed to augment the cardiac-vagal withdrawal that characteristically appears when a subject does mental arithmetic. Laforest et al. (1990) reported that muscles of physically active individuals exhibited a greater resistance to fatigue. There is also evidence that aerobic fitness improves autonomic nervous regulation and increases immunoglobulin A secretion (Boutcher et al. 1998, Winzer et al. 1999). Overall, it appears that healthy individuals react differentially to stressful stimuli, such as psychological and physical stress (Schwartz et al. 1991, Shannon et al. 1997, Wood et al. 2002). Singh et al. (1999) reported that men who were highly responsive to exercise stress were also highly responsive to psychological stress compared to less physically active individuals.

2.3 Ageing and psychophysiological stress responses

The definition of an ageing worker is generally based on the period during the course of the working life when major changes occur in the relevant work related functions. Therefore, the ages of 45 or 50 years have often been used as the base criterion for the term "ageing worker" (Ilmarinen et al. 1997). By the year 2005, the age group of 50-64 years will account for 27% of the European Union workforce, while the age group of 18-24 years will account for only 18%. It has been predicted that in 2025 there will be twice as many workers aged 50 years or older than those aged 25 years or younger (Ilmarinen 1999). The Work Ability Index indicated that the age period 50-55 years seemed to represent a hazardous period in working life (Ilmarinen and Tuomi 1993). The occupational health of older workers needs to be addressed also with the respect to the relationship between work and leisure time, to permit adequate recovery of these older workers (Griffiths 1997). Rapid technological developments and globalization demands have meant that employees need to possess new skills and knowledge (Paulsson and Sundin 2000). Even in China, the level of occupational stress and strain increased with age and the occupational stresses and strains experienced by secondary school teachers were significantly higher than those felt by primary school teachers (Wang et al.
In Finland, teachers prefer to retire prematurely more often than workers in other occupations, this may due to both the normal biological ageing and inadequate recovery after work (Kinnunen et al. 1994).

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 they may compensate with their professional experience, motivation and competence for most of these physical and mental deficiencies (Wegman 1999). Changes in physical work capacity have often concentrated on the cardiovascular and musculoskeletal systems, tissue characteristics e.g. bone density and fat deposition, and some important sensory systems. VO$_{2}$max declines progressively with adult ageing and these changes are strongly dependent on the amount of aerobic exercise enjoyed after the age of 30 years (Shvartz and Reibold 1990, Ilmarinen 1992a,b). Changes in musculoskeletal capacity can be pronounced after the age of 45-50 years. In follow-up studies, both the maximal isometric trunk extension and flexion strength of male workers in physically and mentally demanding jobs decreased by 40-50% during a period of 10 years (Nygård et al. 1999). HRV that determines ANS based modulation of HR is known to decrease with age (Schwartz et al. 1991, Shannon et al. 1997, Wood et al. 2002). Wood et al. (2002) have proposed that despite the age-related differences in HRV, the central cardiovascular response to mental effort in healthy older adults remains intact. In addition, it is not clear to what extent age-related changes in autonomic modulation of HR are attributable solely to age, as the changes may be influenced by sedentary lifestyle and poor physical fitness. However, positive associations were found between total HRV and aerobic capacity among healthy older adults (Byrne et al. 1996, Yataco et al. 1997, Tulppo et al. 1998). Women seem to have a reduced low to high frequency ratio of HRV compared to men, although the absolute differences are much smaller than those associated with ageing (Huikuri et al. 1996, Jensen-Urstad et al. 1997, Barnett et al. 1999). Ageing decreases arterial and venous compliance due to both thickening of the endothelial linings and to a decline in the smooth muscle mass of blood vessels (Berne and Levy 1997). The consequent elevations in BP levels contribute to the increased afterload. In addition, thickening of the ventricular myocardium and shrinking of the cardiac ventricles of older individuals combine to diminish cardiac output (Wood et al. 2002).

The job performance of older workers has been shown to be at least as productive as that of younger workers. The results between older and younger
age groups have been found to be the same in skill demanding and speed demanding jobs (Spirduso et al. 1995). Pruessner et al. (2004) evaluated two groups of participants subdivided into high and low self-esteem groups. They noted that age-related changes in cognitive and endocrinological variables became more prominent in the low self-esteem group. Age had no significant impact on the changes in cognition and regulation of the HPA axis in the high self-esteem group.

2.4 Work-related stress and health

Stress is a risk factor for a variety of illnesses, ranging from metabolic and cardiovascular disorders to mental illness (McEwen and Stellar 1993). The brain is the organ which controls the interpretation of what is stressful and determines the behavioural and physiological responses that are produced (Heuser and Lammers 2003). The lack of rest and recovery seems to be even more important for health than the mental or physical demands experienced during work (McEwen 1998, Lundberg 2003). While a limited period of controllable stress may be harmless in terms of physical or mental health, a lack of control or coping can produce a chronic state of stress that is believed to enhance vulnerability to stress-related disorders (Frankenhaeuser 1981, Benus et al. 1991, Lazarus 1999). Kivimäki et al. (2002) demonstrated in a Finnish industrial cohort a significant relative risk of 2.2 for cardiovascular disease (CVD) death associated with high job strain. Bacquer et al. (2005) claimed in their 3-year follow-up study, that there was no significant association of job demands, decision latitude, or job strain with the short-term incidence of coronary heart disease, but the importance of a supportive social environment at the workplace by coworkers and/or supervisors in the prevention of coronary heart disease was noted. A similar conclusion was reached by Steptoe et al. (2000b) in a sample of teachers showing that social support in individuals who are working, married and parents reduces the impact of naturally occurring stress on cardiovascular activity. In addition, a systematic review of prospective cohort studies (Hemingway and Marmot 1999) provided strong evidence that psychosocial factors, particularly depression and social support, were independent aetiological and prognostic factors for coronary heart disease.

There are several pieces of evidence that identify the possible mechanisms by which cortisol may lead to CVD. Firstly, excess cortisol production can result in elevated BP (Irony et al. 1989). Secondly, increased cortisol levels may
inhibit the metabolism of catecholamines, thereby their potentiating effects (Gravanis 1987, Oparil and Katholi 1990). They may be also a combined interaction of EPI and cortisol in the way that stress reactivity can lead to CVD; both hormones are involved in lipid metabolism and mobilization and in the maintenance of cardiac functioning (Herd 1986). Andrews and Walker (1999) proposed that insulin resistance, and lipid levels may be affected by the glucocorticoid concentration in the circulation. A prolonged elevation of glucocorticoids as a result of chronic stress may lead to the metabolic and cardiovascular changes that are associated with obesity, type 2 diabetes and cardiovascular disease (Seeman et al. 1997, McEwen 1998, 2000a). In addition, acute or chronic increases in corticosteroid levels are associated with cognitive impairments in both attention and memory (Bohnen et al. 1990, Kirschbaum et al. 1996, Het et al. 2005).

Dysfunctions of the HPA axis are also associated with immunological illnesses such as rheumatoid arthritis, fibromyalgia, and symptoms of upper respiratory tract infections (Mason et al. 1979, Neeck et al. 1990, Chowdrey and Lightman 1993, Griep et al. 1993, Panayi 1993). An increase in the level of cortisol harms the immune system by destroying one of the system’s primary types of cells, the T-cells (Hall et al. 1996). Kropiunigg (1993) suggested that reducing cortisol levels can in turn reverse the negative effects of cortisol on the cells of the immune system. Walsh and DeChello (2001) described excess mortality from autoimmune diseases among teachers and they suggested that, relatively early in their careers, the teachers experience psychophysiological stresses that increase the risk of autoimmune diseases.

Human obesity is characterized by excess body fat (Bray 1992), and abdominal obese individuals have also been shown to display abnormalities in the regulation of the HPA axis (Rosmond et al. 1998). Masuzaki et al. (2001) claimed that a single enzyme in fat cells (11 beta HSD-1) might be to blame for visceral obesity. This enzyme produces cortisol, a hormone that helps people survive in stressful situations. But it also produces cortisol in cells not normally associated with the hormone. Masuzaki et al. (2001) proposed that an elevated level of cortisol is linked to visceral weight gain, which in turn leads to obesity and obesity-related diseases.

Many studies have detected a relationship between job stress and depressive symptoms (Schonfeld 1990, Viinamäki 1997, Griffith et al. 1999, Kendler et al. 2001, van Dick and Wagner 2001, Griffin et al. 2002, Paterniti et al. 2002). According to these studies, the relationship between job and mental health may
be influenced by personality, coping strategies, self-efficacy, and socio-demographic factors. In contrast, Jurado et al. (2005) reported that the personality traits of Spanish teachers modified the development of depressive symptoms independently of other individual characteristics and occupational context. In the Italian study of Lodolo D'Oria et al. (2004), the risk of teachers to develop psychiatric disorders was 2-, 2.5-, and 3-fold higher than that of clerks, health care professionals and blue collar workers, respectively.

2.5 Assessment of work-related stress

A reliable assessment of work-related stress is the first step to improve the ergonomics and safety of work systems, work environments, and work schedule management. The assessment should be executed multidimensionally, using various methods to assess subjective, behavioural, and physiological parameters. The psychophysiological methods can be undertaken in laboratory settings, in order to manipulate stressor settings and study response, or in natural settings i.e. the workplace. The psychophysiological method is often used to gain insight into causal mechanisms, in order to detect a cause-effect explanatory model. One of the most extensively studied cause-effect relationships is the relation between (work-related) stress and cardiovascular disease.

2.5.1 Questionnaires

Questionnaires are the most common subjective methods to measure work-related stress, and they have been developed to assess stressors across occupational groups (Karasek and Theorell 1990). There are more sophisticated assessments, e.g. occupation-specific role stressor measurements (Bacharach and Bamberger 1992, Hemingway and Smith 1999, Van der Doef and Maes 2002). In general, surveys are used to identify prevalences and trends or the profile of risk groups. The assessed perceived stress scores are commonly supplemented with physiological measurements.

