Personal characteristics and work-shift related stress among Intensive Care Nurses: results from EVICURES project

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Abstract

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The present study attempted to explore differences in objective stress indices (heart rate, stress, and relaxation) amongst intensive care nurses based on personal characteristics and work situations. Furthermore, it also aimed to examine the relationship between stress risk with stress indices and subjective perceptions of wellbeing.

Stress is a complex and broadly studied phenomenon. It varies from person to person and in different professions. In the previous studies, it was highlighted that stress is common in the professions dealing with human subjects, such as nursing care where nurses come in contact with diverse patients with different needs. Intensive care nurses are one of the most vulnerable groups to stress as they deal with critical and uncertain situations.

In the previous literature stress was studied extensively based on subjective perceptions. However, fewer studies explored stress using objectively measured physiological indicators due to technical limitations. Among other measures, heart rate variability (HRV) is considered as a reliable and consistent indicator of stress as it reveals essential information about changing physiological functions in real time. Current development in wearable technology has made it possible to collect HRV data to study physiological changes in the body and thus to study the stress indices objectively.

The present study made use of pre-exiting data of HRV based stress indices of intensive care nurses (n=10, representing 27% of total ICU nursing staffs) during varying work shifts and free time. The data was collected as a part of the EVICURES project by Firstbeat Technologies Oy from a hospital in Seinäjoki, Finland. The material constructs of second by second data of stress indices (n=3495848) and analysed using SPSS software. Groups based on age, body mass index, activity, and work shifts were made to perform between groups ANOVA tests to investigate the research questions. One summative variable, Mean Stress Risk, was created based on age, BMI and activity to observe the relationship with stress indices.

Descriptive analysis was done followed by correlations and one way ANOVA. The ANOVA between groups results found that stress indices (Heart Rate, Absolute Stress Vector, Absolute Relaxation Vector) differed significantly based on personal characteristics (age, BMI, activity class) and various work-shift times, where increased stress levels are associated with older age, higher BMI, low physical activity, and extended work hours. This study did not find statistically significant relationship between stress risk and subjective perception of wellbeing. However, these findings cannot be generalized to the larger population. Practical and policy implications such as implementing ergonomic work schedule and considering age, BMI and activity while assigning the work at ICU were discussed.

Keywords: Stress, Relaxation, Intensive care nurses, Heart-rate variability, ANOVA analysis of variances.

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Abbreviations

ANS	Autonomic Nervous System
ARV	Absolute Relaxation Vector
ASV	Absolute Stress Vector
BMI	Body Mass Index
EBD	Evidence-Based Design
EPSHP	Hospital District of South Ostrobothnia
FDF	First Data File
HR	Heart Rate
HRV	Heart Rate Variability
ICU	Intensive Care Units
MSR	Mean Stress Risk
RMSSD	Root Mean Square of Successive Differences
SDF	Second Data File
SWI	Subjective Wellbeing Index
TDF	Third Data File

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1 Introduction

Nurses are one of the most important pillars in the care of patients. Their well-being is important consideration for the welfare of patients. However, there are many research studies that show nurses are stressed, over-worked, suffering from burnout syndrome (Bhatia, Kishore, Anand, & Jiloha 2010; Golubic, Milosevic, Knezevic, & Mustajbegovic 2009; Hall 2004).

Apart from other health care units, intensive care units (ICUs) are characterized by factors that contribute to high stress level amongst nursing staff (Andolhe, Barbosa, Oliveira, Costa, & Padilha 2015; Burgess, Irvine, & Wallymahmed 2010; Cavalheiro, Junior, & Lopes 2008). In particular dealing with death is considered as one of the most stressful aspects of ICU working environment (Foxall, Zimmerman, Standley, & Bene 1990; Milutinovic, Golubovic, Brkic, & Prokes 2012; Poncet, Toullic, Papazian, Kentish-Barnes, Timsit, Pochard, Chevret, Schlemmer, & Azoulay 2007; Rodrigues & Ferreira 2011).

