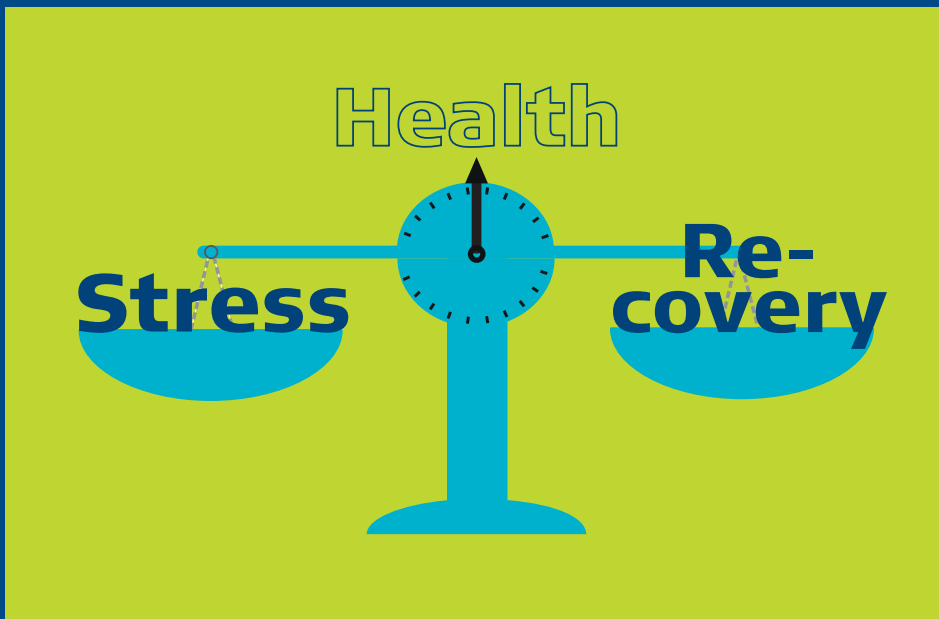


Harri Lindholm

# Physiological determinants and assessment of stress and recovery among media workers



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# **Physiological determinants and assessment of stress and recovery among media workers**

**Harri Lindholm**

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Finnish Institute of Occupational Health  
Helsinki, Finland

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## **ABSTRACT**

Stress arises from the relationship between a person and the environment. In occupational health care settings stress is experienced by the workers as taxing or exceeding their resources and endangering their well-being. Recently, the European Agency for Safety and Health at Work adopted the following definition: “work-related stress is experienced when the demands of the work environment exceed the worker’s ability to cope with (or control) them”. The risk of job stress is increased by several work-related factors, including excessive quantitative demands, low job control, low social support and job insecurity. Prolonged physical strain or high mental and cognitive overload might lead to depletion of adaptive resources.

Physical symptoms of stress are often related to autonomic nervous system activation, to which blood circulation and cardiac function are sensitive. The use of heart rate variability (HRV) has been proposed for the assessment of this activation and subsequent recovery. The hypothalamic-pituitary-adrenal cortex (HPA) axis is a classic pathway of chronic stress. Dysregulation in the HPA system may be associated with stress-related mood changes, sleep disturbances, metabolic dysfunction and cognitive impairment.

The disruption of biological circadian rhythms might play an important role in the development of work related negative health effects. Cortisol and melatonin are diurnally oscillating hormones, which may serve as indicators of disturbances in normal biological rhythm.

A common feature of harmful stress is poor recovery, whereas good recovery helps to restore functional reserves and facilitates the positive effects of stress at work. Workers may recover insufficiently during the workday, after working hours or during weekends and holidays. Lack of job control increases the risk of poor neuroendocrine recovery.

## ABSTRACT

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The short-term negative health effects include sleep problems, fatigue, attenuated work performance and increased risk of accidents. Long-term negative effects might include obesity, breast cancer, cardiovascular diseases, gastrointestinal disorders and depression.

Broadcasting is a good example of a 24/7 occupation in today's society, irregular shift work (ISW) being common in media work. It is unclear whether ISW or subjective dissatisfaction with the current shift schedule is more important in the development of stress.

The main aim of this study was to assess the association between self-reported stress and physiological biomarkers of stress and recovery. We also aimed to identify work-related characteristics of media work that could explain poor physiological recovery. Finally, the association between the critical indicators of recovery and sleep, and some common diseases and general health were analysed among media workers.

A standardized questionnaire was mailed to all employees of the Finnish Broadcasting Company with ISW (N = 750) and to an equal number of randomly selected controls with regular 8-hour daytime work (RDW). The response rates were 58.3% (N = 874, 53.7% men) overall, 82.3% (N = 617, 56.6% men) for the ISW group and 34.3% (N = 257, 46.7% men) for the RDW group. The work tasks of the study population included journalism, broadcasting, programme production, technical support and administration. Seventy respondents from each group (RDW and ISW) were randomly selected for physiological measurements.

The questionnaire covered demographic items, such as gender, age and psychosocial status. Weekly working hours, work satisfaction, work ability and other employment details were asked about, as were psychosomatic symptoms, and health care use. Perceived stress was evaluated by asking a validated single question. Questions on perceived poor health were also asked. The Symptom Check List-90 (SCL-90) was used to assess mental health. Sleep and sleep related disorders were evaluated using the Basic Nordic Sleep Questionnaire (BNSQ). Cortisol and melatonin hormones were analysed from five salivary samples taken while subjects were awake. HRV was calculated from 24 hour electrocardiogram (ECG) recordings. Body movements during day and night and actual sleeping time were monitored by actigraphy.

The ratio of salivary cortisol level 60 min (T1) after waking to the level immediately after waking (T0) was calculated to define the reactivity of

## ABSTRACT

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morning cortisol response. In a regression model severe subjective stress on the single item stress scale, irregular shift work, and short actual sleep time were all significant explanatory variables of augmented morning cortisol response.

The risk of morning drowsiness and daytime sleepiness was nearly twofold in the ISW group compared to the RDW group. Gender, age, body mass index, alcohol consumption, or tobacco smoking did not explain increased risk. Vagal recovery as reflected by reduced HRV was significantly attenuated among ISW workers with enhanced daytime sleepiness compared to ISW workers without enhanced sleepiness. The difference was especially pronounced during the early nighttime and first few hours in bed. After waking the salivary cortisol/melatonin ratio did not differ between the groups, but after 8 hours the ratio was attenuated in the ISW group.

Reported job control was highest in the 46–65 year age group. In all, 39% of workers in this group reported high job control and 43% low control. In the 36–45 year age group high job control was reported by only 21% of workers, and low control by 51% of workers. The difference between these two groups was significant ( $p < 0.01$ ). During the recovery period (from 18.00 to 06.00 hrs between working days), those who experienced high job control at work had significantly higher parasympathetic activity than workers with low or moderate experienced job control. Vagal recovery during the early hours of sleep was especially improved in the 36–45 year age group with high job control.

Depression, hypertension and poor general health were associated with many types of sleep disorders and they all increased the risk of nocturnal waking. Depression, in particular, increased the risk of all types of sleep disorders. Severe stress doubled the risk of difficulties initiating sleep (DIS) and the risk of non-restorative sleep (NRS).

In modern 24/7 media work subjective stress is associated with salivary cortisol changes, a physiological determinant of HPA axis function. The dynamics of salivary cortisol after waking might be useful in further stress studies of media workers. Analysis of recovery should be included in the evaluation of workers' health and well-being. In some cases physiological determinants of autonomic nervous system (ANS) function, such as HRV, might be used in the assessment of recovery, at least at a group level. Sleep plays an essential role in good recovery.

## ABSTRACT

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Actigraphy is useful for assessing sleeping time and daily activities more precisely. Simultaneously analysed ANS function and neuroendocrine indicators provide additional information about stress and recovery. Ambulatory measurements in real life settings could offer new insights in occupational health studies, once their validation has been achieved. New indicators are also needed to characterize the complex network of physiological recovery. As far as we know diurnal profiles of salivary cortisol and melatonin among media workers have not been previously analysed. Only limited information exists about HRV and recovery among media workers.



## TIIVISTELMÄ

Stressi syntyy ihmisen ja ympäristön vuorovaikutuksesta. Työntekijän voimavarat ylittävä stressi uhkaa terveyttä ja hyvinvointia. Euroopan unionin hyväksymän määritelmän mukaan ihminen kokee työstressiä, kun hänen mahdollisuutensa eivät riitä vastaamaan työympäristön vaatimuksiin tai hallitsemaan niitä. Haitallista työstressiä lisäävät muun muassa liiallinen työn määrä, vähäiset mahdollisuudet hallita työtään, sosiaalisen tuen puute ja työn epävarmuus. Jatkuva fyysinen tai henkinen ylikuormitus kuluttaa elimistön voimavarat loppuun.

Monet fyysiset stressioireet, kuten sydämen toiminnan ja verenkierron muutokset, johtuvat tahdosta riippumattoman eli autonomisen hermoston aktivaatiosta. Sydämen sykevälivaihtelun analyysia käytetään stressireaktioiden ja niistä palautumisen arvioinnissa. Pitkäaikainen stressi heijastuu aivolisäkkeen ja lisämunuaisen kuoren välisen hormonijärjestelmän toiminnassa. Tämän hormonijärjestelmän häiriintymiseen voi liittyä mielialan muutoksia, univaikeuksia, aineenvaihdunnan häiriöitä tai kognitiivisen toimintakyvyn laskua. Muutokset korjautuvat usein ennalleen, kun stressi saadaan hallintaan.

Työstä johtuva biologisten vuorokausirytmien häiriintyminen on haitallista terveydelle. Kortisoli- ja melatoniinihormonien eritykset aaltoilevat luontaisesti vuorokauden mittaan. Niiden pitoisuuksien seuranta voidaan käyttää, kun tutkitaan biologisiin rytmeihin liittyviä fysiologisia elinvaikutuksia.

Huono palautuminen lisää stressin haittoja, hyvä palautuminen vahvistaa voimavaroja ja tukee stressin myönteisiä elinvaikutuksia myös työssä. Työntekijä voi palautua riittävästi työpäivän aikana, sen jälkeen, viikonloppuisin tai lomallakin. Työn hallinnan puute lisää hermostollisen ja hormonaalisen huonon palautumisen riskiä.

Haitallisen stressin tyypillisiä ensioireita ovat uniongelmat, uupuminen, työtehon heikkeneminen ja lisääntynyt alttius tapaturmille. Pitkään jatkuva stressi on yhdistetty muun muassa ylipainoon, sydän- ja verenkiertosairauksien vaaraan, maha- ja suolistovaivoihin, syöpäsairauksien vaaraan ja masennukseen.

Tutkimuksessa analysoitiin koetun ja fysiologisesti mitatun stressin välisiä yhteyksiä. Lisäksi tavoitteena oli tunnistaa sellaisia mediatyön piirteitä, jotka altistavat elimistön huonolle palautumiselle tai tukevat hyvää palautumista. Radio- ja TV-työ on tyypillinen esimerkki 24/7-yhteiskunnan työelämästä. Epäsäännöllinen vuorotyö on tavallista media-alan töissä. Tutkimuksessa selvitettiin palautumisen ja unen häiriintymisen yhteyksiä eräisiin tavallisiin kansansairauksiin ja koettuun terveyteen mediatyöntekijöillä.

Postikysely lähetettiin kaikille tutkimusajankohtana epäsäännöllistä vuorotyötä Yleisradiossa tekeville työntekijöille (N = 750) ja yhtä suurelle joukolle säännöllistä päivätyötä tekeviä. Kaikkiaan tutkimukseen vastasi 58 % kyselyn saaneista. Epäsäännöllistä vuorotyötä tekevistä kyselyyn vastasi yli 80 % ja päivätyötä tekevistä hieman alle 40 %. Vastanneiden työtehtäviä olivat toimitustyö, ohjelmatuotanto, tekniset tehtävät ja hallinto. Sekä epäsäännöllistä vuorotyötä tekevien että säännöllistä päivätyötä tekevien joukosta satunnaistettiin 70 työntekijää tarkempaan fysiologisiin mittauksiin.

Laaja kyselykartoitus sisälsi osakokonaisuuksia työn piirteistä, stressistä, fyysisestä ja psyykkisestä terveydestä, unesta ja elintavoista. Kortisolin ja melatoniinin pitoisuudet määritettiin viidestä sylkinäytteestä, jotka tutkittavat itse ottivat työpäivän aikana. Autonomisen hermoston tilaa seurattiin hormonaaliseen mittaukseen liittyen 24 tunnin ajan 3-kanavaisella EKG-laitteella. Ranteeseen kiinnitetty liikeanturi tallensi tiedot kehon liikkeistä ja tarkensi siten tietoa nukkumisesta.

Kortisolin erityksessä todettava tavallista voimakkaampi erityksen kiihtyminen heräämisen jälkeen voi olla viite haitallisesta stressistä. Mediatyöntekijöillä korostunutta vastetta selittivät koettu stressi, lyhyt uni ja itsenäisesti myös epäsäännöllinen vuorotyö.