2.5.2 Neuroendocrine assessment

The neuroendocrine parameters used in assessing human reactions to different occupational activities are EPI and cortisol. Cortisol is widely regarded
as an objective marker of changes in psychological stress (Kirschbaum et al. 1995, Kudielka et al. 2004) and cortisol levels have been shown to increase during periods of both acute (e.g. al’Absi et al. 1997) and chronic (e.g. Vedhara et al. 1999) stress. However, no unequivocal links between cortisol and work stress have been established (Steptoe et al. 2000a). An increased basal activity of the HPA was reported with higher urinary, plasma or salivary cortisol levels, and some evidence was found for lowered HPA activity in chronically stressed individuals (Baum et al. 1985, Jacobs et al. 1987, Ockenfels et al. 1995). Measurement of salivary cortisol concentration is a non-invasive method to assess HPA axis activity, since its levels closely mirror the free active cortisol in serum (Kirschbaum and Hellhammer 1994). EPI and NE excretions increase in challenging situations e.g. when the SAM system is activated (Henry 1993) and these hormones have been the focus of stress research since Cannon (1928) and Selye (1936).

2.5.3 Autonomic nervous system assessment

Autonomic indices such as HR, BP and their variability are the most common methods used to assess psychophysiological stress. The fluctuations in circulatory parameters can reflect either the rapid or the long-term adaptation to stressors. These oscillations can be presented in power bands by methods of signal processing and spectral analysis (Malik 1998). In general the increases in the intervals between heart beats i.e. R-R intervals (RRI) are associated with decreases in stress. The decrease of HR is often observed when an individual is fatigued or is doing monotonous or low arousal work tasks (Myrtek et al. 1994, Milosevic 1997, Raggatt and Morrissey 1997) whereas an increase is associated with work tasks demanding high tension and mental exertion (Tattersall and Hockey 1995, Boucsein and Ottmann 1996, Rau 1996, Richer et al. 1998). BP values are increased while performing a variety of mentally stressful tasks both under laboratory and field conditions (e.g. Seibt et al. 1998). The extensive variability in the results of autonomic function studies is attributable to differences in individual and context factors and also to physiological recording and processing differences (Luczak and Goebel 2000). A combination of different tests is often used to obtain a comprehensive view of the ANS (Piha 1988, Malik 1998).
2.5.4 Muscle tension assessment

There is a general assumption that mental stress may cause muscle tension, particularly, in the neck-shoulder region (Hägg 1991, Johansson and Sojka 1991, Toivonen et al. 1993a). Low-threshold motor units of muscles are activated during their long-term activation and during the psychological stress (Waersted and Westgaard 1996, Kadefors et al. 1999, Sjögaard et al. 2000). Electromyography (EMG) which is based on measurements on the skin surface, is a suitable method for determining the muscular load. A long-term and / or high static load and fast repetitive movements are associated with work-related musculoskeletal disorders (Hansson et al. 1997). To compensate for the large inter-individual variation in the derived EMG amplitude, normalization to a reference muscle contraction is usually performed (Mathiassen et al. 1995). Usually the static contraction may be either maximal or submaximal and performed in a variety of postures, and incremental submaximal load levels are used. The principal is that the reference contraction should resemble the actual muscle contractions at work.

The Amplitude Probability Distribution Function (APDF) method is based on rectified and low-pass filtered surface EMG (Jonsson 1982). It has been common practice to report three standard levels of the APDF curve, i.e. "the static level", the level below which the signal is for 10% of total time, "the median or intermittent level", the median level of the signal and "the maximal or dynamic level", the level below which the signal is for 90% of total time. One must be able to have muscle rest during work if one wishes to avoid chronic muscle pain (Veiersted et al. 1993). However, these measurements may not be optimal for predicting the risk of muscular disorders in the repetitive work that is characterised by sustained and low level muscle activity (Westgaard 1988, Hansson et al. 2000). EMG gap frequency provides information about muscle rest, fatigue and recovery. The EMG gap frequency refers to brief occurrences of total muscle relaxation when the surface EMG amplitude is close to zero (Veiersted et al. 1990).

2.6 Work-related stress of teachers

All over the world teaching is recognized as being one of the most stressful occupations (e.g. Travers and Cooper 1993, van Horn et al. 1997, Vandenbergh and Hubernan, 1999), and there are many international and
domestic teacher stress studies (e.g. Haikonen 1999, Salo 2002). Those studies have usually been cross-sectional and focused mainly on psychological stress indicators. There is a reasonably large body of published research available which categorizes teaching as being a 'highly' or 'extremely highly' stressful occupation for up to one-third of teachers (Pithers 1995). The generalisation of such a conclusion may depend on specific terminological and methodological problems, for instance, ranging from confusion about the actual definition of stress through to how this is to be measured. The methodological problems inherent in some of the research used to examine the area of teacher stress extend to confusion about the effect of intervening variables in the interaction of stress and strain (van der Doef and Maes 2002). Summary, the teaching profession is considered as stressful and especially mentally rather demanding (e.g. Travers and Cooper 1996, Kalimo and Toppinen 1997, Rudow 1999).

The stresses associated with teaching as an occupation may include high mental stress, role ambiguity, conflict and time pressure, inadequate resources, pupil misbehaviour, poor working conditions and hostile parents (e.g. Kinnunen 1989, Cooper and Kelly 1993, Salo ja Kinnunen 1993, Burke and Greenglass 1995, Pithers and Fogarty 1995, Manthei et al. 1996, Pithers and Soden 1998, Griffith et al. 1999, Leithwood et al. 1999, Rasku and Kinnunen 1999). Teaching has been associated with significant levels of burnout, psychological stress and absenteeism (e.g. DeFrank and Stroup 1989, Pierce and Molloy 1990, Kalimo and Toppinen 1997, Schaufeli and Enzmann 1998, Griffith et al. 1999, Farber 2000, Kalimo and Hakanen 2000, Maslach et al. 2001). Mills and Huebner (1998) claimed that the relationship between work stressors and burnout was found to be reciprocal. When the initial burnout status was controlled, work stressors predicted no subsequent burnout. In the study of Viinamäki (1997), mental disorders as defined in General Health Questionnaire-12 were found in 41% of teachers and 46% of social workers in Finland. The incidence of depression was also rather high for teachers and social workers (24% and 25%, respectively). Haikonen (1999) found teachers' stress to be related to threats which were directed at his/her personality as well as the job of being a teacher. Rasku and Kinnunen (1999) see teachers' work as active (high demands but high control) and emphasize the importance of personal control by teachers over the lessons given and the methods used. Teacher stress is found to be associated with both subjective (e.g. interaction with pupils) and objective (e.g. age, sex, school level) factors (Salo 2002). One way to reduce the negative
impact that teaching apparently has on health is to identify the main occupational stressors and their sources. Overall, the nature of teaching and teacher stress is highly individualistic and dynamic (Salo and Kinnunen 1993). Teaching work is identified by seasonal cycles present in the school year. Longitudinal studies found that extent of teacher stress varies during the school year, increasing during autumn term (Rajala 1988; Salo and Kinnunen 1993). In Salo and Kinnunen's study (1993) teacher stress was found to accumulate during the autumn term so that weekend recovery disappeared in November-December. Rajala's findings suggest that stress increases with time during the autumn term and requires more coping at the end of the autumn term.

In a comparative study across Europe, the Finnish higher secondary school teachers classified their job conditions, on the average, as being good. In particular, task variety and decision authority were considered as satisfying, as were their relationships with pupils. The Finnish teachers were more satisfied with their job conditions than other European teachers. Furthermore, the level of well-being among Finnish teachers was at the same level as that of their colleagues in other European countries despite the greater work load of the Finnish teachers (Rasku and Kinnunen 1999).
3 THEORETICAL FRAMEWORK OF THE STUDY

Stress usually refers to an event or sequence of events that challenge homeostasis and evoke a negative response, often in the form of stress but also, in some cases, referring to a challenge that leads to a feeling of exhilaration i.e. positive stress (Goldstein and McEwen 2002). Canon (1928) and Selye (1947) argued that psychological stress could produce physiological effects that are similar to those produced by physical demand / load or challenge. Stress can be used to describe the physiological and behavioural responses to a 'stressor', defined as a challenge to the individual that either perturbs homeostasis and requires an adaptive response or can be interpreted as threatening resulting in a hormonal or behavioural response even though physiological homeostasis has not been compromised. The types of perceived stress that lead to hormonal or behavioural responses are largely the result of the individual's perception that there is a threat. The reaction of the mind and body to the perceived threat causes problems, particularly if this condition becomes chronic (Lazarus 1999).

Psychological and experiential factors are some of the most powerful of stressors. These may include novelty, withholding of reward, and anticipation of punishment rather than the punishment itself, and these stressors are most potent at activating the HPA axis and SAM system (Mason 1975, Burchfield 1979). Work-related stress is experienced primarily due to daily work. This is not considered to be a problem if enough recovery time is provided (McEwen 1998, Lundberg 2003) but it may also depend on how an individual manages to cope with stress in a particular situation (Lazarus and Folkman 1984). In behavioural terms, the response to stress may consist of fight or flight reactions, but it also may include potentially health-related life-style habits such as overeating, heavy alcohol consumption, smoking and other forms of substance abuse. Another type of reaction to a potentially stressful situation is an increased state of vigilance or enhanced anxiety (Lazarus 1999).