Above mentioned studies and several other studies relies on subjective reports of ICU staff in evaluating stressful conditions (Cavalheiro et al. 2008; Preto, & Pedrão 2009). However, fewer studies opt for using physiological measurement of stress (e.g. heart rate, hormonal indicators of stress) (Centre for Studies on Human Stress 2007; Chandola, Heraclides, & Kumari 2010). This could be partly due to technological barriers (e.g. inadequate/inaccurate real-time measurement of physiological conditions). However, recent developments in wearable technologies made it possible to collect real-time measurements (Föhr, Tolvanen, Myllymäki, Järvelä-Reijonen, Rantala, Korpela, Peuhkuri, Kolehmainen, Puttonen, Lappalainen, Rusko, & Kujala 2015; Teisala, Mutikainen, Tolvanen, Rottensteiner, Leskinen, Jaakko, Kolehmainen, Rusko, & Kujala 2014).

1.1 Background of the study

The present study is derived from a larger EVICURES project (2014–2016). It is a joint venture of VTT Technical Research Centre of Finland, Hospital District of South Ostrobothnia, Seinäjoki University of Applied Sciences, Granlund (energy solutions provider), Saint Gobain Ecophon (acoustic solutions provider), and Jääskeläinen Architects Ltd. Master students in Laurea University of Applied science participated in research and development in the field of intensive care nursing in this project.

The project aims at developing “a new user-friendly design model for intensive and intermediate care facilities” (Nykänen, Tuomaala, Laarni, Dhinakaran, Saarinen, Yli-Karhu, Hämäläinen, Koskela, Eerikäinen, Salminen-Tuomaala, Hellman, Rintamäki, Vimpari, Kilpikari, Jääskeläinen, & Kotilainen 2016, 8) by studying evidence-based design (EBD) and the views of hospital staff as well as patients and their families. Broader aims of the project is to assess effects of EBD in improving the quality of care, decreasing complication incidences, enhancing staff wellbeing and satisfaction of patients, and cost-effectiveness of hospital operations. Results from the projects may help designing new and better intensive and intermediate care facilities. There are two parts of the project. The first part is focused on physical environment and it is concerned with developing and evaluating technological improvements (e.g. energy efficiency, improving air quality, better acoustic and reduced noise).

The second part is focused on social environment and end-users of the facility (e.g. their perception of wellbeing, environmental satisfaction, stress). The overall aim of the second part was to record and understand the social environment before the introduction of new designs in the ICU. In this context, one of the goals is to measure stress and relaxation patterns amongst ICU nursing staff by using devices and software developed by the Firstbeat Technologies Oy (Firstbeat Technologies Ltd. 2014). The company developed a technology for measuring various physiological conditions based on heart rate variability (HRV). HRV is found to be a reliable indicator by a number of studies (details in section 2.5). This technology enables to create a picture of health and performance, stress periods, and recovering (Teisala et al. 2014; Föhr et al. 2015). With the help of this analysis, it is possible to recognise factors that improve stress management, quality of sleep and the effects of exercising (Nykänen, et al. 2016). This current study made use of the data generated using Firstbeat Technologies with ICU nurses under the EVICURES project.

1.2 Purpose of the present study

The primary aim of the present study is to explore project-generated data to understand how personal characteristics (e.g. age, BMI) and various situations (e.g. work shift timing and duration) interact with stress, relaxation and heart rate patterns. In addition to that, it is also aimed to explore the relationship between subjective perception of wellbeing (as reported by the participants in a short questionnaire) and physiological indicators of stress and relaxation.

2 Theoretical Background

This chapter provides brief overview of the stress as a function of physiological and psychological demands, stress at workplaces and more specifically in a hospital environment, factors that contribute stress amongst nursing staff, measuring and mitigation of stress.

2.1 Multidimensionality of the stress

In physical world, stress is a pressure exerted on an object. In living systems it is a results of an environmental pressure or internal functions. Extended environmental stress may leads living systems to find new ways to adapt or simply vanish. In human society, stress is used in various sense and with different meanings and interpretations. It is used in both social and psychological sense and specific physiological reactions associated with stress (Cox, Griffiths, & Rial-González 2000).