Päiväaikaisen väsymyksen riski oli epäsäännöllistä vuorotyötä tekevillä mediatyöntekijöillä kaksinkertainen säännöllistä päivätyötä tekeviin verrattuna. Sukupuoli, ikä, paino, alkoholinkäyttö tai tupakointi ei ole selittävä tekijä. Epäsäännöllistä vuorotyötä tekevillä ja päiväväsymystä ko-

kevilla autonomisen hermoston rentoutuminen oli yön aikana huonompi kuin niillä epäsäännöllistä vuorotyötä tekevillä, joilla ei ollut merkittävää päiväväsymystä. Samoin heillä todettiin kortisolin ja melatoniinin välisen tasapainon muutos, joka voi altistaa nukahtamisen vaikeuksille.

Kaikista työntekijöistä noin 40 % koki työn hallintansa hyväksi ja 40 % huonoksi. Hyvän työn hallinnan kokemus oli tavallisinta 46–65-vuotiaiden ryhmässä. Riippumatta työvuorotyypistä autonomisen hermoston palautuminen nukkuessa oli parempi hyvää työn hallintaa kokevilla kuin kohtalaista tai huonoa työn hallintaa kokevilla. Hyvän työn hallinnan positiivinen vaikutus oli selvin 36–45-vuotiailla työntekijöillä.

Masentuneisuus, kohonnut verenpaine ja huonoksi koettu terveys olivat yhteydessä unihäiriöihin, joista tyypillinen oli yöllinen toistuva heräily. Erityisesti masennusoireet liittyivät hyvin monen tyyppiin univaikeuksiin. Kovasti stressaantuneilla mediatyöntekijöillä oli kaksinkertainen riski unen saannin vaikeuksiin ja huonosti palauttavaan uneen.

Palautumisen arviointi on aiheellista sisällyttää osaksi 24/7-yhteiskunnan työntekijän terveyden ja hyvinvoinnin arviointia. Työterveyshuollon tulee kartoittaa unen laatu osana työntekijän terveyden seurantaa. Kova stressi ja huono palautuminen ovat yhteydessä mitattavissa oleviin autonomisen hermoston tilan, stressihormonien ja vuorokausirytmien säätelyyn osallistuvien hormonien erityksen muutoksiin. Uudet mittaustekniikat, kuten luotettava sykevälivaihtelun rekisteröinti ja biokemiallisten merkiaiaineiden analyysi sylkinäytteistä, mahdollistavat tiedon keräämisen monipuolisesti myös työntekijän todellisessa elinympäristössä. Tulosten analyysi edellyttää kuitenkin kykyä tulkita tuloksia suhteessa kliinisiin ja muihin taustatietoihin sekä kokemusta virhelähteiden tunnistamisesta.

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Helsinki, October, 2013

*Harri Lindholm*

## **ABBREVIATIONS**

AL	allostatic load
ANOVA	analysis of variance
ANS	autonomic nervous system
AUC	area under the curve
BMI	body mass index
BNSQ	Basic Nordic Sleep Questionnaire
CAT	cognitive activation theory
CAR	cortisol awakening response
CI	confidence interval
CNS	central nervous system
COR	cortisol
DSM	diagnostic and statistical manual of mental disorders
DIS	difficulties initiating sleep
ECG	electrocardiogram
EMA	early morning awakenings
ELISA	enzyme-linked immunosorbent assay
GLM	general linear model
HF	high frequency
HPA	hypothalamus-pituitary-adrenal cortex
HRP	horseradish peroxidase
HRV	heart rate variability
IMT	intima media thickness
ISW	irregular shift work
LF	low frequency
ln	natural logarithm
LTPA	leisure time physical activity
MEL	melatonin

## ABBREVIATIONS

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NAW	nocturnal awakening
NRS	non-restorative sleep
NS	non-significant
OR	odds ratio
OSHA	Occupational Safety and Health Administration
pNN50	percentage of NN intervals differing by > 50 ms from the preceding NN interval
RDW	regular daytime work
RLU	relative luminescence unit
RMSSD	root mean square of the averaged squares of differences between adjacent RR-intervals
Sa	salivary
SCL	Symptom Check List
SD	standard deviation
SDNN	standard deviation of the durations of all NN intervals
SWD	shift work disorder
TMB	tetramethylbenzidine
T0	code for salivary sample taken immediately after awakening
T1	code for salivary sample taken 60 minutes after awakening
WAI	work ability index

## LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by their Roman numerals:

- I Lindholm H, Ahlberg J, Sinisalo J, Hublin C, Hirvonen A, Partinen M, Sarna S, Savolainen A. Morning cortisol levels and perceived stress in irregular shift workers compared with regular daytime workers. *Sleep Disord.* 2012;789274. doi:10.1155/2012/789274.
- II Lindholm H, Sinisalo J, Ahlberg J, Hirvonen A, Hublin C, Partinen M, Savolainen A. Attenuation of vagal recovery during sleep and reduction of cortisol/melatonin ratio in late afternoon associate with prolonged daytime sleepiness among media workers with irregular shift work. *Am J Ind Med.* 2012;55:643–9.
- III Lindholm H, Sinisalo J, Ahlberg J, Jahkola A, Partinen M, Hublin C, Savolainen A. High job control enhances vagal recovery in media work. *Occup Med (Lond).* 2009;59:570–3.
- IV Lindholm H, Jahkola A, Ahlberg J, Sinisalo J, Hublin C, Savolainen A, Partinen M. Hypertension, depressive mood and self-assessed poor health are associated with disrupted sleep among media personnel. (submitted)



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# 1 INTRODUCTION

Chronic stress is a prolonged internal process affecting the human body and mind (Selye, 1956). The early stages of harmful stress are difficult to detect by technological or biomedical techniques. Individual experiences of stress vary. Occasional disturbances in well-being do not amount to harmful stress. Continuously increasing stress that overwhelms the individual's functional reserves may cause disabling symptoms. They can be identified by careful interview and standardized questionnaires. Subjective reports provide a generally reliable and simple approach to identifying stress.

Physical symptoms of acute stress are commonly related to sympathetic dominance in ANS activation (Cannon, 1932). Heart rate and blood pressure increase, sweating occurs, respiratory rate rises. Gastrointestinal symptoms and headache are common. The HPA axis is also activated. Hormonal activation associates with mood changes, sleep disturbances, tendency to inflammation and metabolic changes. Prolongation of these changes may predispose to diseases, or contribute to their development (Chrousos and Gold, 1992). Genetic and environmental conditions modulate the regulatory mechanisms (Xiong and Zhang, 2012). Several other central and peripheral pathways are involved in stress reactions.

Simultaneous measurement of physiological indicators of body stress may reflect disturbances in homeostasis more accurately than a single variable. Salivary analyses of hormones and long term recording of HRV can help us create physiological dynamic profiles during everyday life and also in occupational settings (Marques et al., 2010). Mental and physiological recovery is essential after work stress. Good recovery protects the worker against adverse effects of job-related negative health impacts (Geurts and Sonnentag, 2006). Work in modern 24/7 society has many

## 1 INTRODUCTION

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stress triggering features: time pressure, information overload, continuous change in the working environment, global work and irregular working schedules. Although work can be very satisfying, overstretching of adaptive mechanisms is possible. Broadcasting work is a good example of 24/7 work with its typical pros and cons (Ahlberg et al., 2003).

As far as we know diurnal profiles of salivary cortisol and melatonin hormones among media workers have not been previously analysed. Only limited information exists about HRV and recovery among media workers. There are no previous studies in which the stress and recovery of ANS and HPA axis have been analysed simultaneously among employees in broadcasting work.

## **2 REVIEW OF THE LITERATURE**

### **2.1 Physiological theories of stress**

#### **2.1.1 History**

Stress has several meanings. It originally meant to emphasize, to strain, or a focus of attention. It also refers to a subject's experiences or physiological changes in the body during mental or physical load. In working life stress involves a network of stressors, adaptation to stress, and finally the subjective experience. Trigger factors activate brain-body reactions leading to consequences at the individual, social and environmental levels.

The physiological concept of stress was introduced in the 1930s by Hans Selye (Selye, 1956). He defined stress as a non-specific response of the organism to any pressure or demand. The ideas of Selye were preceded by theories of milieu interior presented by Claude Bernard in 1865 (Noble, 2008), and the fight or flight response and homeostasis (Cannon, 1915; 1932). A modern holistic approach introduced by Lazarus (Lazarus and Folkman, 1984) characterises stress as "a particular relationship between a person and the environment that is appraised by the person as taxing or exceeding his or her resource and endangering his or her well-being". Recently the European Agency for Safety and Health at Work has adopted this view in its definition: "work-related stress is experienced when the demands of the work environment exceed the worker's ability to cope with (or control) them" (EU-OSHA, 2000). The risk of job stress is increased by e.g. excessive quantitative demands, low job control, low social support, and job insecurity. Prolonged physical strain or high mental and cognitive overload may deplete adaptive resources.

### **2.1.2 Modern theories of psychophysiological stress**

Although positive stress improves and trains the mental and physical capacity, negative stress may cause decrease in functioning and evoke symptoms of distress. In the worst cases stress promotes processes leading to disease. There are different theories connecting stress and the risk of disease.

According to the cognitive activation theory (CAT) of stress the fight or flight response increases vigilance and activates bodily functions, such as circulatory system. Threat, or lack of the basic needs of the human body, disturbs homeostasis and causes reactions designed to maintain functional ability. Heart rate and blood pressure rise, muscle tension increases and alertness is high. Prolonged cognitive activation has disruptive health effects (Ursin and Eriksen, 2004). In working life stress can be associated with acute high workloads and repeated demanding spells of work. Stress-related health complaints typically include muscle pain, tiredness and mood changes. There is no clear boundary between normal symptoms of adaptation and complaints that require specific medical treatment. These conditions are not uncommon causes for visits to occupational health care. They may even lead to absence from work. It has been proposed that psychobiological sensitization within neural loops maintained by sustained activation predisposes to chronic diseases. The ANS and HPA axis are important pathways leading to positive adaptation, but can also cause negative health consequences. Good recovery prevents a harmful vicious circle developing.

The allostatic load theory suggests that the human body changes its adaptive physiological mechanisms (allostasis) if the physiological balance is impossible to maintain or restore (McEwen, 2000). The adverse effects of continued adaptation are known as the allostatic load (AL). An allostatic burden develops if the load is very high or frequent. Physiological mechanisms are sensitized or exhausted by reaction to the load and the symptoms are experienced as harmful. Both hyperactivation and hypoactivation of the physiological mechanisms of stress regulation can be detected. Insufficient recovery is an integral part of this theory. Work related factors may play a central or additive role in the allostatic burden. The theory emphasizes the significance of hormonal regulators, especially glucocorticoids and catecholamines, and the brain in the protective and harmful effects of stress. The AL theory is useful when assessing the health

## 2 REVIEW OF THE LITERATURE

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effects of chronic stress. AL is expressed in terms of neuroendocrine, immune, metabolic and cardiovascular system functioning (Juster, 2011). The AL model has been used in many studies to evaluate mental stress in the development of cognitive disorders, diabetes, cardiovascular diseases and depression (McEwen, 2008).

Resilience theory is closely connected to AL theory. Resilience emphasizes neurobiological modelling in stress reactivity (Feder et al., 2009). It underlines genetic background and early life epigenetics in the development of stress adaptive systems. Glucocorticoids, central neurobiology and inflammation play key roles in the pathophysiology of stress-related diseases. Adequate balance between catabolic (mobilization of energy) and anabolic (growth, healing) processes is considered necessary for long term health and survival (Lundberg, 2005). Catabolic processes mobilize energy in stress states and anabolic processes restore functional reserves, enhancing growth and healing. In modern society time pressure, high work demands, and demands for efficiency and competitiveness cause lack of rest. Resilience-based interventions might have positive health impacts in workers' wellbeing (Spangler et al., 2012). Insufficient recovery and restitution are more important health risk factors than the absolute level of stress. In addition to mental stress this model is useful in the assessment of effects related to physical overstrain (Eliakim, 2010).

The disruption of biological circadian rhythms might be, at least in some cases, a more important cause of negative work-related health impacts than job stress or even sleep loss itself (Castanon-Cervantes et al., 2010). Prolonged activation of the immune system, in particular, is independently associated with shift work, which constantly causes conflict between the social environment and basic biological rhythms (Puttonen et al., 2011). In the global work environment jet lag caused by travel, or dyssynchrony in working times with the need for constant personal communication, may disrupt the circadian clock (Comperatore and Krueger, 1990). Symptoms of circadian dysfunction closely mimic traditional functional or stress symptoms. Dyssynchrony affects physiological mechanisms profoundly and has been associated with cardiovascular, metabolic, inflammatory and neurological diseases, as well as cancer (Boivin et al., 2007, Karatsoreos, 2012). Circadian disruption is a challenge to working life in modern 24/7 society (Härmä and Ilmarinen, 1999).