The conceptual models most often used in epidemiologic studies of work-related stress are the Job Demand-Control model developed by Karasek and Theorell (1990), Johnson's (1989) Job Demand-Control-Support model and the Effort-Reward-Imbalance model proposed by Siegrist et al. (1990). Kwakman (2001) tested the Karasek and Theorell (1990) model by performing a survey of 542 Dutch secondary school teachers. The results indicated that the teachers who perceived their job to have high demands associated with their own low
control over their work reported greater levels of stress than those with high demands and high own control over work demands.

The theoretical framework of the present study is based on the allostatic load model (McEwen and Stellar 1993, McEwen 1998). The adaptive responses of the body that maintain homeostasis under stressful situations can be called 'allostasis'. Physiological mediators produced by the immune system, the ANS and the HPA axis act upon receptors in various tissues and organs to produce effects that are adaptive in the short term but can be harmful if the release of mediators such glucocorticoids from the adrenal cortex and epinephrine from the adrenal medulla is not suppressed when no longer needed. Allostasis is the term introduced by Sterling and Eyer (1988) to characterize how BP and HR responses vary with experiences and time of the day. This type of allostasis helps to maintain oxygen tension in the brain. Therefore, allostasis supports homeostasis or helps maintain stability through change and promotes adaptation and coping, at least in the short term (McEwen 2000a).

A normal allostatic response occurs when a response is initiated by a stressor, this being sustained for an appropriate interval, but it is then turned off after the stressful situation is over. This is considered as a 'good' stress and protective to the body (McEwen 1998). Therefore allostasis and allostatic state are necessary in the short-term, but if the imbalance continues they may have negative health consequences. Failure of recovery from stress may be indicative of sustained allostatic load and may lead to tissue damage if the load on target cells is prolonged. This refers to the 'cost' of adaptation (McEwen and Stellar 1993, McEwen 1998, McEwen 2000a,b). McEwen (1998) described four alternative patterns in the response of stress and these situations illustrate what is called the allostatic load: 1) Frequent stress stimulation (repeated 'hits') in which the stress response may be turned on by many different events. This is what happens with 'chronic stress'. 2) Lack of adaptation in which the body fails to habituate to repeated stressors of the same kind. This has been demonstrated in a repeated public speaking challenge, there are individuals who do not habituate and their cortisol excretion does not decrease even after several public speaking occasions. 3) Prolonged response due to the inability to shut off allostatic response efficiently such as the hyperexcretion of cortisol in the evening in people who have been sleep-deprived. 4) Inadequate response in some allostatic system, such as in disorder of chronic fatigue syndrome where the cortisol excretion is lower-than-needed, leading to a compensatory
hyperactivity in other systems (McEwen 1998, McEwen and Lasley 2003) (Fig. 2).

Recently, McEwen and Wingfield (2003) have also re-classified the allostatic load as also containing an allostatic overload. They have defined two types of allostatic overload. In type 1 allostatic overload, the energy demands of the body exceed the energy supply and may lead to a limited ability to maintain health if the individual is not able to replenish the depleted energy. The more common allostatic overload in modern society is type 2 in which the capacity of the individual to cope with physiological and social demands fails (McEwen and Wingfield 2003). For example, social conflict at work may lead to an allostatic state reflected in elevated glucocorticosteroids levels which increase appetite and then the energy stores of the body (especially fat) may become higher than needed, leading to visceral weight gain. If the situation is long-lasting, this kind of 'flight or fight' stress reaction may have far-reaching effects on the body e.g. leading to dysfunctions in lipid metabolism.
Stressor (e.g. time pressure, mental stress, conflict) → Individual characteristics (e.g. age, physical fitness) → Normal allostatic response
Physiological stress responses (e.g. cortisol, heart rate and blood pressure) turn on and then turn off when the stressful situation is over

Four damaging allostatic responses:

**Frequent stress stimulation**
Body fails to manage stress response since almost every event evokes overactivity of the stress response

**Lack of adaptation**
Body fails to habituate to repeated stressors of the same kind

**Prolonged response**
Body fails to turn off each response efficiently e.g. recovery time is not sufficient

**Inadequate response**
Body stress response is inadequate

**Figure 2.** A protecting normal allostatic load and four alternative damaging allostatic stress responses leading to release of stress hormones and evoking cardiovascular responses in the body.
4 AIMS OF THE STUDY

The purpose of this study was to investigate a year and week based seasonal work-related psychophysiological stress experienced by healthy younger and older teachers with different aerobic fitness.

The specific aims of the study were to investigate:

1. Work-related psychophysiological stress in high school teachers associated with the four seasons of the year (I).

2. The recovery from work-related psychophysiological stress after a weekend and after summer holidays in high school teachers (II).

3. The effects of aerobic fitness of high school teachers on their psychophysiological stress at work (III).

4. The responses of the psychophysiological work-related stress in younger and older female high school and secondary school teachers during the periods of low and high perceived work stress (IV).

5. The associations of allostatic load indicators (i.e. lipids, cortisol, DBP, SBP and WHR) and psychosomatic symptoms in high school and secondary school female teachers in their work during periods of high and low perceived work-related stress (V).
5 MATERIALS AND METHODS

5.1 Study design

In the first part of the present study, teachers’ psychophysiological stress responses were assessed during four key periods of the years 2001-2: the first measurement was done in December; the second in March; the third during the summer holidays in July. The fourth measurement was completed in October.

In the second part of the study, ANS response was assessed three times during the year 2001. The autonomic function tests were performed at 11:00 – 16:00 p.m. during the workday in April. The tests were repeated at the same time of the day after the weekend in May, four weeks apart from the first measurement. The third measurement was performed in July during the holidays.

In the third part of the study, VO₂ max was assessed in addition to psychophysiological assessment during ordinary workdays in October 2002.

In the fourth part of the study, the effects of ageing to psychophysiological stress responses were examined. Morning cortisol, BP, HR, and plasma lipids were assessed during the periods of low and high perceived stress associated with habitual working periods during the years 2003-4.

In the fifth part of the study, the associations with allostatic load indicators (i.e., BP, cortisol excretion rate, plasma lipoprotein cholesterol levels, WHR) and psychosomatic symptoms were examined during the perceived high and low work stress period in healthy female teachers. The Kuopio University Hospital Ethics Committee approved the study design and measurements.

5.2 Study participants

In Study I, the participants consisted of 17 (10 female, 7 male) high school teachers with a mean age of 43 years (SD 7, range 33 - 53 years). The participants reported good health. In Study II, the participants were 9 (5 male, 4 female) healthy teachers with a mean age of 42 years (SD 5, range 37 - 54 years) who had worked for at least 5 years in the high school system. They were screened for good health and were using no medications.

In Study III, the participants consisted of 26 healthy (17 female and 9 male) teachers aged 33 – 62 years. The mean age of the female and male participants was 50 (SD 8, range 35 – 61) years and 47 (SD 6, range 33 – 62) years, respectively.
In Study IV, the participants were 28 female teachers. They were healthy and free of cardiovascular disease. Five of the participants had postmenopausal hormone replacement therapy, and seven were taking contraceptives. The participants were divided into two age groups \( (p = 0.002) \) representing younger \( (n = 14, \text{mean age 31 years, SD 3, range 26-35 years}) \), and older \( (n = 14, \text{mean age 54 years, SD 2, range 50-57 years}) \) female teachers.

In Study V, the participants consisted of 30 healthy female teachers with a mean age 42 years \( (SD 11, \text{range 26–57 years}) \). The study participants were the same as the study IV except that there were two new participants. Five of the participants were receiving postmenopausal hormone replacement therapy, and seven were taking oral contraceptives. More detailed characteristics of the participants are available in the original articles (I-V).

5.3 Methods

5.3.1 Questionnaires

The perceived psychophysiological work stress in the Studies I-V was assessed using one question from the Work Stress Enquiry (Elo et al. 1990). The stress was defined as follows: "Stress refers to the feelings of tenseness, restless, nervousness or anxiety or sleep disturbances since 'things' continuously irritate the mind. Have you experienced this kind of stress at work during the past two weeks?" The results of each experienced work stress were reported via a visual analogue scale (VAS) (Price et al. 1983) modified to assess perceived stress \( (\text{scale 0 – 100 mm, with the end points of no stress and extremely high stress}) \). In studies IV and V, perceived work stress was classified as high when the VAS was higher than 60 mm and low when the VAS was under 30 mm. In Studies I, III and V, the various psychosomatic symptoms were inquired with the scales of 1 –5, where “never” = 0 and “every working day” = 5. The registered symptoms in the items were headache, tiredness, anxiety, tenseness, nervousness, depression, stomach pain, mild fever, indisposition, sleep disturbances and exhaustion. The theoretical range of the sum-scale of the 11 items was 0 – 55. The sum-scale was modified from that of Pohjonen (2001). The Cronbach’s alpha value of the sum-scale was 0.78.
5.3.2 Surface electromyography (I, III)

EMG was recorded from the surface of the muscle bilaterally by a portable ME3000P device and analysed by ME300P software (Mega Electronics Ltd., Kuopio, Finland). The ME300P device enables the muscle activity to be monitored as averaged fully rectified signals from 15 to 500 Hz with the averaging period of 1 s to give root-mean-square values (RMS). The skin was cleaned with an alcohol swab before pairs of disposable surface electrodes (Ag/AgCl, type M-00-S, N-00-S Medicotest, Ölstykke, Denmark) were attached bilaterally to the upper rim of the trapezius muscle with a 2 cm inter-electrode spacing about 2 cm lateral of the midpoint between C7 and acromion. The reference electrodes were attached to the skin approximately 9 cm laterally from the recording electrodes. The positions of the electrodes were selected according to the recommendation of Zipp (1982).