### 2.2 Recovery

Recovery is one of the common features in the various concepts of work stress (Figure 1). Recovery is a process of psychophysiological unwinding after exposure to demands and stressors. It plays a crucial role in protecting employees against the adverse effects of work stress (Geurts and Sonnentag, 2006). Recovery depends upon engagement in valued, self-chosen non-work activities. Workers may recover insufficiently during the workday, after working hours or during weekends and holidays. Insufficient recovery may be caused by working overtime or by the prolonged cognitive effects of daily stressors (Van Hooff et al., 2007; Kompier et al., 2012). Sleep provides a crucial physiological element of restoration. Emotions may strongly affect physiologically assessed recovery (Radstaak et al., 2011). Poor neuroendocrine recovery is more prominent after combined stress of mental and physical factors than after mental or physical stress alone (Sluiter et al., 2000). Lack of job control increases the risk of poor neuroendocrine recovery (Berset et al., 2009)

The detrimental effect of job stressors on health and well-being of employees has been well established. Exposure to job stressors may trigger potentially harmful physiological responses or strengthen the negative health effects of lifestyle factors such as smoking, alcohol consumption, unhealthy diets, lack of exercise and disturbed sleep. Prolongation of physiological stress responses such as elevated blood pressure, raised heart rate, increased secretion of catecholamines and cortisol hormone following the end of demands and stressors has negative impacts on health and well-being (Schnall et al., 1998; Vrijkotte et al., 2000; Brosschot, 2006; Brosschot et al., 2010). Lifestyle factors, however, may have the most prominent role in the development of poor health outcomes, such as cardiovascular diseases (Kivimäki et al., 2012).



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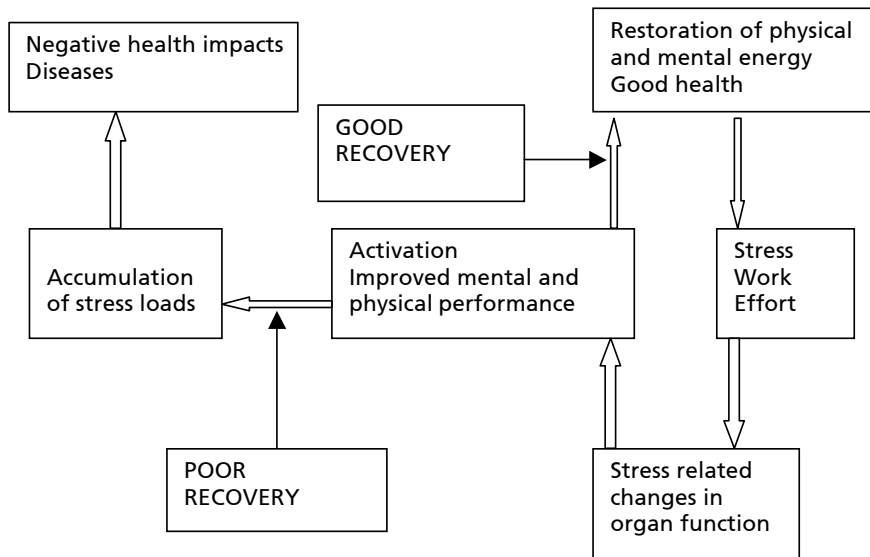


Figure 1. The role of recovery in health and diseases.

The Effort-Recovery Theory suggests that stress unavoidably associated with working will not have long-term negative health consequences as long as workers recover sufficiently after work (Meijman and Mulder, 1998). Recovery after work is inadequate, if prolonged exposure to high work demands or work-related cognitive processes maintains continuous physiological activation. Insufficient recovery forces employees to perform new job tasks while in a sub-optimal state. This increases the need for recovery and a vicious cycle may develop. Chronically insufficient recovery may predispose to exhaustion with physiological findings (Zanstra et al., 2006).

The AL theory proposes that prolonged physiological activation disturbs the homeostatic (especially sympathetic/parasympathetic) balance in the body. It causes chronic hyperactivity or inactivity in stress pathways. Unwinding from load effects is crucial for preserving health and well-being (de Bloom et al., 2009). An association exists between biological processes and self-rated recovery from work stress. Insufficient recovery may result in high AL (von Thiele et al., 2006).

Recovery can also be enhanced by self-chosen and pleasing activities. The conservation of resources theory (Hobfoll, 1989) claims that harmful subjective stress results when valued resources are threatened, lost, or not gained after personal investments in them. Physiologically the consumption of energy is necessary to stabilize the production of energy.

In self-determination theory autonomy and relatedness are considered fundamental human needs (Ryan and Deci, 2000). The satisfying of these needs elicits positive emotions, while their neglect produces negative affect. It has been demonstrated that workers experience higher positive and lower negative affect during off-job time compared with work periods, due to satisfaction of their need for autonomy and relatedness (Ryan et al. 2010). According to the broaden-and-build theory, positive and negative emotions have complementary adaptive functions and effects (Tugade and Fredrickson, 2007). Negative emotions evoke survival-oriented behaviour while positive emotions activate novel and exploratory thoughts and actions. Positive emotions are associated with the production of certain 'pleasure reward' hormones, such as serotonin and dopamine, which down-regulate the stress response (Esch and Stefano, 2004). Fredrickson et al. (2000) have reported that positive emotions can indeed rapidly undo the unfavourable cardiovascular arousal induced by negative emotions. Positive emotions have long-term favourable effects on stress adaptive psychological mechanisms. On the other hand, depressive mood is an example of a negatively loaded emotional state with increased risk of somatic health problems.

### **2.3 Work in a 24/7 society with broadcasting as an example**

Increasing numbers of workers in broadcasting have irregular shifts. Despite attempts to optimise work-rest periods to preserve functioning, sudden changes in information flow, technical problems and alterations in team resources may hinder recovery and increase stress. Time pressures and cognitive strain due to overflow of media inputs enhance stress. New technology requires constant learning and implementation of new working modalities. Although working time at the workplace is restricted, employees tend to continue work-related activities at home and outside the workplace. This may lead to overcommitment and extension of the real working time.

Broadcasting is a good example of working life in modern 24/7 society. It requires shift work that is often irregular. The short-term effects include sleep problems, fatigue, attenuated work performance and increased risk of accidents (Härmä 2006; Ohayon et al., 2010). Long-term negative effects of shift work include increased risk of obesity (Di Milia and Mummery, 2009), breast cancer (Stevens et al., 2011), cardiovascular diseases (Puttonen et al., 2010), gastrointestinal disorders, and depression (Roth, 2012). Poor recovery has been suggested to play a very important role in the development of negative health outcomes associated with shift work (Härmä, 2006).

It is probable that variations in stress potential exist between different work schedules. ISW has been associated with insomnia (Järnefelt et al., 2012), prolonged subjective and neuroendocrine stress (Ulhoa et al., 2011), changes in brain biochemistry (Kakeda et al., 2011), depressed mood (Driesen et al., 2010) and sleepiness (Sallinen et al., 2005). Whether ISW or subjective dissatisfaction with the current shift schedule is more important in the development of stress and stress-related symptoms remains unresolved (Ahlberg et al., 2003). Long working hours have been related to poor health, especially in workers with low socioeconomic background and family responsibilities (Artazcoz et al., 2012). Long working hours have been associated with central obesity (Gu et al., 2012), coronary heart disease (Virtanen et al., 2012), subclinical atherosclerosis (Charles et al., 2012) and depression (Virtanen et al., 2011). The increased risks between poor health and working times can also be explained by other job-related, or behavioural and lifestyle factors (van der Hulst, 2003; Holtermann et al., 2010; Zolnierczyk-Zreda et al., 2012).

### **2.4 Job control and workers health**

There is strong evidence that high job demands, low job control, low co-worker support, low supervisor support, low procedural justice, low relational justice and a high effort-reward imbalance predict the incidence of work stress-related disorders (Karasek and Theorel 1990; Nieuwenhuijsen et al., 2010). Transition from low to high control improves the quality of sleep (de Lange et al., 2009). Low job control, rather than high job demands, has an important role in work stress-related disorders

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(Collins et al., 2005). Low job control is associated with subclinical atherosclerosis (Fujishiro et al., 2011), stroke (Toivanen, 2008) and elevated blood pressure (Steptoe and Willemsen, 2004). Psychosocial risk factors prevailing before working age predispose to unfavourable cardiovascular health in low control workers (Hemmingsson and Lundberg, 2006). Job strain and prolonged stress are modifying and contributing factors to negative health impacts (Figure 2). Brain-body interactions play a crucial role in the development of common diseases with increased risk of lower work ability and functioning.

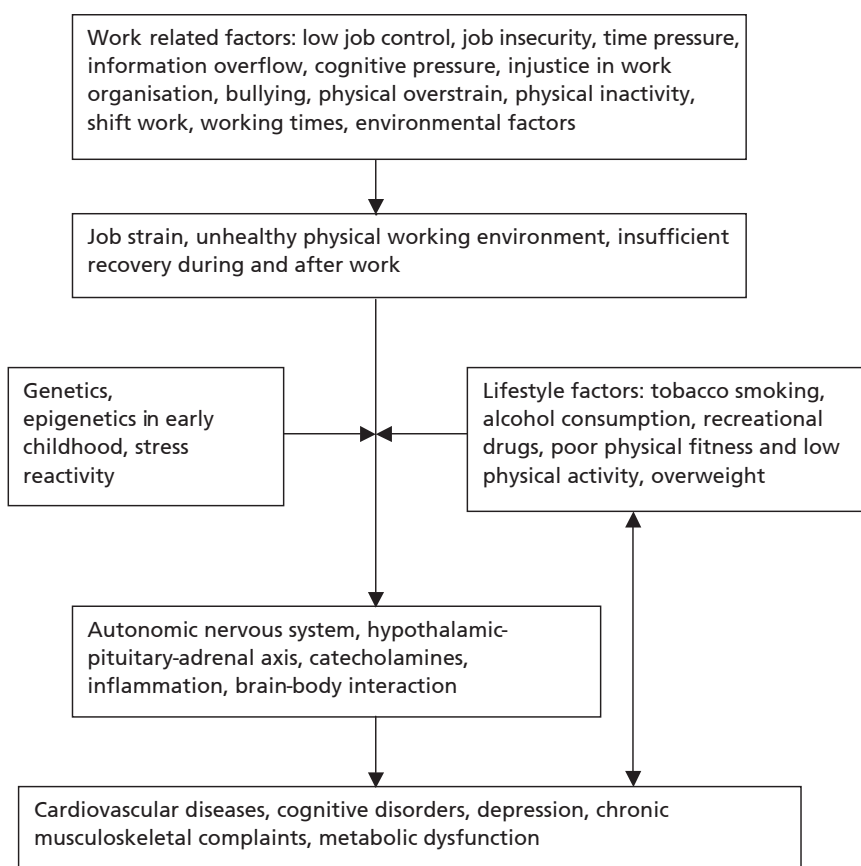


Figure 2. A simplified model of interactions between work-related factors, physiological determinants of stress and some common diseases with the risk of decreased work ability.

## **2.5 Salivary hormones and heart rate variability in the assessment of work strain and recovery**

### **2.5.1 Salivary cortisol**

Salivary cortisol analysis has been developed to monitor the diurnal cortisol excretion profile, with the highest level in the morning and lowest in the evening. Saliva sampling has improved the possibility to detect tonic alterations in basal excretion and daily dynamic changes in relation to chronic or acute stress (Kirschbaum and Hellhammer, 1989; Hellhammer et al., 2009). Cortisol awakening response (CAR) is normally defined as increase of salivary cortisol level during the first 30 minutes after waking (Fries et al., 2009). In a recent review by Golden the use of multiple salivary cortisol measurements across the diurnal curve (with awakening cortisol) had similar between-visit reliabilities to dexamethasone-suppressed cortisol and adrenal gland volume, and salivary sampling was considered a feasible measure of HPA-axis function in population-based studies (Golden et al., 2011). Salivary analyses of cortisol have also been introduced in clinical work (Gozansky et al., 2005). There is an optimal time window to perform saliva collection for determination of CAR, and actigraphically assessed waking time is better than self-assessed waking time (Smyth et al., 2013).

In a PubMed search from 1990 to February 2013 the terms salivary cortisol, occupational health, work, and worker were used. Reports from strict laboratory settings were excluded and the remaining reports are presented in Table 1. Effort-reward imbalance and poor recovery have been reported in several studies to be associated with alterations in cortisol level. The results from using cortisol waking response in the assessment of stress are controversial, but most reports support the correlation between increased stress and augmented response. There are three recent studies in which long-term HRV and salivary cortisol were monitored simultaneously in real-life occupational settings. Increased cortisol and reduced HRV were found to associate with each other. There have been no studies of salivary cortisol responses among media workers.

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**Table 1. Salivary cortisol in measurements of work-related real-life settings.**

<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Eek et al., 2012	581 workers, Sweden	Chronic lack of recovery was associated with cortisol levels. Gender might influence the responses.
Eller et al., 2012	480 workers, Denmark	Effort-reward imbalance was negatively correlated with cortisol awakening level, and positively correlated with cortisol awakening response.
Fekedulegn et al., 2012	65 police officers, USA	Long-term midnight shift work was associated with decreased absolute mean level of salivary cortisol.
Hansen et al., 2012	4066 civil servants, Denmark	Low morning cortisol was associated with sleep problems at baseline. Flattened cortisol profile was associated with sleep problems during 3 months follow up. Low cortisol levels in general were associated with awakening problems.
Izawa et al., 2012	33 teachers (kindergarten), Japan	Cortisol levels increased during the first weeks of teaching practice.
Klein et al., 2012	38 anaesthesiologists, Israel	Implicit job stressors correlated with elevation in morning cortisol.
Maina et al., 2012	63 females and 24 males, Italy	In the assessment of day-to-day variability during three weeks, salivary cortisol levels were affected by several confounding factors, such as educational level and smoking.
Österberg et al., 2012	45 former burnout patients, Sweden	Diurnal salivary cortisol was unrelated to the extent of work resumption.
Anjum et al., 2011	16 nurses, India	Night shifts changed cortisol diurnal profile and recovery was incomplete during the day shift.
Eller et al., 2011	70 healthy workers, Denmark	Among male workers a greater number of hours spent doing homework was associated with low cortisol levels and effort-reward imbalance at work with elevated cortisol levels. Among female workers lack of control was associated with reduced HRV.

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<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Limm et al., 2011	174 lower or middle managers (99% males), Germany	Stress management intervention reduced depression, anxiety, effort-reward imbalance. Improvement was associated with decrease in sympathetic activity assessed by salivary $\alpha$ -amylase, but not with cortisol. The positive effects remained for at least one year.
Wetzel et al., 2011	16 surgeons, case-control study, UK	Stress management group showed improved team-work, reduced stress, reduced HRV. Cortisol changes were not significant.
Wirth et al., 2011	68 police officers, USA	Waking cortisol values were lower among officers working with short-term night or afternoon shifts than day shifts. The maximal difference occurred after 5 days of shift work. Duration of long-term shift work was not associated with cortisol awakening response.
Wright, 2011	98 direct-care disability workers, Australia	The association between effort-reward imbalance and cortisol was only weak.
Izawa et al., 2010	20 workers, Japan	Cortisol awakening response was negatively affected by sympathetic activity during awakening time assessed by HRV. Cortisol awakening response was not associated with subjective sleep quality.
Klaassens et al., 2010	53 male railway employees, the Netherlands	Basal cortisol levels were lower among workers exposed to trauma in adulthood than cortisol levels among workers without exposure.
Looser et al., 2010	88 nurses, Germany	During everyday low-level stress, reduced HRV and increased cortisol occurred independently, but during high stress they occurred in synchrony.
Backé et al., 2009	24 workers, Germany	The cortisol awakening response was higher in emergency ambulance shift than in normal patient transport. Responses during work did not differ.
Berset et al., 2009	69 workers, Switzerland	Low job control predicted elevated cortisol and poor recovery during the rest day.
Garde et al., 2009	21–40 workers participating 5 lifestyle sub-studies, Denmark	Differences in relative cortisol awakening responses on workdays and duty-off days were related to time and mode of awakening, not other lifestyle factors.

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<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Hong et al., 2009	20 female workers, Korea	Appropriate sampling times for salivary cortisol were at 7:00 (time of awakening), 8:00 (1 hour after awakening), 17:30 (early evening), and 22:30 (before sleep).
Kumari et al., 2009	2751 subjects in a large community dwelling population, UK	Short sleep duration and sleep disturbances were associated with flattening of diurnal cortisol curve, increased awakening response and elevated evening cortisol. Stress or awakening time did not affect the findings.
Maina et al., 2009	36 call-handlers, Italy	Job strain significantly influenced the total amount of cortisol response to waking. Response was more evident among females than males.
Metzenthin et al., 2009	82 nurses, Switzerland	A one-item subjective work stress assessment was correlated with increased cortisol level. No correlation was found between objective assessment of work load and cortisol.
Thomas et al., 2009	7855 subjects, UK	Night work was associated with elevated cortisol levels.
Vangelova, 2008	25 sound engineers, Bulgaria	Cortisol was higher during morning and night shifts and quality of sleep was worse in work with very fast backward-rotating shifts than with very fast forward rotating shifts. This may indicate insufficient recovery.
Badrick et al., 2007	3103 male and 1128 female subjects, civil servants, UK	Cortisol daily level and awakening response were higher among current smokers than ex-smokers or non-smokers.
Fekedulegn et al., 2007	68 police officers, USA	Area under the curve (AUC) in cortisol profile might be a useful parameter in cortisol analyses.
Garde et al., 2007	40 male construction workers, Denmark	The diurnal profile for cortisol differed between workdays and days off for construction workers with extended work weeks. No indications of insufficient recovery were found in terms of increased catabolic or decreased anabolic metabolism in construction workers with 12-h workdays and extended workweeks compared to construction workers with regular work schedules.
Nickel et al., 2007	72 male workers case-control study, Germany	A significant reduction was found in daily systolic blood pressure, salivary cortisol concentration and three subjective stress scales during behavioural/psycho-educational training in the treatment of men suffering from chronic stress due to overworking.



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<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Carlsson et al., 2006	141 workers, 3 environmentally annoyed groups and reference group, Sweden	Environmentally irritated group showed no signs of increased HPA-axis activation. Subjects annoyed by electrical devices and smells seem to be related to increased psychological activation in terms of self-reported stress.
Eller et al., 2006	83 healthy workers, Denmark	Among females time pressure and effort-reward imbalance were significantly associated with elevated levels of cortisol. Among males high degrees of effort, effort-reward imbalance and overcommitment were significantly associated with elevated levels of cortisol.
Zefferino et al., 2006	30 policemen, Italy	Cortisol at the start of work-shift was higher than at the end. There was a significant difference between mean cortisol concentrations at the same hour during work vs. holiday.
Eller et al., 2005	95 workers, Denmark	The awakening cortisol response associated with intima media thickness (IMT) progression among women but not among men.
Heinrichs et al., 2005	43 fire fighters, Switzerland	Neuroendocrine activity assessed by cortisol awakening and diurnal profiles and 24-hour urinary catecholamine excretion during basic training did not predict the risk of post-traumatic stress disorder in 2 year follow up.
Kunz-Ebrecht et al., 2004	97 male and 84 female workers, UK	Job control did not influence cortisol awakening responses. In men cortisol levels over the day were inversely and independently correlated to job control.
Lac and Chamoux, 2004	32 male shift workers and 18 daytime workers, France	Consistent changes appeared in cortisol circadian profile among the two groups of shift workers, particularly in the 7/5 group. Changes correlated with self-perceived constraints of work.
Lac and Chamoux, 2003	63 shift workers case report of one subject, France	Very high cortisol values (approximately 6-fold increase) were observed for the morning shift, but with normal values found for evening and night shifts in one worker. Cortisol rise was deduced to be caused by sleep deprivation as a result of rapidly rotating shift patterns.
Weibel et al., 2003	8 emergency dispatchers, 8 controls, France	Emergency medical dispatchers had higher mean daytime augmentation in cortisol levels compared to control subjects. Subjective perception of emotional stress was positively correlated with total cortisol concentrations.

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<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Evans and Steptoe, 2001	61 nurses and 32 accountants, UK	Work social support was not related to cortisol on work days. On leisure days cortisol was elevated among individuals reporting high social support. Low social support at work was associated with elevated heart rate during the daytime and evening of work days. The effect persisted after controlling for psychological distress, age, gender, smoking and physical activity.
Ganster et al., 2001	105 nurses, USA	Subjective and objective indicators of work demands interacted with the personal perception of job control. Tonic elevations in salivary cortisol mediated the effects of demands and control on health care costs of the employees during the 5-year follow up.
Yang et al., 2001	23 emergency department and 50 general ward nurses, Singapore	Morning salivary cortisol concentration was correlated with professional stress.
Brody et al., 2000	85 fire fighters, Germany	Social desirability scores (defensiveness) were associated with higher cortisol levels in fire fighters under the age of 45 years, but not in older fire fighters.
Fischer et al., 2000	84 nurses, Switzerland	Organisational changes reduced cortisol secretions. Loss of team coherence was a strong confounding factor.
Melamed et al., 1999	37 workers with burn out, 74 controls, Israel	Workers with chronic burnout symptoms had higher levels of tension at work, post-work irritability, more sleep disturbances and complaints of waking up, subjective exhaustion, and higher cortisol levels during the work day compared to controls with no chronic burnout symptoms.
Hakola et al., 1996	20 shift workers, Finland	The circadian rhythm of body temperature, salivary cortisol, and time in bed changed between the work shifts. No differences were found between men and women in circadian adjustment of physiological variables to night work.

### **2.5.2 Salivary melatonin**

Excretion of melatonin from the pineal gland is highest during the dark hours of the day and attenuates rapidly in daylight or other light exposure. Salivary melatonin was developed to monitor the light-dark cycle and synchrony of the circadian clock (McIntyre et al., 1987; Koller et al., 1994). A disturbed circadian cycle of salivary melatonin has been associated with mental disorders (Frey et al., 2012), inflammation (Gröschl, 2009) and psychosomatic symptoms (Nagane et al., 2011). In some studies salivary melatonin measurement has been considered a reliable, sensitive and easy method to monitor changes in the circadian rhythms of melatonin (Zhou et al., 2003). The accuracy for assessing low levels of melatonin might be limited (Kozaki et al., 2011).

In the PubMed search from 1990 to February 2013 the terms salivary melatonin, occupational health, work, and worker were used. Reports from strict laboratory settings were excluded and the remaining reports are presented in Table 2. Although salivary melatonin has been used in several controlled studies in laboratory environments, there have been only six studies in real-life occupational settings and none among media workers.

**Table 2. Salivary melatonin in the measurements of work-related real-life settings.**

<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Gumenyuk et al., 2012	5 asymptomatic night shift workers, 5 night workers with shift work disorder (SWD), USA	SWD workers could not adjust their circadian rhythm to night work.
Sasseville and Hébert, 2010	4 sawmill shift worker, light treatment, Canada	Bright-light treatment reduced disruption in circadian melatonin.
Grundy et al., 2009	61 nurses with rotating shift work, Canada	Two nights of rotating shift did not change the timing of melatonin production.
Boivin et al., 2002	10 nurses in the bright-light treatment group, 5 controls, Canada	Bright-light intervention improved circadian adaptation to rotating shift work.
Goh et al., 2000	20 naval workers on board, Singapore	Half the workers retained their circadian cycle, half had changes in circadian rhythm.
Koller et al., 1994	14 permanent night workers, Austria	Salivary melatonin profile might be useful in the characterization of night shift adaptation.

### 2.5.3 Heart rate variability

The first studies of the interplay between respiration, heart rate and blood pressure were reported by Hales in 1733 (Hales, 1733). HRV is a term that describes the oscillations in consecutive cardiac cycles. Physiologically the accurate way to assess rapid changes in heart rate is to measure the time (ms) between adjacent P-waves, because cardiac rhythm normally originates from the sinoatrial node. The first recordings of respiratory sinus arrhythmia were introduced in the 19<sup>th</sup> century (Ludwig, 1847). After Norman Holter introduced a portable ECG recorder in the 1960s, the analysis of HRV developed rapidly (Holter, 1961). Novel computer-based techniques now allow us to analyse ECG or R-R intervals in different domains.

Analysis of changes in time intervals between adjacent R-waves (electrical depolarisation of cardiac ventricles) has been accepted in practice

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to reflect HRV (Task Force, 1996). HRV can be measured from short-term (5–10 minutes) or from long-term recordings (hours-some days). The variation of R-R intervals calculated directly statistically in the time domain represents originally derivatives of simple indicators, such as standard deviation. Frequency domain analyses have been developed to characterize more accurately the dynamic changes and the most recent non-linear analyses also take into account sudden and even chaotic changes in R-R intervals. A great number of indices of HRV exist (Task Force, 1996; Billman, 2011).

Reduced HRV associates with attenuated parasympathetic and/or increased sympathetic activity in cardiac autonomic control. Because attenuation in the parasympathetic regulation of heart rate is mediated mainly via the vagus nerve, the term vagal attenuation has also been used. In the 1990s the first studies of HRV during real-life stressful situations were reported (de Meersman et al., 1996, Lucini et al., 2002), since when the use of HRV analysis has developed rapidly (Britton and Hemingway, 2004).

In a PubMed search from 1990 to February 2013 the terms heart rate variability, occupational health, work, and worker were used. Reports from strict laboratory settings were excluded and the remaining reports are presented in Table 3. Most work-related long-term HRV analyses have focused on effects of environmental factors, such as noise, nanoparticles, other air pollutants and chemicals. Several studies have explored exercise-induced and post-exercise recovery changes in HRV (Achten and Jeukendrup, 2003). Recently, HRV-based monitoring was reported to improve the accuracy of assessment of oxygen consumption during physical work (Smolander et al., 2011).

The results of HRV used in stress and recovery related studies are controversial (Table 3). Most studies have found an association between HRV and stress. Some reports emphasize the role of the vagal component of HRV in detecting good recovery, whereas in other studies no effect has been found (Aasa et al., 2006; Togo and Takahashi, 2009; Collins and Karasek, 2010). It is clear that work-related studies with analyses of actual sleeping time are rare (Clays et al., 2011; Malmberg et al., 2011). There exist no studies of stress and recovery in broadcasting work.