The EMG activity was measured during the actual workday. The RMS values were normalised with a reference period of voluntary electrical activity obtained during a static submaximal reference voluntary contraction. The normalisation values achieved in this way (100%) corresponded to about 10-15% of the maximal voluntary contraction of the trapezius muscle. EMG levels were analysed according to the Amplitude Probability Distribution Function introduced by Jonsson et al. (1982). From a cumulative frequency distribution, the 10% percentile was defined as the static load level.

5.3.3 Catecholamine, cortisol and lipids (I, III-V)

In Studies I and III, the neuroendocrine reactivity was assessed by following the diurnal urine excretion of EPI and NE by 24-h urine collection. Urine samples were collected in polyethylene jars containing 10 ml of 6 mol/L HCl as preservative and stored in a refrigerator (5 °C ± 3 °C) during the collection. The volume of 24-h urine was measured and 60 ml of the aliquot was frozen at -70°C until analysed. The chromatographic system consisted of the Shimadzu LC-10A pump (Shimadzu, Japan), the Waters 717 Autosampler (Waters Inst., USA), an ESA, Chromsystems HPLC column for urinary catecholamines (# 6100) (Chromsystems Instruments and Chemicals GmbH, Munich, Germany), an ESA, Coulochem II detector equipped with a Guard Cell (Model 5020), and Analytical Cell (Model 5011) (ESA, Bedford, MA, USA). The data were analysed by the HP Kayak XA computer (Hewlett Packard, USA) equipped with the HP ChemStation chromatography program.
An aliquot of sample, standard or control (3.0 ml), was transferred to the vessel, followed by the addition of 100 μl of internal standard and 6.0 ml of dilution buffer. The diluted urine was applied to prepared clean-up columns. The effluent was discarded. Thereafter, the clean-up columns were rinsed once with one column volume of distilled water. Finally, catecholamines were eluted out of the clean-up columns with 6 ml of elution buffer. An aliquot of 20 μl was injected for the HPLC system. The absolute recovery of catecholamines was 81-87%, analytical recovery 89-102%, linear range of the method 0.06-6 nmol/l, intra-assay variation 3-5% and inter-assay variation 5-7%.

In Studies III, IV and V, the venous blood samples were taken at 8:00 – 9:00 a.m. from the forearm of the participants for the cortisol analyses. The blood samples were aliquoted into appropriate prechilled vacutainer tubes and centrifuged within one hour. 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 chemiluminescence detection was used to quantitate cortisol levels (Diagnostic Products Corporation, Los Angeles, CA, USA).

The venous blood samples for the lipoprotein lipid assays (studies IV and V) were drawn in the morning between 8 and 9 a.m. from the forearm with the participants seated after a 12 h fast. 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 (high density lipoprotein) (Konelab HDL-CHOLESTEROL, Thermo Electron Co) and LDL (low density lipoprotein) 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.

5.3.4 Blood pressure and heart rate (I, III-V)

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) and HR were measured in the morning (7.00 – 10.00 am) before work tasks and in the afternoon (15.00 - 16.00) after the workday using an automatic digital device (Omron M4, Matsusaka Co., Ltd., Japan). Measurements were obtained in a
sitting position after a 10-min rest period (I, III, V). In Study IV, the participants measured their own BP and HR with an automatic device (Omron M4, Matsusaka Co., Ltd., Japan). They were instructed to make themselves comfortable in a chair and relax for 5 minutes before each reading, and having refrained from drinking coffee or tea, smoking or doing sporting activities for at least 1 h. The BP and HR readings were taken three times. The average of the three measurements at 1-minute intervals was used.

5.3.5 Autonomic function test (II)

The electrocardiogram was recorded with a three-channel Mingograph 34 electrocardiogram apparatus (Siemens, Elema, Sweden). All data acquisition and analyses were performed with a menu-driven software package (CAFTS, Medikro Ltd, Kuopio, Finland). The use of alcohol and smoking was prohibited for 24 h before the measurement. The participants were also asked not to change their diet during the study or to alter their activity level during leisure time. The participants performed a series of tests. The order of tests was the same for all participants: 5-min controlled breathing, deep breathing and active orthostatic test. The tests were performed in a temperate laboratory condition. The ambient temperature was of 21°C (SD 1.5°C) and the relative humidity was 60% (SD 4%).

In the controlled breathing test, the participants breathed for 5 minutes with a respiratory cycle of 5 s (0.2 Hz) maintaining normal tidal volume. Spectral estimates RRI were obtained from stationary regions of the registrations. After detrending of the signals (first degree), a modified covariance autoregressive model (fixed model order of 14) was used to obtain a power spectral estimate of RRI variability. Total power (TP) was divided into three frequency bands: very low frequency (VLF) (0.0 to 0.04 Hz), low frequency (LF) (0.04 to 0.15 Hz) and high frequency (HF) (0.15 to 0.40 Hz) bands. Signal powers in the three frequency bands were calculated as integrals under the respective power spectral density function and were expressed in absolute units in milliseconds squared (ms²). In addition, the low frequency to high frequency (LF/HF) ratio was calculated.

In the deep breathing test, the participants breathed for 60 s with maximal vital capacity with a respiratory cycle of 10 s (0.1 Hz). Four breathing cycles were analysed. During each cycle, the ratio of longest RRI to the shortest RRI
was calculated and the mean of the four ratios was taken as the expiration to inspiration ratio.

In the orthostatic test, the participants actively stood up after resting quietly in the supine position for 5 min. SBP and DBP were measured with a calibrated aneroid sphygmomanometer at the end of the resting period and at 1, 3 and 6 min in the standing position. The shortest RRI 15+-5 cardiac cycles after standing up was measured, as well as the longest RRI 30+-5 cardiac cycles after standing up. The ratio of this longest RRI to the shortest RRI was calculated (30/15 ratio). The frequency domain analysis of HRV was determined from the recordings during the active orthostatic test both in the supine and in the upright position.

5.3.6 Aerobic fitness (III)

Aerobic fitness was defined by estimated maximal oxygen uptake (VO$_2$max) in the submaximal cycle-ergometer test in the laboratory. The target HR was set at the level of 220 - age beats/min minus 15% (Fletcher et al. 1995). HR was recorded with the cardiac monitor of Polar Accurex Plus (Polar Electro Ltd., Finland). The Ergoline 900 Cycle ergometer (Ergoline GmbH & Co. KG, Germany) was used in the test. The initial workload was 40 W for the female and 50 W for the male participants with a pedalling speed of 60-70 revolutions/min. The workload was increased by 10 W for the females and 20 W for the male participants every minute until the target HR was reached. The data of HR and workload was analysed and VO$_2$max was estimated with FitWare software (FitWare Ltd., Vantaa, Finland). The rating of perceived exertion was inquired on a scale of 6 - 20 at intervals of 2 min in the test (Borg, 1982).

5.3.7 Body habitus

The body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (Bray 1992). The waist circumference was measured at the mid point between the lowest rib and iliac crest, and the hip circumference was measured at the level of the great troCHANTERS (WHO, 1995). The waist-to-hip ratio (WHR) was then calculated (studies IV and V).
5.3.8 Statistical methods

The descriptive values of data include means, standard deviations and ranges. Statistical analyses were performed by using the Statistical Package of Social Science (SPSS) for Windows (version 10.0 and 11.0). The normality of the distributions was assessed with the Kolmogorov-Smirnov test. In Studies I and II, repeated measures analyses of variances were conducted to assess the variation of the cardiovascular reactivity, and period differences were tested using the Bonferroni pairwise comparison.

In Study III, since VO\textsubscript{2}\text{max} is known to be highly age-dependent, the values of VO\textsubscript{2}\text{max} were standardised for age using residuals from the linear regression analyses, labelled by suffix ‘(res)’. The associations between the VO\textsubscript{2}\text{max}_{res} and psychophysiological stress responses were determined by linear regression analyses with the calculation of Pearson Product correlation coefficient for the male and female subjects separately. Covariance analyses of variances were used to calculate the effects of predicted VO\textsubscript{2}\text{max}_{res}, and relevant confounders (BMI, working experience, gender) to psychophysiological stress responses and perceived stress.

In study IV, Student’s t-test was used to examine group differences in psychophysiological stress response, lipids and psychosomatic symptoms. Differences between the low and high stress periods within the groups were calculated using Student’s t-test with paired samples.

In Study V, linear regressions were performed to analyse the associations between allostatic load indicators: cortisol, BP and psychosomatic symptoms included, apart from high and low work stress parameters. Relevant covariates (age, BMI, WHR, time of wakening and sleeping hours) were entered into the equation. In addition, multivariate models were fitted by a combination of backward and best subsets regression methods using high workload parameters. In all analyses, a p-value less than 0.05 was considered as statistically significant.

A summary of study sample, study design, variables and methods used in studies I-V is shown in Table 1.
Table 1. Summary of study sample, study design, variables and methods used in studies I-V. DBP = diastolic blood pressure, SBP = systolic blood pressure, HR = heart rate, HRV = heart rate variability, EMG = electromyography, VAS = visual analogue scale, WHR = waist-to-hip ratio, \( VO_{2\max} \) = maximal oxygen uptake, NE = norepinephrine, EPI = epinephrine, BMI = body mass index.