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**Table 3. Heart rate variability recordings in work-related real-life settings.**

<b>Author</b>	<b>N, country</b>	<b>Main results</b>
Jackowska et al., 2012	199 female workers, UK	Reduced HRV might be a potential pathway linking sleep problems with cardiovascular diseases.
Clays et al., 2011	653 healthy male workers, Belgium	The work stressor index was significantly associated with lower pNN50 (percentage of differences between adjacent normal RR intervals > 50 ms), with lower high frequency power of HRV and higher ratio of low frequency to high frequency power in HRV.
Malmberg et al., 2011	19 anesthesiologists, 16 pediatricians, Sweden	Physiological recovery in HRV was sufficient and did not differ between medical specialities. Dynamic changes of HRV were weaker among anesthesiologists after daytime work and during night-call duty, which may indicate higher physiological stress level.
Uusitalo et al., 2011	19 hospital workers, Finland	Chronic work stress correlated with vagal activity index of HRV. Higher effort during work was associated with lower daytime HRV and relaxation time assessed by HRV.
Collins and Karasek, 2010	36 healthy male workers, USA	Job strain was associated with reduced cardiac vagal activity in HRV. The HRV profile of exhausted workers was characteristic.
Lee et al., 2010	140 industrial workers, Korea	HRV was a potential indicator of job stress among employees with short duration of employment, but not job stress in general.
Loerbroks et al., 2010	591 workers, Germany	Inverse association was found between effort-reward imbalance and HRV, especially in the 35–44 year age group.
Thayer et al., 2010	60 workers in traditional office environment, 20 workers in modern office environment, USA	Workers in the traditional office environment had flatter slopes, less circadian variation and less HRV at night than workers in the modern office. Workers with attenuated HRV had an augmented cortisol awakening response.
Togo and Takahashi, 2009	Review	Environmental exposures, psychosocial job stressors and shift work had associations with low vagally mediated HRV.
Orsila et al., 2008	30 healthy workers, Finland	Perceived mental stress was associated with root mean square of differences of successive R-R intervals (RMSSD) in HRV obtained in the morning and during the workday.

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Aasa et al., 2006	26 ambulance workers, Sweden	Stress markers did not show differences between work shift and leisure time.
Collins et al., 2005	36 healthy worker, USA	Job strain and low decision latitude were associated with reduction in cardiac vagal control throughout the 48 hrs monitoring. Job strain was also associated with elevations in the sympathetic component of HRV during working hours.
Riese et al., 2004	159 nurses, The Netherlands	High job strain among young female nurses was not associated with unfavourable ambulatory cardiovascular profile.
Park et al., 2001	238 engineers, Korea	Especially the low frequency component of HRV may serve as early objective biological indicator of chronic stress effect of regular overtime work.
Sato et al., 2001	6 long-distance truck drivers, Japan	Parasympathetic nervous activities in HRV were more dominant than sympathetic nervous activities in the morning during long distance truck driving, including midnight work. High HRV during driving might indicate drowsiness.
Myrtek et al., 1999	29 blue collar and 57 white collar workers, Germany	During working hours from 8 to 16 h differences were found in heart rate (physical activity) and non-metabolic heart rate, but not in HRV.
Sasaki et al., 1999a	278 engineers, Japan	There were no significant relationships between working hours and HRV.
Sasaki et al., 1999b	147 engineers, Japan	Urinary noradrenaline in the afternoon and LF/HF ratio in HRV were lower among workers aged 30–39 years and with long working hours.
Adams et al., 1998	12 physicians, USA	HRV measures indicated increased sympathetic tone compared to parasympathetic tone during the period before work compared with after work.

### **3 AIMS OF THE STUDY**

The main aim of this study was to assess the association between self-reported stress and physiological biomarkers of stress and recovery among media workers. We also aimed to identify work-related characteristics that could explain poor physiological recovery. Finally, the association between the critical indicators of recovery and sleep, and some common diseases and general health were analysed in the study population representing modern 24/7 occupations. This thesis is based on four studies. The aim and main hypotheses of each study were as follows:

1. **To assess the association between self-reported stress and physiological biomarkers of stress on the HPA axis**

The main hypothesis was that cortisol as a biomarker of stress on the HPA axis correlates with subjective stress among media workers. The other hypothesis was that salivary cortisol is suitable for detecting dynamic changes in 24/7 type media work.

2. **To evaluate combined physiological recordings of stress and recovery in ANS function and HPA axis in the assessment of poor recovery in media work**

The hypothesis was that simultaneous recordings may reveal more information about stress and poor recovery than separate analyses due to the possible circadian disruption and altered sleep, especially among media workers with ISW.



3. **To detect work related characteristics of media work that could explain poor physiological recovery**

The hypothesis was that job control plays an important role in maintaining the recovery potential of media workers. It was also hypothesised that HRV measured during sleep better reflects recovery than recordings made when awake.

4. **To assess the relationship between sleep quality and common diseases, such as hypertension and depression, among media workers.**

The hypothesis, based on previous studies, was that sleep problems have an association with negative health effects. The association between sleep as an indicator of poor recovery and two common health risks, hypertension and depression, was tested among media workers. It was also hypothesised that it is beneficial to characterize systematically in occupational health care the type of sleep-related disorders.

## **4 MATERIALS AND METHODS**

### **4.1 Study design and population**

A standardized questionnaire was mailed to all employees of the Finnish Broadcasting Company with irregular shift work (ISW, N = 750) and to an equal number of randomly selected controls with regular 8-hour daytime work (RDW). The aim was to analyze whether ISW and RDW have different risks for the development of stress or poor recovery. The response rates were 58.3% (N = 874, 53.7% men) overall, 82.3% (N = 617, 56.6% men) for the ISW group and 34.3% (N = 257, 46.7% men) for the RDW group. The employees' work included journalism, broadcasting, programme production, technical support and administration. Of the respondents (N=874), 70 employees from both groups (RDW and ISW) were randomly selected for physiological measurements (Figure 3).

Shifts were characterized according to the following criteria: night shift – at least 3 h of the shift, or the whole shift, was between 11:00 p.m. and 6:00 a.m.; evening shift – ended between 11:00 p.m. and 1:59 a.m. and was not a night shift; morning shift – commenced between 3:01 a.m. and 6:59 a.m. and was not a night or an evening shift. Daytime work regularly took place between 7:00 a.m. and 5:00 p.m.

There was some variation in the number of study subjects in different sub-studies. The few drop outs were caused by technical issues in the ECG, and errors in saliva sample collections (studies I–III). The week-end recordings were performed only in the ISW group without any reference group with RDW and the results are not included in this study.

All participants gave written informed consent. Study protocols were approved by the Ethics Committees of the Hospital District of Helsinki and Uusimaa, Finland.

## 4 MATERIAL AND METHODS

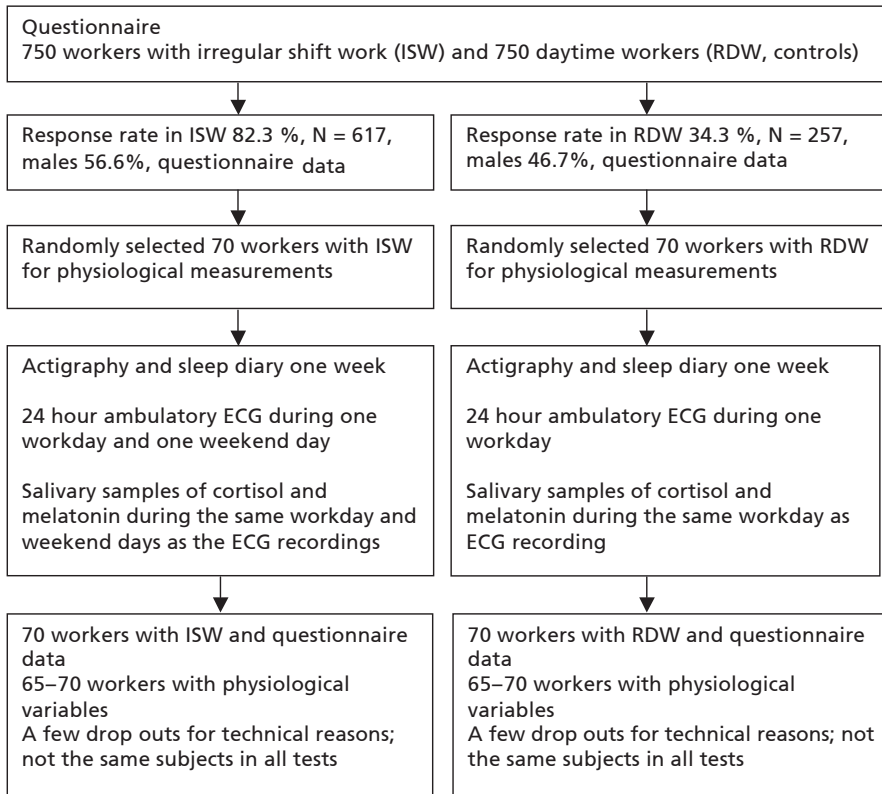


Figure 3. Study flow chart.

## 4.2 Questionnaires

The questionnaire had been validated in a previous stress study performed in the same company (Ahlberg et al., 2002). The questionnaire covered demographic items, such as gender, age and psychosocial status. Weekly working hours, work satisfaction, work ability and other employment details were asked. There were also items on psychosomatic symptoms, alexithymia and health care use. Perceived stress was evaluated by asking the following validated single question: “Stress means the situation when a person feels tense, restless, nervous or anxious, or is unable to sleep because his/her mind is troubled all the time. Do you feel that kind of stress these days?” Response alternatives were: 1) “not at all”, 2) “only a little”, 3) “to some extent”, 4) “rather much”, and 5) “very much” (Elo et al., 2003). Life satisfaction was asked as “How satisfied are you with your present life?” Response alternatives were 1) “very satisfied”, 2) “rather satisfied”, 3) “neither satisfied nor dissatisfied”, 4) “rather dissatisfied”, and 5) “very dissatisfied”. Subjects were classified as dissatisfied with their life if they responded 4 or 5.

Perceived poor health was asked as “In your opinion, how is your general health compared to other persons of the same age?” Alternatives were 1) “excellent”, 2) “good”, 3) “not good, not bad”, 4) “poor”, and 5) “very poor”. Subjects were classified as having poorer health than others of the same age if they responded 3, 4 or 5. The assessment of depressive mood was based on the SCL-90 (Symptom Check List-90, Finnish version), which includes items of mental health (Holi et al., 1998).

Sleep and sleep related disorders were evaluated by the Basic Nordic Sleep Questionnaire (BNSQ, Partinen and Gislason, 1995). Response alternatives to each of the following items, if not otherwise specified, were: 1) “never or less than once a month”, 2) “less than once a week”, 3) “on 1–2 days weekly”, 4) “on 3–5 days weekly”, and 5) “every day or almost every day”. The words “day” or “days” were replaced by “night” or “nights” when asking about night time symptoms. Insomnia symptoms during the past three months were assessed by the following questions: 1) “Have you had difficulties falling asleep?” 2) “How often have you woken up during the night?” 3) “If you wake up often at night, how many times on average do you wake?” 4) “How often have you woken too early in the morning without being able to fall asleep again?” 5)

“How quickly do you usually fall asleep in the evenings?” (“over 40 minutes”, “31–40 minutes”, “21–30 minutes”, “10–20 minutes” and “less than 10 minutes” 6) “If you suffer from insomnia at the moment, have your difficulties in falling asleep, or staying asleep, continued for at least one month?” 7) “How many nights during the previous month has your sleep lasted less than 5 hours or about 5 hours?” Alternatives were “never”, “1–5 nights”, “6–10 nights”, “11–15 nights”, “16–20 nights” and “over 20 nights”. In addition, subjects were asked about length of sleep, times of falling asleep, waking up times, and about snoring and history of breathing pauses (apneas) while sleeping.

### **4.3 Salivary cortisol**

Salivary cortisol levels were measured using a commercially available chemiluminescence immunoassay for the quantitative determination of cortisol in human saliva (Cortisol Saliva LIA, IBL Immuno-Biological Laboratories, Hamburg, Germany). The assay is based on the competition principle and microtiter plate separation. An unknown amount of cortisol present in the sample and a fixed amount of enzyme labelled cortisol compete for the binding sites of the antibodies coated onto the wells. After 3h incubation the wells are washed to stop the competition reaction. Having added the luminescence substrate solution the relative luminescence units (RLUs) is read after 10 minutes and within 40 minutes. The concentration of cortisol is inversely proportional to the luminescence measured.

The first salivary sample of cortisol was collected at bedtime the preceding day, the second sample immediately after waking and the following samples one, three and eight hours after waking. Salivary cortisol was successfully analysed in 65 workers with IRW and 66 workers with RDW.

### **4.4 Salivary melatonin**

Salivary melatonin levels were measured using a commercially available Direct Saliva ELISA kit (Bühlmann Laboratories AG, Schönenbuch, Switzerland). The assay is based on the competition principle and micro-

titer plate separation. Briefly, an unknown amount of melatonin present in the sample and a fixed amount of biotinylated melatonin compete for the binding sites of the antibodies coated onto the wells. After a 3 h incubation the wells are washed to stop the competition reaction and the enzyme label, streptavidin conjugated to horseradish peroxidase (HRP), is added. During a 1 h incubation this binds to the melatonin-biotin-antibody complex captured on the coated wells. Unbound enzyme label is then removed by a second washing step and TMB (tetramethylbenzidine) substrate is added to the wells. In a third 0.5 h incubation step, a coloured product is formed in inverse proportion to the amount of melatonin present in the sample. The colour turns from blue to yellow after the addition of an acidic stop solution and can be measured at 450 nm.

The first salivary sample of melatonin was collected at bedtime on the preceding day, the second sample immediately after waking and the following samples one, three and eight hours after waking. Salivary melatonin was successfully analysed in 65 workers with IRW and 66 workers with RDW.

### **4.5 Heart rate variability**

In all, 140 employees (70 with ISW and 70 with RDW) were monitored for 24 hours according to guidelines of validated ambulatory ECG methodology (Crawford et al, 1999). The recordings were performed by three channel ECG recorder during one workday and sampling rate was 128 Hz (Braemar DL700 Holter Monitor, Burnsville, USA). The ISW group was additionally monitored for one day at the weekend. Only the recordings lasting over 20 hours were included. If the number of ectopic beats exceeded 10 % of all heartbeats the recordings were not included in further analyses. All recordings were first scanned by an experienced nurse specialized in the analyses of Holter recordings. Thereafter every recording was rescanned by a physician and medical specialist in clinical physiology (HL). Eight recordings were excluded due to short duration (N = 3) or prominent cardiac arrhythmias (N = 5). The time domain parameters of 132 ECG recordings (48% males) were calculated using a validated software for long term ECG recordings (Century 2000, BMS Inc., St Louis, USA). The time domain parameters were used, because

they are less sensitive to scanning errors and are preferred to use in hourly analyses of 24 hour recordings instead of spectral analyses (Lombardi and Stein, 2011).

The hourly mean of the root mean square of the standard deviation (SD) of the adjacent R-R intervals (RMSSD) was selected to represent mainly vagally mediated cardiac autonomic control. Also pNN50 (% , percentage of pairs of adjacent R-R intervals differing more than 50 ms from all recorded R-R intervals) was analysed. SDNN (ms, standard deviation of R-R intervals over the selected time interval) reflects the overall HRV and in long term analyses the cyclic components.

### **4.6 Actigraphy**

The actual sleeping time (Ancoli-Israel et al., 2003) was assessed with an activity sensor (Actiwatch, Cambridge Neurotechnology, UK) worn on the wrist, which continuously monitors body movements and body position. The duration of the actigraphy was one week. The actigraphs also reveal information about differences in movements during the day and night, fragmentation of the sleep and the effectiveness of sleep.

### **4.7 Statistical analyses**

In study I the logarithmic transformation ( $\ln$ ) for the Sa-Cor T1/T0 ratio was computed due to the skewness of the distribution. This was also used as the dependent variable in a multiple linear regression model. Independent variables entered in the model were shift work (no = 0, yes = 1), severe stress ('very much') (no = 0, yes = 1) and actual sleep time assessed by actigraphy. The model was adjusted for age and gender. Due to the asymmetry of the distribution of the Sa-Cor T1/T0 ratio and the bedtime Sa-Mel the salivary hormone levels were compared between the work groups (mean, SD) using the Mann-Whitney U-test. All analyses were performed using a standard statistical programme (SPSS 15.01 for Windows, Chicago, Illinois, USA).

In study II the profiles of the cardiovascular autonomic indices between the groups were analysed using an analysis of variance with

## 4 MATERIAL AND METHODS

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repeated measures (GLM, SPSS 12.01 for Windows, Chicago, Illinois, USA). The skewness of distribution of HRV and salivary hormones was analysed by the Kolmogorov-Smirnov test. The RMSSD values, salivary cortisol values and salivary cortisol/melatonin ratios were logarithmically transformed ( $\ln$ ) due to the skewness of the distribution. The single hourly means between the groups were compared using non-parametric tests (Mann-Whitney). Group differences in continuing variables were tested by ANOVA and classified parameters by the  $\chi^2$ -test. The linear regression model was performed to test the dependencies.

In study III the profiles of the cardiovascular autonomic indices between the groups were analysed using an analysis of variance with repeated measures (SPSS 12.01 for Windows, Chicago, Illinois, USA). Comparison of single hourly means between the groups was made using non-parametric tests (Kruskal-Wallis). The  $\chi^2$ -test was used to study associations between categorical variables.

In study IV STATA 10.1 (StataCorp, USA) was used in statistical analyses. Normality of distributions was defined by the Shapiro-Wilk and Skewness tests. Student's t-test, the Mann-Whitney U-test, or median tests were used to compare group means, depending on the type of distribution. The  $\chi^2$ -test was used to study associations between categorical variables. Logistic regression models were used to analyse the independent effects of the background variables on the probability of occurrence of different types of insomnia complaints. The independent potential risk factors (odds ratios, OR) included in all multivariate models were: gender (females compared to males), age (each 10 years of age; continuous variable), BMI ( $\text{kgm}^{-2}$ ; continuous variable), perceived severe stress (vs. no severe stress), history of apnoea on at least one night per week (vs. no history of apnoea), life dissatisfaction (vs. no dissatisfaction), perceived poor health (vs. no poor health), depressive mood (vs. no depressive mood), diagnosed arterial hypertension (vs. no hypertension), working hours per week (continuous variable), ISW vs. RDW, and dissatisfied with present shift schedule (vs. satisfied with present shift schedule).

In all analyses P-values  $< 0.05$  were considered statistically significant.



## 5 RESULTS

### 5.1 Demographics

The questionnaire data covered about 60% (N = 874, males 53.7%) of the target population (N = 1500). Over 80% (82.3%, N = 617) of the ISW workers (N = 750) responded to the questionnaire study (males 56.6%). In the RDW group (N = 750) the responding activity was lower, at 34.3% (N = 257, males 46.7%). In the ISW group with questionnaire data the mean age of the male workers was 45.0 years (SD 10.6) and of the female workers 42.6 years (SD 10.7). The corresponding mean ages in the RDW group were 47.4 years (SD 9.7) and 45.5 years (SD 10.1, NS), respectively. The mean body mass index (BMI) of the ISW group was 24.5 (SD 4.6) and of the RDW group 24.7 (SD 3.4, NS). Nearly 60% (56.6%) of the men and about a third (32.6%) of the women had BMI > 25 ( $p < 0.01$ ). A BMI > 30, however, was equally common among the male (10.4%) and female (10.2%) workers. Regular leisure time physical activity (LTPA) was performed by 53% of male workers and 61% of female workers. There were no differences between the ISW and RDW groups in LTPA. Regular smokers were 29% of the men and 25% of the women ( $p < 0.05$ ). There was no difference in tobacco smoking between the ISW and RDW groups.

In the study population of media workers with physiological measurements (N = 132) the employees with ISW were younger (39.2 years, SD 10) than the employees with RDW (43.6 years, SD 10). The basic anthropometric data and lifestyle habits of the groups did not differ significantly (Table 4).

## 5 RESULTS

**Table 4. Demographics and lifestyle habits among media workers with physiological measurements of stress and recovery.**

	ISW (N = 66)	RDW (N = 66)	P-value
Male	47%	48%	0.533
Age (mean years)	39.2 (SD 10)	43.6 (SD 10)	0.017
BMI (mean)	24.4 (SD 3.2)	24.5 (SD 4.7)	0.839
Current smoking	21%	27%	0.288
Alcohol consumption > 10 doses/week	22%	20%	0.865
Single, divorced or widowed	38%	52%	0.093
Leisure time physical activity < 3 times/week	69%	60%	0.339

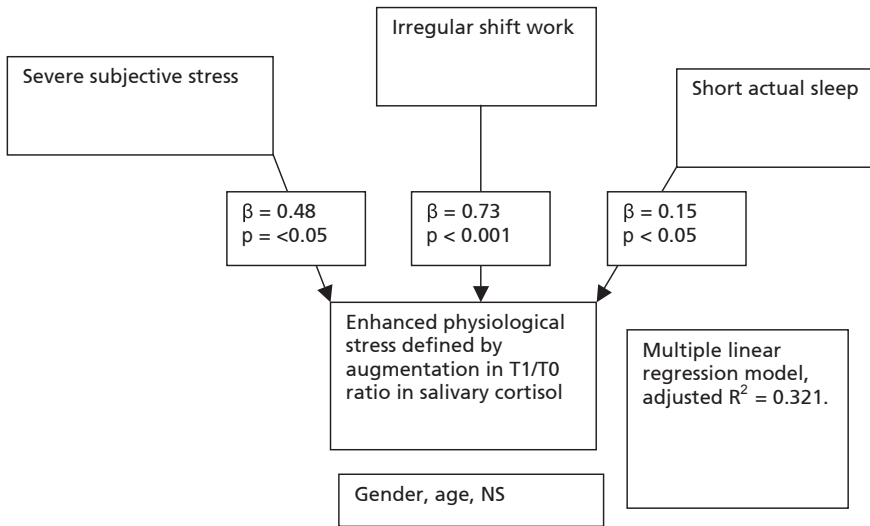
BMI = body mass index, weight (kg)/length (m)<sup>2</sup>; SD = standard deviation

### 5.2 Mental stress and salivary cortisol response

In the RDW group complete salivary cortisol collection was available from 66 employees and complete salivary melatonin collection from 64 employees. In the ISW group 65 employees collected both salivary cortisol and melatonin samples successfully. General lifestyle habits and demographics did not differ between the groups, except for age. The actual sleeping time assessed from actigraphy data was about 45 minutes (0.7 hours) shorter in the ISW group than in the RDW group ( $p < 0.001$ ). Salivary melatonin level was significantly ( $p < 0.01$ ) higher in the RDW group (30.3 pg/ml, SD 27.2) than in the ISW group (19.7, SD 16) at the time of falling asleep.

Physiological stress on the HPA-axis was evaluated by the cortisol response after waking (Study I). The 60 min (T1) salivary cortisol level was related to the salivary cortisol immediately after waking (T0). Because the T1/T0 cortisol ratio was skewed in distribution it was logarithmically transformed (ln). In a regression model (Figure 4) severe subjective stress on the one item stress scale, irregular shift work, and short actual sleep time were significant explanatory variables of an augmented morning cortisol response.

## 5 RESULTS



NS = non-significant, T1 = salivary cortisol at 60 minutes after waking,  
T0 = salivary cortisol immediately after waking

Figure 4. Explanatory factors in the multiple regression model of increased T1/T0 cortisol ratio.

### 5.3 Salivary cortisol, salivary melatonin and heart rate variability as indicators of poor recovery

In both the RDW and ISW groups 66 ECG recordings were analysed in order to study especially nocturnal HRV in relation to poor subjective recovery as reported by prolonged morning and daytime sleepiness during the last two months (Study II). The risk of morning drowsiness and daytime sleepiness was nearly twofold in the ISW group compared to the RDW group (odds ratio 2.08; 95% confidence limits, CI, 1.03–4.22,  $p < 0.05$ ). Gender, age, body mass index, alcohol consumption and tobacco smoking did not explain the increased risk.

## 5 RESULTS

In the group of workers with ISW subjective insufficient recovery was reported by 58% (N = 38) of employees and sufficient recovery by 42% (N = 28). In the RDW group the respective frequencies were 37% and 63%. The vagal indexes of HRV were significantly lower among ISW workers with insufficient recovery than among ISW workers with sufficient recovery. The difference was significant ( $p < 0.05$ ) during the early night and first few hours in bed (Figure 5). The relation between the two circadian hormones was evaluated to compare salivary cortisol and salivary melatonin levels at different time points in the ISW and RDW groups. After waking the salivary cortisol/melatonin ratio did not differ between the groups, but 8 hours later the ratio was attenuated in the ISW group.

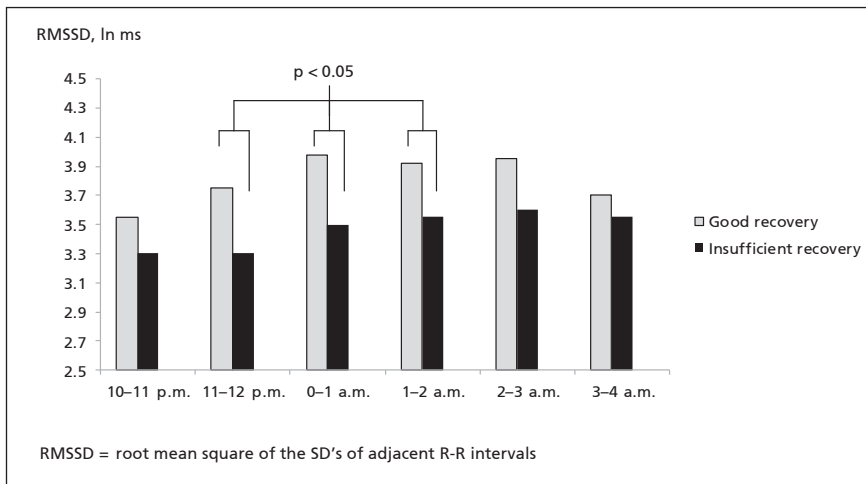


Figure 5. Vagally mediated HRV (ln RMSSD, ms) during late evening and sleep in ISW workers with insufficient (increased morning drowsiness and daytime sleepiness) or good recovery.

## 5.4 Job control and vagal recovery of heart rate variability

All workers with complete ECG ( $N = 132$ ) were divided into three age groups: 25–35 years ( $N = 49$ , males 42%), 36–45 years ( $N = 39$ , males 43%), 46–65 years ( $N = 44$ , males 57%). The mean age of the whole group was 41.3 years (SD 10.3) and the mean BMI 24.5 (SD 0.9).

Job control was highest in the age group 46–65 years (Study III), of whom 39% reported high job control and 43% low control. In the 36–45 year age group high job control was reported by only 21% of workers, and low control by 51% of workers. The difference between these two groups was significant ( $p < 0.01$ ). Job control in these three age groups is presented in Figure 6.