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Study design</th>
<th>Variables</th>
<th>Data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>10 female 7 male</td>
<td>Psychophysiological stress response: December March July October</td>
<td>DBP, SBP, HR NE, EPI EMG VAS Psychosomatic symptoms</td>
<td>Repeated measures of ANOVA Pairwise comparison with Bonferroni correction</td>
</tr>
<tr>
<td>II</td>
<td>4 female 5 male</td>
<td>Psychophysiological stress response and recovery: Workday in April After the weekend in May During the holidays in July</td>
<td>Autonomic function tests: HRV, DBP, SBP VAS</td>
<td>Repeated measures of ANOVA Pairwise comparison with Bonferroni correction</td>
</tr>
<tr>
<td>III</td>
<td>17 female 9 male</td>
<td>Effects of aerobic fitness: Physiological stress response during the ordinary workday</td>
<td>( VO_{2\max} ) HR, DBP, SBP, EMG, cortisol, NE, EPI VAS, psychosomatic symptoms Control variables: BMI, gender, work experience</td>
<td>Pearson product-moment correlations Linear regression analyses (( VO_{2\max} ) was standardised for age using residuals) Analyses of covariance (ANCOVA)</td>
</tr>
<tr>
<td>IV</td>
<td>28 female</td>
<td>Younger (n=14) and older (n=14) teachers: Physiological stress response during the perceived low and high work stress periods</td>
<td>Cortisol, HR, DBP, SBP psychosomatic symptoms Perceived stress: VAS (&lt;30 mm = low stress, &gt;60 mm = high stress)</td>
<td>Student's t test for independent samples and paired samples</td>
</tr>
<tr>
<td>V</td>
<td>30 female</td>
<td>Associations with allostatic load indicators and relevant covariates variables during the perceived low and high work stress periods</td>
<td>Allostatic load: -DBP, SBP -cortisol -lipids -WHR Covariates: -age -BMI -time of wakening -sleeping hours Psychosomatic symptoms Perceived stress: VAS (&lt;30 mm = low stress, &gt;60 mm = high stress)</td>
<td>Linear regression analyses Multivariate analyses (using high stress variables)</td>
</tr>
</tbody>
</table>
6 RESULTS

6.1 Psychophysiological stress in teachers during four seasons of the year (I)

VAS, psychosomatic symptoms, blood pressure and static muscle tension were significantly lower during the summer holiday compared to the working days in December, March and November. Diurnal urine epinephrine excretion was significantly higher in October compared to July \((p < 0.05)\), and in March the difference also approached the level of significance \((p = 0.067)\) (Table 2). There were no significant differences between the working days.

Table 2. Perceived stress (VAS), psychosomatic symptoms, diurnal urine excretion of epinephrine and norepinephrine, diastolic blood pressure (DBP) and systolic blood pressure (SBP) and static level of EMG activity in the participants. Analysis of variance was done between periods in four repeated measurements over one year. Periods: 12 = December; 3 = March; 7 = summer holidays of teachers; 10 = October \((n = 17)\). Values are means (SD).

<table>
<thead>
<tr>
<th>Months</th>
<th>12</th>
<th>3</th>
<th>7</th>
<th>10</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS (mm)</td>
<td>63 (18)***</td>
<td>52 (28)***</td>
<td>15 (20)</td>
<td>59 (23)***</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Psychosomatic symptoms</td>
<td>14 (8)**</td>
<td>14 (10)**</td>
<td>9 (10)</td>
<td>13 (7)*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Epinephrine (μmol/24 h)</td>
<td>0.04 (0.02)</td>
<td>0.04 (0.03)</td>
<td>0.03 (0.02)</td>
<td>0.05 (0.02)*</td>
<td>0.048</td>
</tr>
<tr>
<td>Norepinephrine (μmol/24 h)</td>
<td>0.29 (0.11)</td>
<td>0.23 (0.06)</td>
<td>0.23 (0.05)</td>
<td>0.22 (0.08)</td>
<td>0.212</td>
</tr>
<tr>
<td>DBP (mmHg) morning</td>
<td>80 (8)*</td>
<td>82 (9)*</td>
<td>76 (8)</td>
<td>80 (11)*</td>
<td>0.011</td>
</tr>
<tr>
<td>afternoon</td>
<td>81 (8)*</td>
<td>82 (9)*</td>
<td>74 (8)</td>
<td>81 (9)**</td>
<td>0.004</td>
</tr>
<tr>
<td>SBP (mmHg) morning</td>
<td>131 (14)*</td>
<td>130 (12)*</td>
<td>122 (14)</td>
<td>128 (14)*</td>
<td>0.024</td>
</tr>
<tr>
<td>afternoon</td>
<td>132 (13)**</td>
<td>131 (16)*</td>
<td>122 (15)</td>
<td>131 (18)*</td>
<td>0.050</td>
</tr>
<tr>
<td>Static EMG (%)</td>
<td>5 (1)*</td>
<td>5 (1)*</td>
<td>2 (1)</td>
<td>5 (1)*</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

DBP and SBP in the morning (8:00 - 10:00) and in the afternoon (15:00-16:00) significantly different from values for period 7; * = \(P<0.05\), ** = \(P<0.01\), *** = \(P<0.001\), pairwise comparison with Bonferroni correction.
6.2 Relief of work stress after weekend and holiday season (II)

In the controlled breathing test, HF power was higher during the holiday season compared to the workday and approached statistical significance ($p = 0.079$). The LF/HF ratio, VLF and LF power components did not differ significantly between the three measurements. No statistically significant differences in E/I between workdays, weekend and holidays were found in the deep breathing test (workday, $1.28 \pm 0.15$; weekend, $1.34 \pm 0.17$; holiday, $1.28 \pm 0.13$).

In the active orthostatic test TP, VLF power and the LF/HF ratio tended to increase in the upright position during the holiday season compared to the corresponding workday ($p = 0.071$, $p = 0.089$, $p = 0.091$, respectively). Systolic blood pressure decreased significantly at rest in the supine position during the holidays ($p = 0.044$) compared to the working days (SBP mmHg, workday, $133 \pm 25$; weekend, $129 \pm 24$; holiday, $122 \pm 17$).

6.3 Effects on aerobic fitness to psychophysiological stress response (III)

The effect of the estimated VO2max_{res} on HR at work was significant ($p < 0.01$). BMI approached the level of significance ($p = 0.064$) but no gender or work experience effects were observed on HR. The model, which included VO2max_{res}, BMI, work experience and gender, predicted 39% of the variance of HR at work ($F = 4.18$, $p = 0.01$).

With respect to the static level of EMG activity, the model predicted 37% of the variance ($F = 6.51$, $p = 0.003$). The effect of VO2max_{res} was significant ($p < 0.05$) but no effects of BMI, gender or work experience were found on the static EMG activity.

The corresponding model for VAS predicted 33% of the variance ($F = 4.07$, $p = 0.013$). The effects of VO2max_{res} were significant ($F = 4.7$, $p = 0.05$) but no other variables made significant contributions to VAS.

No significant predictive power of VO2max_{res} was observed with respect to SBP and DBP as well as catecholamine and cortisol excretion (Table 3).
Table 3. The effects of covariates related to heart rate (HR) at work, static level of electromyography (EMG) and perceived stress according to the visual analogue scale (VAS) at work (n=26). VO2max_res = age-standardised estimated maximal oxygen uptake, BMI = Body mass index.

<table>
<thead>
<tr>
<th>Variables</th>
<th>F</th>
<th>p-value</th>
<th>Covariates</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>4.81</td>
<td>0.006</td>
<td>VO2max_res</td>
<td>8.99</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BMI</td>
<td>3.81</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work experience</td>
<td>0.04</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gender</td>
<td>0.15</td>
<td>NS</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static EMG</td>
<td>4.71</td>
<td>0.007</td>
<td>VO2max_res</td>
<td>5.59</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BMI</td>
<td>0.88</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work experience</td>
<td>0.09</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gender</td>
<td>0.13</td>
<td>NS</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS</td>
<td>4.07</td>
<td>0.007</td>
<td>VO2max_res</td>
<td>4.72</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BMI</td>
<td>0.55</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work experience</td>
<td>0.34</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gender</td>
<td>0.23</td>
<td>NS</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.4 Effects of ageing on response of psychophysiological stress (IV)

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 their older colleagues during both high and low stress periods (p < 0.05). They had also significantly lower serum triglyceride levels during the low stress periods compared to the older participants (p < 0.05) (Table 4).
Table 4. Psychosomatic symptoms, triglycerides, total cholesterol, LDL = low density lipids, HDL = high density lipids and cortisol of the younger and older participants during the low and high stress periods. The values are means (SD).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Younger (n=14)</th>
<th>Older (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Psychosomatic symptoms</td>
<td>15 (7)</td>
<td>22 (10)***</td>
</tr>
<tr>
<td>Triglycerides (mmol/l)</td>
<td>0.98 (0.70)</td>
<td>0.85 (0.71)</td>
</tr>
<tr>
<td>Cholesterol, total (mmol)</td>
<td>4.65 (0.68)*</td>
<td>4.50 (0.59)*</td>
</tr>
<tr>
<td>Cholesterol, LDL (mmol)</td>
<td>2.53 (0.59)</td>
<td>2.45 (0.44)</td>
</tr>
<tr>
<td>Cholesterol, HDL (mmol/l)</td>
<td>1.59 (0.29)</td>
<td>1.53 (0.33)</td>
</tr>
<tr>
<td>Cortisol (mmol/l)</td>
<td>323 (161)</td>
<td>355 (168)*</td>
</tr>
</tbody>
</table>

Significance between the low and high stress periods within the groups, * = P < 0.05, *** = P < 0.001, † = P < 0.05 between groups.

DBP and SBP values measured in the morning were the same 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 between work and evening systolic and diastolic BP values were insignificant (Table 5).
Table 5. Systolic (SBP) and diastolic blood pressures (DBP) and heart rate (HR) of the younger and older participants during the low and high work stress periods. The values are means (SD).