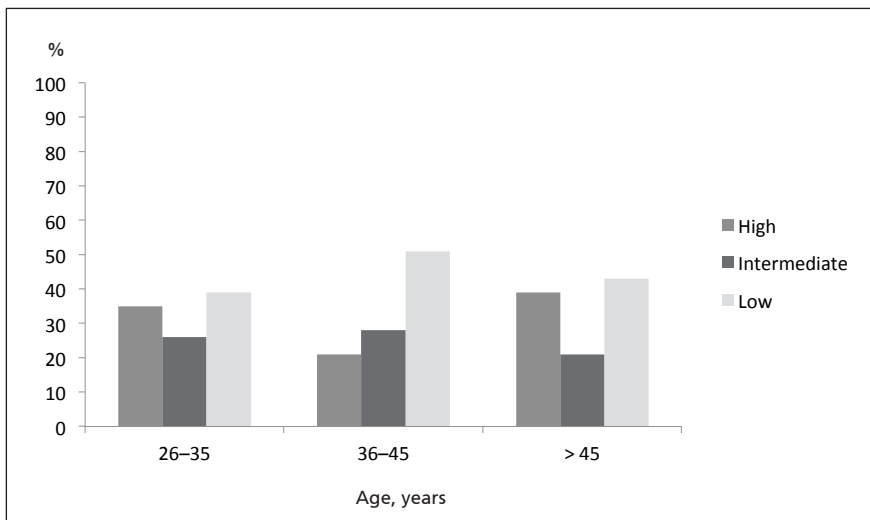


Figure 6. Frequency of self-reported high, intermediate and low job control in media workers aged 25–35 years, 36–45 years and 46–65 years ( $N = 132$ ).

Parasympathetic activity as defined by RMSSD (ms) did not differ during the day and early evening among workers with low, intermediate or high job control (Figure 7). During the recovery period (from 18 to 06

## 5 RESULTS

between working days), those who experienced high job control had significantly higher parasympathetic activity. Vagal recovery was markedly better in the high control group than in the other groups during the early hours of sleep in the group of 36–45 years. ( $p < 0.01$ ).

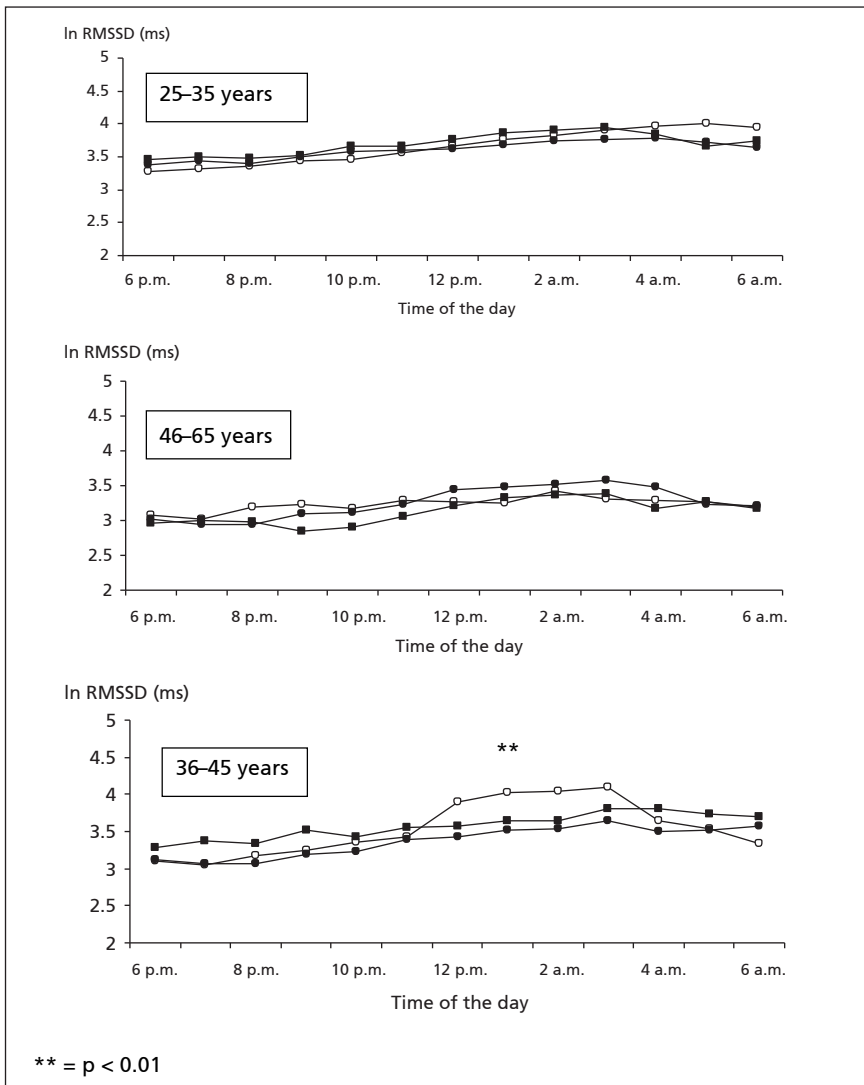


Fig. 7. Job control and HRV (RMSSD) during recovery (evening and sleep) among Finnish media workers ( $N = 132$ ) in three age groups. Job control: high = ○, moderate = ■, low = ●).

## 5.5 Poor sleep related recovery, depression and hypertension

The occurrence of self-reported insomnia symptoms among the ISW and RDW workers was evaluated according to DSM-IV criteria (Study IV). Classification of sleep disorders among the workers (N = 874) was based on the BNSQ responses. Every sixth worker (16.9%) reported difficulties initiating sleep (DIS) on at least three days per week. Every tenth (10.8%) worker reported at least three nocturnal awakenings (NAW) per night and nearly half (44.8%) reported NAWs at least three nights per week. Every tenth worker (10.4%) reported early morning awakenings (EMA) at least three nights per week and nearly two thirds of workers reported non-restorative sleep (NRS 64.2%). A depressive mood score > 1.63 SCL-90 (Finnish version) is clinically significant and was used as a criterion of depression. Poor health was based on subjective assessment of own general health. Hypertension was evaluated from occupational health medical records.

Depression, hypertension and poor general health were associated with many sleep disorders and they all increased the risk of NAWs (Table 5). Depression increases the risk of all sleep disorders. Severe stress doubled the risk of DIS (OR 2.1; 95% CI 1.2–3.7) and NRS (OR 2.28; 95% CI 1.42–3.69).

**Table 5. Risk (OR; CI, 95 % confidence interval) of nocturnal awakenings (NAW) among media workers with hypertension, depression or poor health compared to other workers. Both models also included gender, age, BMI, work schedule (regular/shift) and perceived stress.**

Condition	One variable in model		Both variables in model	
	NAW 3 ≥ week	NAW 3 ≥ night	NAW 3 ≥ week	NAW 3 ≥ night
Hypertension	1.4 (0.9–2.1)	2.3 (1.2–4.3)	1.2 (0.8–2.0)	2.2 (1.1–4.1)
Depression	1.8 (1.3–2.5)	1.7 (1.01–3.0)	1.7 (1.2–2.4)	1.4 (0.8–2.5)
Poor health	1.8 (1.4–2.5)	2.7 (1.7–4.4)	1.7 (1.2–2.3)	2.3 (1.4–3.7)

## **6 DISCUSSION**

### **6.1 Determinants of stress and recovery in media work**

The risk of job stress is increased by several work-related factors, including excessive quantitative demands, low job control, low social support and job insecurity. Prolonged high mental and cognitive overload might lead to depletion of adaptive resources. Good recovery helps to restore functional reserves. Media work in broadcasting is a good example of a 24/7 occupation. This is the first study reporting physiological and self-assessed determinants of stress and recovery among media workers. The results show that good job control enhances more effective recovery of autonomic nervous system during sleep even among workers with high job demands.

The disruption of biological circadian rhythms plays an important role in the development of work related negative health effects. Physical symptoms of stress are often related to autonomic nervous system imbalance and hormonal activation of the HPA system. The mental stress was associated to enhanced activity of HPA axis among media workers of this study. The ISW was, however, an independent risk for disruption of normal oscillations of cortisol/melatonin hormones. The hormonal imbalance was associated to the increased daytime sleepiness and attenuated recovery of autonomic nervous system. The physiological findings of insufficient recovery can be found even among the workers with only minor self-assessed mental stress. The short-term negative health effects include sleep problems, fatigue, attenuated work performance and increased risk of accidents.



## 6 DISCUSSION

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Long-term negative effects of ISW might include obesity, breast cancer, cardiovascular diseases, gastrointestinal disorders and depression. In this study two common health complaints with a potential to decrease work ability, depressivity and hypertension, were associated to poor sleep and, thus, to poor recovery. Sleep problems were more common among the media workers with reduced self-assessed general health compared to workers with good self-assessed general health. It can be recommended that the assessment of sleep is mandatory in occupational health evaluations.

The dynamics of salivary cortisol after waking might be useful in further stress studies of media workers. Physiological determinants of autonomic nervous system function, such as HRV, might be used in the assessment of recovery, at least at a group level. Sleep plays an essential role in good recovery. Simultaneously analysed autonomic nervous system function and neuroendocrine indicators provide additional information about stress and recovery.

The strength of this study was a homogenous population of media workers with several features of modern 24/7 society's occupations. Ambulatory measurements in real life settings offered new insights in occupational health studies.

The main limitations of this study are the cross-sectional set-up and limited number of study subjects. The lower response rate among employees with regular daytime work was partly expected as the study was transparently targeted to examine the health effects of ISW. The possible selection bias in questionnaires is probably to more distressed subjects, but the main demographic variables were similar in both groups. The population enrolled for physiological measurements was randomly selected in ISW and RDW groups and might be considered representative. The high response rate to baseline questionnaire among ISW group should be noted.

There exist confounding factors in the assessment of physiological variables. The integrative use of ambulatory collection of biochemical samples and continuous recordings of physiological indicators in real life settings allow us to determine more precisely the complex nature of work related stress factors and recovery. Especially interventional studies are needed.

## **6.2 Salivary cortisol – physiological determinant of stress in media work**

Work-related stressors have been associated with alterations in cortisol responses (Maina et al., 2009). In Study I stress, short sleep and irregular shift work explained the augmented salivary cortisol response after awakening; the absolute salivary cortisol morning level was significantly lower in workers with ISW. The low morning levels have been reported in workers with sleep problems (Hansen et al., 2012). The sleep problems were more common in media workers with ISW (Study IV). On the other hand the increased cortisol awakening response is usually associated with increased mental stress. Poor recovery, long working hours, heavy physical workload, short sleep and sleep disturbances have been found to affect cortisol reactivity (Sluiter et al., 2001; Thomas et al., 2009; Kumari et al., 2009; Eller et al., 2012). In other studies, however, no associations between work-related factors and salivary cortisol levels have been observed (Kunz-Ebrecht et al., 2004; Wright, 2011).

Salivary cortisol measurement allows us to interpret the circadian variation of cortisol and to evaluate the dynamic responses during the day. Cortisol awakening response has been suggested as an indicator of stress (Chida and Steptoe, 2009). We did not collect the 30 minutes after waking sample due to workers' practical difficulties such as travelling to work. The sampling time after waking was 60 minutes. Because we could not calculate the absolute difference between 30 min after waking and immediately after waking (CAR) we developed a new indicator to describe the cortisol response, the T1/T0 ratio (salivary cortisol 60 minutes after waking/cortisol level immediately after waking).

Although we could have missed some information due to absence of the 30 minutes sample, our findings of association between stress, sleep, shift work and cortisol reactivity support the results from other studies (Kumari et al., 2009; Klein et al., 2012; Eller et al., 2012). There is one other study in which the one-item subjective stress evaluation correlated with cortisol responses. The results of study I support the association between simple self-rated stress and cortisol findings (Metzenthin et al., 2009).

The HPA axis is an important pathway of human stress adaptation (Tsigos and Chrousos, 2002). Cortisol is excreted by the adrenal cortex under the control of centres in the brain. Stress increases cortisol

production. Continuously elevated cortisol levels are harmful for the brain and metabolism (Anagnostis et al., 2009; Bengtsson et al., 2010; Pruessner et al., 2010). Cortisol production has a circadian oscillation and environmental factors or mental stress may disrupt the cycle (Papadimitriou and Priftis, 2009). In this study the findings of the altered cortisol profile among employees with increased subjective stress or short sleep underline the need for further follow up studies of metabolic health of media workers.

Salivary analyses of cortisol and other biomarkers of stress are promising tools for characterizing the dynamic changes in HPA axis function in real working life settings (Chandola et al., 2010). However, there are many technical, environmental and individual confounding factors, such as medications and diseases, in the assessment of work related and other variables in salivary cortisol analyses (Hansen et al., 2003; Hellhammer et al., 2009; Clow et al., 2010; Kudielka et al., 2012). In this study, hormonal diseases and medications affecting markedly HPA axis were exclusion criteria.

### **6.3 Diurnally oscillating hormones and heart rate variability –physiological determinants of poor recovery in media work**

Salivary analyses of two circadian hormones, cortisol and melatonin, might provide new ambulatory information on disruptions in biological rhythms related to work (Golden et al., 2011; de Almeida et al., 2011). In study II it was found that prolonged morning drowsiness and daytime sleepiness were associated with changes in hormonal activity and autonomic nervous system function among the media workers with ISW. The cortisol/melatonin ratio was altered during the day and vagal recovery in HRV was delayed during the first hours of sleep. The disturbed circadian oscillation of the cortisol and melatonin hormones may increase the risk of metabolic and cardiovascular diseases (Corbalán-Tutau et al., 2012). The poor recovery of the autonomic nervous system may potentiate these negative health impacts.