<table>
<thead>
<tr>
<th>Periods</th>
<th>Groups</th>
<th>Stress</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>HR (beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At home</td>
<td>Younger</td>
<td>low</td>
<td>108 (13)</td>
<td>70 (8)</td>
<td>62 (12)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high</td>
<td>109 (14)</td>
<td>70 (8)</td>
<td>69 (10)</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>low</td>
<td>117 (15)</td>
<td>75 (8)</td>
<td>63 (8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high</td>
<td>116 (19)</td>
<td>76 (10)</td>
<td>65 (8)</td>
</tr>
<tr>
<td>At work</td>
<td>Younger</td>
<td>low</td>
<td>121 (11)#</td>
<td>78 (9)#</td>
<td>63 (7)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high</td>
<td>124 (10)#</td>
<td>77 (9)#</td>
<td>68 (11)</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>low</td>
<td>125 (17)**</td>
<td>78 (6)***</td>
<td>65 (9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high</td>
<td>134 (23)</td>
<td>87 (8)</td>
<td>68 (11)</td>
</tr>
<tr>
<td>At home</td>
<td>Younger</td>
<td>low</td>
<td>111 (11)</td>
<td>70 (7)</td>
<td>59 (7)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high</td>
<td>117 (14)</td>
<td>72 (9)</td>
<td>69 (11)</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>low</td>
<td>116 (13)*</td>
<td>75 (8)*</td>
<td>63 (7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high</td>
<td>124 (17)</td>
<td>80 (7)</td>
<td>66 (9)</td>
</tr>
</tbody>
</table>

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.

6.5 Association of physiological stress responses during the work periods with perceived low and high stress (V)

Psychosomatic symptoms and triglycerides positively significantly associated with the cortisol level during the high work stress period (β=.43, β=.46, p<0.05). Among the confounders, time of waking and sleeping hours seemed to be negatively associated with morning cortisol level but this did not reach a level of statistical significance (Table 6).
Table 6. Linear regression analyses (standardized β) of associations with morning cortisol level during low and high work stress period in teachers (n=30). HDL = high density lipoprotein.

<table>
<thead>
<tr>
<th></th>
<th>Low stress</th>
<th>High stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychosomatic symptoms</td>
<td>0.20</td>
<td>0.43*</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>-0.13</td>
<td>0.28</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>0.06</td>
<td>0.46*</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.30</td>
<td>0.19</td>
</tr>
<tr>
<td>Age</td>
<td>0.16</td>
<td>-0.30</td>
</tr>
<tr>
<td>Sleeping hours</td>
<td>-0.25</td>
<td>-0.33</td>
</tr>
<tr>
<td>Time of wakening</td>
<td>-0.27</td>
<td>-0.32</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.33</td>
<td>0.36</td>
</tr>
</tbody>
</table>

* = P < 0.05

A significant association between psychosomatic symptoms and DBP (β = .49, p < 0.05) and SBP (β = .56, p < 0.01) was found during the high work stress period. HDL cholesterol negatively associated with BP and reached a level of statistical significance during the high work stress period (p < 0.05). Among the confounders, age associated significantly positively with SBP (p < 0.05) during the high work stress period (Table 7).

Table 7. Linear regression analyses (standardized β) of the associations with diastolic blood pressure (DBP) and systolic blood pressure (SBP) during the low and high work stress period in teachers (n=30). HDL = high density lipoprotein.

<table>
<thead>
<tr>
<th></th>
<th>Low stress</th>
<th>High stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBP</td>
<td>SBP</td>
</tr>
<tr>
<td>Psychosomatic symptoms</td>
<td>-0.18</td>
<td>-0.09</td>
</tr>
<tr>
<td>Cortisol</td>
<td>0.31</td>
<td>0.07</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>-0.21</td>
<td>-0.16</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>-0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Age</td>
<td>0.36</td>
<td>0.20</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.33</td>
<td>0.27</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.42</td>
<td>0.01</td>
</tr>
</tbody>
</table>

* = P < 0.05, ** = P < 0.01
Cortisol level was a significant determinant to increased psychosomatic symptoms ($r^2 = .14, p < 0.05$). DBP and triglycerides were determinants of the cortisol level accounting for 40% of the total variation ($p = 0.001$). LDL cholesterol, age and cortisol were determinants of DBP accounting for 46% of the total variation ($p = 0.001$). WHR was a significant factor in terms of its correlation with HDL cholesterol levels ($r^2 = .41, p = 0.001$) (Table 8).

**Table 8.** Multiple regression models of psychosomatic symptoms, cortisol, diastolic blood pressure (DBP) and HDL (high density lipoprotein) cholesterol during high work stress period in teachers. LDL = low density lipoprotein, WHR = waist-to-hip ratio

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>r²</th>
<th>p-value</th>
<th>Independent variable</th>
<th>β</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychosomatic symptoms</td>
<td>0.14</td>
<td>0.027</td>
<td>Cortisol</td>
<td>0.41</td>
<td>2.35</td>
<td>0.027</td>
</tr>
<tr>
<td>Cortisol</td>
<td>0.40</td>
<td>0.001</td>
<td>DBP</td>
<td>0.32</td>
<td>1.96</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Triglycerides</td>
<td>0.52</td>
<td>3.18</td>
<td>0.004</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>0.46</td>
<td>0.001</td>
<td>LDL cholesterol</td>
<td>0.67</td>
<td>3.08</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Age</td>
<td>0.55</td>
<td>3.42</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cortisol</td>
<td>0.42</td>
<td>2.88</td>
<td>0.008</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>0.41</td>
<td>0.001</td>
<td>WHR</td>
<td>-0.73</td>
<td>-4.38</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
7 DISCUSSION

7.1 Participants and study design

All participants selected for this series of studies were healthy and volunteers. Study I was carried out over four key periods including summer holidays which enhances its value, providing a realistic perspective of teachers' work load and possible consequences. The number of men and women studied was unequal, but this factor was not considered important with respect to the aims of Studies I and III. However, gender and ageing are factors which may influence the physiological variables among teachers and this has been discussed out in the analyses. The number of participants was rather limited and this decreases the statistical power to detect differences between the groups (Study IV). Especially in Study 2 there were relatively large standard deviations and a rather small sample size (n= 9) and thus the statistical power is low making difficult to detect significant differences between the three periods.

The timing of the cardiovascular sampling in relation to the menstrual cycle could be important, since differences were 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 the 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 included in a between-subjects design. Moreover, usually no effect of the menstrual cycle phase has been detected on the cardiovascular stress responses in studies with within-subjects designs. 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.

The follow-up period of Studies IV and V was short, and the results are based on upon a limited sample and only female teachers were included into the studies. The limitations on study design i.e. perceived high and low work periods, meant that environmental effects may have influenced the responses to the different "conditions". These aspects restrict the possibilities to draw general conclusions. In addition, the volunteer and healthy (only healthy subjects as assessed by medical screening) sample of teachers participating in
these studies were probably selective and this makes it difficult to provide a general description of the level of psychophysiological work stress experienced by teachers.

7.2 Methodological considerations

The BP and HR were measured with a non-ambulatory method. It is probable that BP and HR are higher during stressful periods because individuals are more active at work and home. These various confounding factors were controlled during the BP and HR measurements by performing the recordings in the same position and after the same resting time in each recording and by self-monitoring (Study IV) to avoid 'white coat' effects. To fully exclude this kind of bias, all day ambulatory BP and HR values with calculations of expenditure of energy during work and leisure time could be undertaken in future studies.

The reliability of EMG can be considered as being sufficient as many of the factors influencing the results can be controlled. The placement of the electrodes was done carefully by palpating the muscles and following the recommendations of Zipp (1982). The EMG amplitude was normalized during a static submaximal muscle contraction and the effect of underlying tissue thickness was eliminated (Cram et al. 1998). The EMG amplitudes are given as percentages of reference voluntary muscle contraction. Due to the instinct of self preservation and other protective mechanisms, the measurement of maximal voluntary muscle contraction always remains somewhat inaccurate. The Amplitude Probability Distribution Function method was used for describing the occupational loads. However, the drawback is that the repeatability on the load is not reflected in these standard parameters.

A variety of factors can influence HR but under carefully controlled conditions, HR is a practical and relatively straightforward variable for assessing differences in cardiorespiratory function between and within individuals. VO₂max was estimated from submaximal external workloads and HR responses obtained during cycle-ergometer exercise. Submaximal responses were extrapolated to age-related maximal HR according to the equation (HRmax = 220 – age) (Laukkanen 1993). In general, submaximal tests for determining VO₂max are commonly used in work physiology in conjunction with stress and strain assessments in the field (Oja 1991) although several problems are related to validity and reliability of submaximal exercise tests (Howley et al. 1995). Non-direct assessment of VO₂max is considered appropriate for the
estimation of cardiovascular capacity in middle aged and older population (Adams 1994).

When assessing HRV, the duration of the recording was set to 5 minutes. To confirm the stability of the signals and to avoid influences of different confounding factors, the conditions during the recordings were carefully standardized including control for time of the day and room temperature as well as control for participants’ nutrition, fluid balance and preceding physical activities. The breathing frequency was also controlled to minimize the influence of differences in breathing patterns.

In Study III, the sequence of measurements was the same for all participants i.e. workday first, then weekend and finally the holiday, for obvious practical reasons. In the first measurements the HR was high and the high frequency component low, then they remained fairly steady in the weekend and holiday measurements. This may be due to the fact that the participants became used to the procedure. Also climatic changes (spring vs. summer) may have influenced the physiological parameters.

The morning cortisol levels were assessed, since the increase of morning cortisol excretion has been shown to be associated with prolonged psychological stress (e.g. Schulz et al. 1998, Pruessner et al. 1999, Steptoe et al. 2000a, De Vente et al. 2003). The weakness of the morning cortisol assessment is that the plasma cortisol concentration increases markedly in the first 30 to 60 minutes after awakening and then begins to decline (Pruessner et al. 1997, Schulz et al. 1998, Federenko et al. 2004). As cortisol levels decline very rapidly after awakening in the morning, any difference between awakening time of the participants between blood samples may have affected on cortisol levels due to the normal diurnal variation. Pruessner (1997) and Wüst et al. (2000) found no impact of awakening time on the subsequent cortisol response. In contrast, other studies have revealed a marked impact of awakening time, i.e. those participants waking up early have a higher morning cortisol rate than those waking up late (Edwards et al. 2001, Kudielka and Kirschbaum 2003, Federenko et al. 2004). No impact of age, smoking habits, use of oral contraceptives, menstrual cycle phase, sleep quality and physical activity has been found in several studies e.g. according to Pruessner et al. 1997, Wüst et al. 2000, Kudielka and Kirschbaum 2003. Born et al. (1999) observed a higher ACTH response in participants who had been woken unexpectedly compared to those who woke up at the expected time. Since the HPA axis responds sensitively to external stimulation such as invasive procedures, a more
appropriate assessment of cortisol could have been stress-free salivary sampling. In addition, the assessment of HPA axis function should include measurements of cortisol under basal conditions and functions during provocation by food intake or suppression by dexamethasone which would then take into account an individual's normal (high cortisol variability) and differentiate this from a pathological (low cortisol variability) HPA axis function (Rosmond and Bjöntrop 2000). Also diurnal urinary of measurements catecholamines EPI and NE were chosen because they can act as indicators of prolonged work stress. The weakness of our method is that the diurnal period includes not only the time of work stress but also daily activities in the evening at home, as well as night sleep.

Recording of psychosomatic symptoms seems to be an appropriate method to assess emotional strain and they strongly correlated with physiological measurements. VAS is an easy method to assess perceived stress and it is widely used to determine the intensity of pain (Jensen et al. 2003) but the method has also been used to measure satisfaction and acute perceived stress (e.g. Sneed et al. 2001). Elo et al. (1999) assessed the validity of this kind of stress question in stress research. They concluded that the validity was good at the group level, but it was not appropriate at the individual level to assess subjective stress level since there was the possibility of random error.

7.3 Psychophysiological stress in teachers

Recovery from the psychophysiological stress was found during the summer holidays in the teachers of this study. Both the perceived stress and physiological stress responses were lower during the summer holidays than during the three working days. It seems that there were only slight differences with perceived stress and physiological responses between the three working days in October, December or March. These results are inconsistent with the studies of Kinnunen (1989) and Salo and Kinnunen (1993) where the teachers were found to be more stressed towards the end of the autumn term. The explanation may be that many changes have occurred in the past 10 years in the school system of Finland. For instance, a six-week period system may have minimized teachers' stress throughout the year. Furthermore, the introduction of new information technologies has changed teaching practices greatly. In addition, the present study consisted only of high school teachers whereas the
previous studies (Kinnunen 1989, Salo and Kinnunen 1993) consisted of both comprehensive and high school teachers.

The increases in EPI and the cardiovascular responses on workdays suggest that the teachers experienced increased sympathetic tone during their work. These results are consistent with the studies on teachers where the activity of sympathetic adrenal medulla was used to investigate the stress response (Kinnunen 1989, Salo and Kinnunen 1993, Steptoe et al. 2000b).

Muscle tension was at the same level during the three workdays and was significantly lower during the holiday. In addition to movements of the arm, psychological stress also seemed to increase muscle tension in teaching work. Several studies in other occupations (Svebak et al. 1993, Lundberg et al. 1994, Waersted and Westgard 1996) have also shown, that psychological stress and cognitive demands can increase muscle activity, even in the absence of physical demands. However, it is difficult to differentiate physiological and / or psychological sources for the observed changes in muscle activity. Psychologically induced muscle activity is relatively low compared to that attributable to heavy physical demands. It may, however, cause overactivity of single motor units, causing fatigue, reduced satisfaction and poor performance at work. Lundberg (2003) reported that psychosocial stress is related to neck and shoulder pain so that the mental stress may keep low threshold motor units active also during rest pauses at work and after work. This phenomenon was observed also in the present teachers during the rest pauses. The EMG results were in the accordance with the allostatic load model (McEwen 1998).

7.4 Relief of work stress after weekend and holiday season

The major finding of this study is that SBP at rest was significantly lower in the studied teachers during the summer holidays compared to the workdays. This result suggests that sufficient rest is desirable and may be beneficial for health by reducing the allostatic load during the holidays. In general, RRI increases are associated with decreases in stress. In this study, ANS tended to recover in terms of the parasympathetic input during the holiday season but not after the weekend. Apparently the teachers' ANS in this study did not recover during the weekend. There are no other studies on the teachers' stress where the autonomic function test in the laboratory has been used. Toivonen et al. (1993b) reported that occupational mental stress attenuated the capacity of ANS and regular six months, deep relaxation seemed to normalize the cardiac function in
hospital cleaners and bank employees. These results were line with the allostatic load model, which postulates that long-term stressors may produce an elevated allostatic load. The long-term HRV recordings in the real working environment and night-sleep recordings will be a more appropriate and convenient method to assess ANS response and recovery from the work-related stress in the future.

7.5 Associations between aerobic fitness and psychophysiological variables

The major findings of this study were that good aerobic fitness associated with static muscle tension, HR and perceived stress during the working day. These findings may indicate that higher aerobic fitness, which can be achieved by regular physical activity (Bouchard et al. 1990), alleviates muscle tension during work, and has a positive buffering effect on stress, perhaps reducing musculoskeletal problems such as tight muscles. Augustine (1999) also suggested that regular physical activity may reduce the tightness of muscles and help to ease stress. Brandon et al. (1991) found also a negative relationship between the levels of frontalis EMG and aerobic fitness in individuals performing subtraction tasks. Several studies have revealed that stress can contribute to static level of EMG activity at work (e.g. Theorell et al. 1991a, Svebak et al. 1993, Lundberg et al. 1994, Waersted and Westgard 1996, Rissen et al. 2000). In addition, aerobic fitness is significantly negatively associated with perceived stress indicating that higher aerobic fitness may affect self-confidence and personal appearance. The significant association survived in the analyses of covariance in the present study.

A significant negative association between estimated aerobic fitness and HR was observed. In the analyses of covariance, the significant association still survived but the model showed that the effect of BMI approached the level of significance. This observation supports previous findings that, in general, physically active individuals have lower resting and submaximal HR than more passive ones. Also BP may be lower in physically fit individuals. (e.g. van Hoof et al. 1989, Bouchard and Rankinen 2001). The participants in the present study were normotensive with a narrow BP range, and, thus it was not possible to confirm the BP findings. In addition, Georgiades et al. (2000) suggested that physical activity, particularly when combined with a weight loss program, may lower BP and HR levels at rest and during conditions of mental stress.
In the present study, estimated aerobic fitness was not associated with diurnal catecholamine excretion. Moyna et al. (1999) reported that NE levels increased in the speech task, but the neuroendocrine response to the psychological stressor factors was independent of the level of aerobic fitness. There are few non-laboratory studies related to this topic and, thus, it is difficult to find previous results that could be compared with the present observations. Methodological differences and terminological differences with regard to the definition of the aerobic fitness and stress complicate the comparisons of studies which have evaluated the relationship between aerobic fitness and mental stress (Summers et al. 1999). However, the results of the present study provide substantial support for the theory that aerobic fitness is an important factor in reducing the allostatic load during the working day as assessed by HR and static EMG.

7.6 Effects on ageing of response of psychophysiological stress

The main observation of study IV was that cortisol excretion, BP and HR recovered during the low perceived stress period in the younger teachers. However in the older teachers, HR and cortisol excretion were equal during both periods. The higher BP values in the older participants and the higher HR in the younger ones 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. 1991b). In principal, cardiac autonomic control varies throughout the day as a function of self-reported stress (Sloan et al. 1994). The present elevated HR and BP values at work are consistent with other non-ambulatory studies (Frankenhaeuser et al. 1989, Stoney 1992, Ritvanen et al. 2003) as well as ambulatory studies (Goldstein et al. 1999, Steptoe et al. 2000b).

Usually cardiovascular responses increase at work and decrease after work at home (Steptoe 1997), as was observed in the present study in younger teachers. In contrast, the older teachers failed to experience SBP and DBP reductions in the evening during both perceived high and low stress periods. The allostatic model of chronic stress proposes that impaired physiological recovery following termination of aversive stimuli may be more harmful than the magnitude of the acute responses (McEwen 1998). Frankenhaeuser et al. (1989) reported that women in high status jobs failed to show BP reductions in
the evening. However, conflicting results have been reported 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 factors generally relies on self-reporting, and, thus, has a subjective bias (Theorell 1990, Muneta et al. 1997). For example, some individuals may not admit that they experience stress and, therefore, underreport occupational strain in questionnaires.

The results revealed that age predicted increased BP reactivity with or without perceived stress. The relative 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 everyday life (Whelton 1994). In the present study, we failed to detect any differences in HR responses between the perceived low and high stress periods at work in older teachers. This might indicate that age decreases HRV during high stress (Fukusaki et al. 2000). One explanation for lower HR levels of the older teachers may be that because of their long work experience in teaching, they have learned the skills needed for coping with the many stress evoking problems encountered at work. Those individuals 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 normal working day. Another explanation is that the teachers of this study limited their activities in some way 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 are more active or physically fit have lower cardiovascular responses to psychosocial stress factors, which may have also affected the present results.

In the present study, the younger teachers exhibited significantly greater cortisol excretion during the perceived high level stress period, but no significant difference was found among the older teachers between the perceived low and high stress work periods. This seems to indicate that the HPA axis 'shuts off' when it is no longer needed in the younger teachers during the low stress period. In contrast, the allostatic load occurs when inactivation of the stress response systems is inefficient. Hellhammer et al. (2004) observed that hypocortisolemic individuals had a lower allostatic load but they scored higher on the assessments of depression, perceived stress, and physical complaints.
On the other hand, the hypocortisolemic stress response may protect against cardiovascular and metabolic disorders, particularly in older individuals.