Cortisol hormone has a natural biological rhythm, with the peak in the morning and the lowest level in the evening. Daily stressors may change the responses (Papadimitriou and Priftis, 2009). Melatonin is the light-dark hormone. The highest levels are found at night and they begin to rise before bedtime, preparing the body for sleep (Lazar et al., 2013). In a laboratory environment simulated shift work changed melatonin secretion (Hakola et al., 1996). Due to the technical challenges, however, studies involving ambulatory collection of salivary melatonin are rare (Gumenyuk et al., 2012). Salivary melatonin can be used in the monitoring of the effects of interventions. Recently the effect of night-day cycle adjusted light treatment changed the salivary melatonin profile associating with improved vigilance during the work and better sleep quality among shift workers (Sasseville and Hébert al., 2010). The assessment of autonomic nervous system function during sleep by HRV may reveal new aspects of recovery (Stein and Pu, 2012). In recent reports attenuated HRV in time domain parameters was associated with sleep problems (Jackowska et al., 2012). Our results support the previous findings between physiologically measured non-restorative sleep, alterations in diurnally oscillating hormones and subjectively reported daytime sleepiness.

Vagal recovery can be evaluated by HRV. In study II the vagal or parasympathetic recovery indicated by RMSSD of HRV declined among the ISW workers with signs of insufficient recovery. In recent reports attenuated time domain indices of HRV were associated with sleep problems (Jackowska et al., 2012). The initial hours of sleep seem to be very important for recovery of the autonomic nervous system. These results accord with other studies, which emphasizes the importance of HRV analyses during sleep (Otzenberger et al., 1997; Otzenberger et al., 1998; Thayer et al., 2010). It has been recommended that HRV analysis of recovery should be done during slow wave sleep (Brandenberger et al., 2005). Since slow wave sleep occurs mainly during the first half of the sleep period, attenuation in vagal recovery of workers with ISW during the early hours of sleep and prolonged daytime sleepiness may reflect chronic insufficient physiological recovery.

The ambulatory salivary melatonin assessment was challenging in this study. The individual variation is large and concentrations are small. Cortisol and melatonin interactions have been studied mainly in labora-

tory settings. In cancer patients attenuated cortisol/melatonin ratio has been found to associate with progression of the disease (Mazzoccoli et al., 2005). We developed a simple index to track simultaneous cortisol and melatonin changes during the workday. Attenuation of cortisol/melatonin ratio was found among ISW workers with symptoms of insufficient recovery. In study I we also found a reduction in salivary melatonin levels among ISW workers at bedtime. Our findings support the view that stress-related changes in neuroendocrine and autonomic nervous system function may be connected to disrupted sleep and they also might have interactions in diurnal oscillations and recovery (Meerlo et al., 2008, Boudreau et al., 2012).

### **6.4 Vagally mediated attenuation in heart rate variability is a determinant of job control related recovery in media work**

High job control improved vagal recovery during sleeping hours (Study III). The effect was most prominent among workers aged 35–45 years. Lifestyle habits did not have a significant impact on the finding. In younger or older broadcasting workers the positive effect of high job control was not evident. Younger employees may change their workplace more easily than workers with stabilized social networks. The younger workers have also often better possibilities to adapt irregular working times. Among older workers the healthy worker effect might be important. The employees having difficulties with stress factors of media work or irregular shift work have re-oriented their working career. Even the high job strain may have markedly less negative effects on cardiovascular health, if the job control can be maintained. The balance between positive and negative health impacts of work features might be monitored physiologically by long term HRV recordings.

“Good” stress with physical and mental challenges promotes health. Chronic stress is a risk factor for diseases. Recovery plays an important role in maintaining psychological and physiological functional reserves between demanding work periods (Geurts and Sonnentag, 2006). Low job control predisposes to poor recovery (Berset et al., 2009). Insufficient work-related recovery associates with fatigue, sleep problems and health

complaints in general (van Veldhoven and Sluiter, 2009). The association between poor recovery and absenteeism from work is still controversial (Aguirre, 1994; van Veldhoven and Sluiter, 2009). Heart rate variability reflects the dynamics of the autonomic nervous system after physical or mental strain. Loerbroks found an inverse relationship between effort-reward imbalance and HRV, especially in employees aged 35–44 years (Loerbroks et al., 2010). Low vagal cardiac activity as measured by HRV has been reported to correlate with job strain and low decision latitude (Collins et al., 2005). In a study by Bos poor work characteristics were more important determinants of work stress in the middle-aged white collar workers than among the employees under the age of 35 or over 50 years (Bos et al., 2009). Job autonomy and the possibility to use professional skills are important factors. Good job control enhances the positive factors of job satisfaction and, thus, possibly improves the resources for mental and physiological recovery.

Among Swedish physicians low HRV was detected during workdays indicating increased stress levels, but the recovery measured by HRV was sufficient (Malmberg et al., 2011). The effect of long working hours as an independent risk factor of attenuated HRV are controversial (Sasaki et al., 1999; Park et al., 2001). The broadcasting professions are occupations with high demands and effort at all ages. Our findings support the report by Loerbroks that job control-related factors might be connected to changes in the age-related psychosocial environment. Differences in career attitudes and accumulation of multiple stressors are possible. The results emphasize that in very high demanding works high job control might be an effective measure to prevent negative health impacts of work strain.

ECG is an accurate method to calculate HRV. Majority of job stress studies have used short-term analyses of HRV both in laboratory and community based studies. Long-term analyses have mainly been performed in controlled laboratory environment. It is, however, possible, that long-term HRV recordings during real life activities may reveal new aspects in stress studies (van Amelsvoort et al., 2000; Grossman, 2007). In this study the dynamic HRV findings during recovery and especially during sleep were important. Because of confounding factors, some additional physiological monitors, such as actigraphy, might be useful

(Martin and Hakim, 2011). In study I the actigraphy data improved the timing of the real sleep period in the analyses.

### **6.5 Sleep-related poor recovery associates with common diseases in media work**

Hypertension increased the risk of NAW among Finnish media workers. Depressivity was associated with the increased risk of most sleep disorders, especially NAW, EMA and DIS. NAW and DIS were more common among the workers with self-assessed poorer health compared to workers with better self-assessed health. (Study IV). The results underline the importance to evaluate sleep, sleep quality and recovery among employees with common somatic and mental complaints.

Insomnia symptoms are associated with overall mortality from somatic diseases (Hublin et al., 2011; Rod et al., 2011). Pickering suggested that the 24/7 society might be a risk factor for hypertension (Pickering, 2006). Prolonged work stress has been associated with increased risk of hypertension, diabetes and lipid disorders (Su et al., 2008; Djindjic et al., 2012, Palagini et al., 2013). Our results support the view that hypertension is associated with NRS (Erden et al., 2010). Brain-body interactions cannot be underestimated in the development of work-related cardiovascular diseases (Pereira et al., 2013).

Insomnia is a typical symptom of depression. In this study, workers with increased depressivity score on the SCL-90 had many types of non-restorative sleep. Poor sleep and chronic insomnia may precede the development of depressive mood or depressive disorders (Paunio et al., 2009). Positive emotions in general have been associated with better sleep (Baglioni et al., 2010).

Two common health complaints, hypertension and depressive symptoms, as well as self-assessed poor general health, were correlated with insomnia among media workers, although the type of work (ISW or RDW) did not have a significant effect. These findings support the view that in modern 24/7 society, with media work as an example, analysis of sleep by occupational health care professionals is very important.

## 7 CONCLUSIONS

The strength of this study is the homogeneity of the study population. Workers' health was monitored in the same occupational health service and the working environment was well-characterized. Media work includes many occupations typical of our modern 24/7 society. There are no previous studies of broadcasting work analysed by self-reports and physiological measurements. The cross-sectional study design limits the generalizing of the results.

It is concluded that:

1. In modern 24/7 work analysis of recovery should be included in the evaluation of health and well-being of workers.
2. Sleep is a promising target for analysing the physiological aspects of recovery. Actigraphy may be useful to assess sleeping time and daily activities more precisely.
3. Simultaneously monitored autonomic nervous system and neuro-endocrine function demonstrate disturbances in recovery.
4. Ambulatory measurements in real life settings open new insights in occupational health studies, but validation of the techniques is essential.
5. New indicators are needed to characterize the complex network of physiological recovery.

The evaluation of self-experienced stress and recovery, assessment of job characteristics, analysis of sleep and in some cases measurements of physiological determinants of stress and recovery may reveal information about health and well-being of media workers (Figure 8).



## 7 CONCLUSIONS

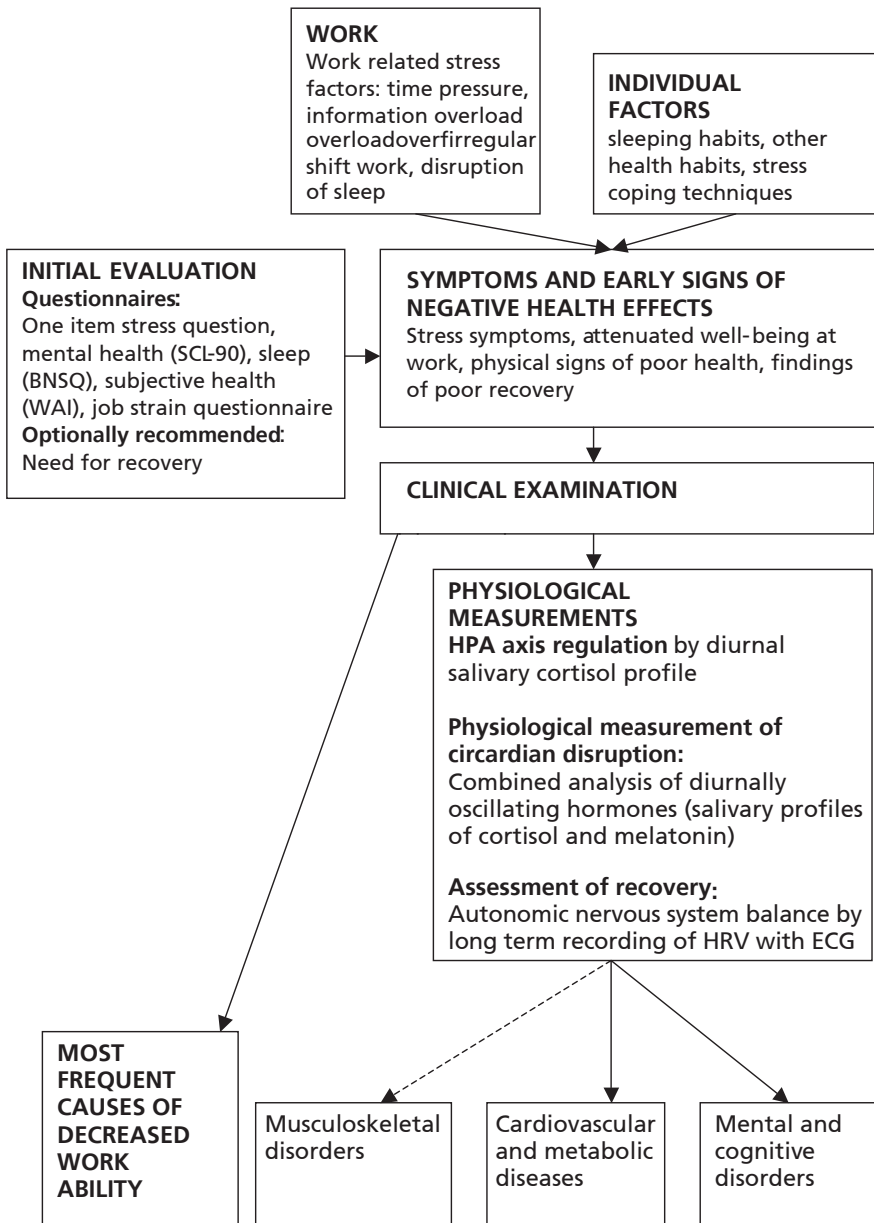


Figure 8. A schematic model for the assessment of stress and recovery among media workers.

## **8 FUTURE DIRECTIONS**

In modern 24/7 society good recovery during work and after work is a very important promotor of workers' health. In addition to validated self-assessments, physiological measurements must be studied. The analyses of physiological recordings during sleep in real life settings are particularly needed. Salivary analyses of biomarkers are a suitable method for collecting dynamic data. New indicators of stress regulation, such as inflammatory markers, are worth of testing in further studies. Inflammatory markers provide an interesting link between stress reactions and disease. HRV is a practical tool for monitoring the state of cardiac autonomic regulation. More sophisticated methods might reveal new information about irregularity in stress adaptation. Validation of HRV for large scale clinical use in occupational health requires further studies.

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Media work is a good example of working life in modern 24/7 society. Time pressure and cognitive strain due to overflow of media inputs enhance job strain. New technology requires constant learning and implementation of new working modalities. Employees might continue work-related activities at home and outside the workplace. This may lead to overcommitment and extension of the real working time. Irregular shift work is common. Sudden changes in information flow, technical problems and alterations in team resources may hinder recovery and increase stress.

On the other hand high demands may increase the well-being, if the worker can use the skills and has good job control. Self-assessments of stress and well-being combined with physiological measurements help us also to identify work-related and personal factors that could explain good or poor recovery.

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