The observed higher plasma concentrations of total cholesterol and triglycerides in the older teachers of the present study 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 perceived low and high stress periods in this study.

The recovery from psychophysiological work stress between high and low perceived work stress periods in the older teachers was not as clear as it was in the younger teachers. This implies that their bodies have not recovered during the low stress work period. The results may due to the self-reporting subjective bias or this result could also be due to the selection of the research days i.e. at end of the week. Longer research periods are needed to investigate the recovery processes from psychophysiological work stress during ordinary weekends over the school year, especially in ageing teachers.

7.7 Association of physiological stress responses during the work periods with perceived low and high work stress

Our results support the hypothesis that long-term allostatic load is a health risk. The associations with morning cortisol, plasma lipids, DBP and WHR during the high perceived work stress period in the present study are in line with the allostatic overload type 2 and may have far-reaching effects on the body, for example, leading to dysfunction in the HPA system and lipid metabolism.

The positive relationship with cortisol level and BP was significant during the perceived high work stress period and DBP survived in the backward multiple regression analysis. Also DBP associated significantly positively with LDL cholesterol and age during the perceived high work stress period. Phillips et al. (1998) also showed in the sample of middle-aged men that cortisol levels recorded at 9.00 a.m. were positively associated with insulin resistance and plasma triglyceride concentration, and negatively correlated with the HDL cholesterol level. Although the present participants were normotensive and had a narrow range of BP, these observations suggest that morning cortisol level, age and LDL cholesterol level were related to DBP in normotensive female teachers during the perceived high work stress period. It seems that elevated
DBP is an important health factor in the teaching profession. Borghi et al. (2004) observed that individuals with elevated normal BP and serum cholesterol might have an exaggerated cardiovascular response to stress and have an increased risk for stable hypertension that can be detected at a young age.

Steptoe et al. (1999) reported that baseline BP was positively associated with WHR in male teachers but ambulatory BP and HR were not independently related to WHR or job control. It was concluded that abdominal obesity in men is characterized by a tendency towards heightened stress-induced physiological activation. Otherwise, there is evidence showing that women are not affected by stress in the same way as men (Light and Turner 1992, Pickering 1997). Traustadottir et al. (2003) also observed that older men, 55-75 years, responded to psychological stress with greater increases in cortisol, compared to women though there were no observed gender differences in HR and SBP.

In this study, there was a positive association with psychosomatic symptoms and morning cortisol level and BP during the perceived high work stress period. In the multivariate analyses, the significant association still survived between psychosomatic symptoms and cortisol but the model excluded BP. The relationship between BP and self-reported psychosomatic symptoms has been suggested to be dependent on the objectivity-subjectivity balance of the measuring instrument and on the heterogeneity of the sample. The assumption underlying this relation is that job stressors contribute to elevations of tonic BP (Theorell et al. 1991b, Nyczicek et al. 1996).

The positive association between cortisol and psychosomatic symptoms may mean that perceived stress with subsequent HPA axis activation is associated with problems in the homeostasis of somatic systems. A number of studies have found that the onset of burnout is related to increased reports of psychosomatic symptoms and impaired health behaviours (e.g. Kahill 1988; Schonfeld 1990; Maslach et al. 2001). Elevated resting HR and elevated early morning cortisol levels are found in burnout patients compared with healthy controls (De Vente et al. 2003). There are also studies where the morning cortisol excretion in burnout patients was found to be either high (e.g. Grossi et al. 2005) or low (e.g. Pruessner et al. 1999). However, there are many confounders which may affect the morning cortisol level, such as quality of sleep during the previous night and individual activities before the blood sampling. In the present study, sleeping hours and time of waking negatively associated with the cortisol level but did not reach a level of statistical significance.
Body habitus i.e. BMI and WHR were not significantly associated with the cortisol level in this study. These results were contrary to the study of Epel et al. (2000) who reported that stress-induced cortisol secretion was consistently greater among women exhibiting central adiposity. The present absence of the association between cortisol excretion and abdominal obesity may be due to the small sample size and the narrow WHR range of the participants (e.g. all of the participants were within normal weight limits). Abdominal obesity is associated with perturbations in the HPA axis (Björntorp 1993). In this study, WHR was a direct determinant of HDL cholesterol and survived correction for BMI. The present results are consistent with the hypothesis that abdominal obesity in men is characterised by a tendency towards heightened stress-induced physiological activation, but that this tendency only becomes manifested in the presence of appropriate environmental challenges such as chronic work stress. The inverse relationship between WHR and HDL cholesterol was consistent with several previous studies. Fraser et al. (1999) reported the lowest HDL cholesterol levels for individuals of both genders with the highest cortisol excretion rates and BMI in the general population. Triglycerides also seem to associate with the cortisol level during the perceived high work stress period, and in fact they represented the only significant determinant in the multivariate analyses to the cortisol level. Fredrikson and Blumenthal (1992) have also reported that plasma cortisol during stress and also at rest correlates positively with triglycerides in healthy type A men. However, the present models are mainly based on cross-sectional data and more information on the causal relationship between poor health and prolonged psychophysiological stress in teaching will dearly need to utilize longitudinal models since stress accumulates with time and only ends after adequate recovery and a successful coping process is developed.
8 CONCLUSIONS AND RECOMMENDATIONS

1. A recovery from work related psychophysiological stress was found during the long summer holiday and allostatic load was lowered when compared with the situation during the working months. There were no significant differences in psychophysiological stress response between the three working months. The long holidays provided to teachers may support their health.

In the high stress working months, one way to decrease the allostatic load would be the adoption of stress coping programs. Provision of complete rest periods during the day and appropriate working conditions should be taken into practice. One way to reduce the negative impact that teaching apparently has on health and well-being is to tackle the occupational stressors. A better understanding of the occupational determinants of stress factors and recovery processes from psychophysiological stress responses in teachers could provide an impetus for the improvement of their workplaces and occupations.

2. The overall cardiac autonomic control of the teachers varies throughout the workday, after weekend rest and holiday season and no significant differences between the workday and the weekend rest were found. A positive recovery in cardiac autonomic control was found only during the summer holiday season.

3. Good aerobic fitness seems to alleviate the allostatic load, lowering muscle tension and HR in the work of the teachers. Proactive individual strategies for coping with stress including encouragement of physical activities may play an important role even if the basic causes of stress cannot be tackled.

4. The findings suggested that SAM and HPA systems were activated in the younger teachers during the perceived high stress work period and the allostatic load was lowered during the perceived low work stress period. In contrast, in the older participants, the allostatic load was equal during both periods, which may attenuate their mental and physical capacity at work. The increase of the DBP in the teachers as they become older 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. Ergonomic and individual measures in terms of work time control, specific relaxing techniques and especially a partial retirement may improve the stress management for older teachers.

5. The association with allostatic load indicators (morning cortisol excretion, BP, lipids, WHR), age and psychosomatic symptoms during the high perceived work stress period was observed. This may lead to an allostatic load in the long-term and increase the risk of ill-health.

The health care system should screen teachers systematically as they are at risk of prolonged allostatic load. The physiological monitoring of stress related control systems such as HRV may prevent the development of illnesses related to work stress.
9 YHTEENVETO


Koettua subjektiivista stressiä mitattiin VAS janalla (0 = ei yhtään stressiä ja 100mm erittäin voimakas stressi) ja oirekyselyllä. Fysiologisina stressivasteiden osoittimina käytettiin stressihormonien erittymistä (kortisoli ja katekolamiinit) sekä verenpaineen ja sydämen sykkeen vaihtelua sekä lisäksi määrättiin veren rasva-arvot ja vydöri-lantio-suhde. Lihasjännitystä mitattiin elektromyografialla (EMG). Koehenkiöiden aerobisen kunnon osoittimena käytettiin maksimaalista hapenottokykyä (VO$_2$-max). Sykevariaatiomittaukset tehtiin laboratoriossa sisältäen kolme autonomisen hermoston toimintaa kuvaavaa testiä.

Opettajien psykofysiologinen stressi oli yhtä korkea kolmen työpäivän mittauksen aikana joulukuussa, maaliskuussa ja lokakuussa. Psykofysiologinen stressi vähäni tilastollisesti merkitsevästi kesäloman aikana verrattuna työpäivän mittauksiin, joten opettajien pitkä kesäloma edistää opettajan palautumista psykofysiologisesta stressistä ja on erittäin tärkeä opettajan


10 REFERENCES


al'Absi M, Bongard S, Buchanan T, Pincomb GA, Licinio J, Lovallo WR. Cardiovascular and neuroendocrine adjustment to public speaking and mental arithmetic stressors. Psychophysiology 1997;34:266-75.


Kudielka BM, Kirschbaum C. Awakening cortisol responses are influenced by health status and awakening time but not by menstrual cycle phase. Psychoneuroendocrinology 2003;28:35-47.


Shvartz E, Reibold RC. Aerobic fitness norms for males and females aged 6 to 75 years: a review. Aviat Space Environ Med 1990;61:3-11.


Sneed NV, Olson M, Bubolz B, Finch N. Influences of a relaxation intervention on perceived stress and power spectral analysis of heart rate variability. Prog Cardiovasc Nurs 2001;16:57-64.


Waersted M, Westgaard RH. Attention-related muscle activity in different body regions during visual display unit work with minimal physical activity. Ergonomics 1996;39:661-76.


ORIGINAL PUBLICATIONS (I-V)
Kuopio University Publications D. Medical Sciences


D 357. Berg, Marja. CT angiography in the assessment of atherosclerotic carotid and renal arteries.


D 367. Lindi, Virpi. Role of the Human PPAR-γ2 Gene on Obesity, Insulin Resistance and Type 2 Diabetes.

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