The term 'stress' to describe a physiological condition is first used by Hans Selye in 1936. Based on various experiments with laboratory animals, he defined it as "the nonspecific response of the body to any demand for change" (The American Institute of Stress 2017, 1).

Relevant scientific studies goes back to over a hundred years when psychologists Robert Yerkes and John Dodson first described arousal in 1908. Based on their research Yerkes-Dodson law was formulated. It describes relationship between arousal and performance as bell shape curve where performance is at its peak during intermediate arousal and with increasing arousal, performance curve goes down (Yerkes & Dodson 1908).

Later, Nixon (1982) used the Yerkes-Dodson bell shape curve to describe the role of stress in optimising the performance and adverse effects of excessive stress stimuli that may lead to burnout and breakdown (Figure 1). In this description of stress both physiological and psychological aspects are intertwined.

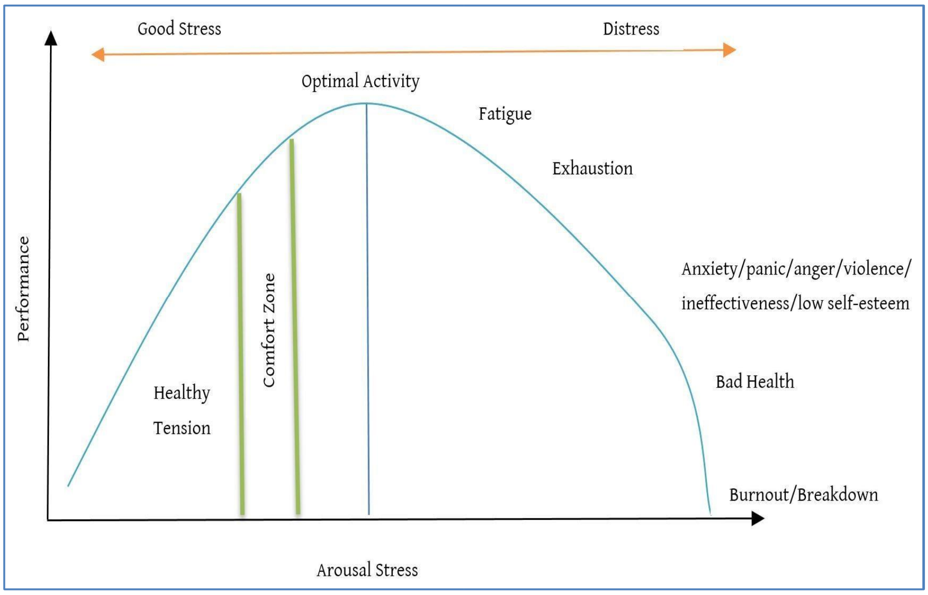


Figure 1: Human function curve. (Original figures of Nixon 1982 and Rapoliene, Razbadauskas, & Jurgelenas 2015 modified by the author.)

In popular culture stress is a broad concept and subjective experience. There are virtually endless stressors (situations or stimuli) that may lead individual towards stress. It could be related to personal or professional life circumstances, so it is challenging to define stress comprehensively. However, there are some broad definitions. For example:
"A particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her wellbeing" (Lazarus and Folkman 1984, 19).

European Agency for Safety and Health at Work defines stress as "a psychological state which is both part of and reflects a wider process of interaction between the person and their (work) environment" (Cox et al. 2000, 13).

Moreover, National Institute of Occupational Safety and Health further elaborated occupational stress as destructive physical and emotional reactions that occur when the worker are unable to fulfil the necessities of the job (Hall 2004, 7). Furthermore, Milutinovic et al. include various dimension that are part of professional stress. They describe stress as a "pattern of emotional, cognitive, behavioural and physiological reactions to adverse and harmful aspects of work content, work organisation and the working environment" (2012, 171).

2.2 Physiology and psychology of stress

Selye (1950) measured stress as physiological responses to external stimuli. He studied sympathetic adrenal-medullary and pituitary-adrenal-cortical activities. He studied a phenomenon known as General Adaptation Syndrome (GAS) during which the physiological response to stress develops in three levels: (a) raising the alarm reaction; (b) triggering of autonomic responses to meet the threat or challenge; (c) system damage or collapse if the stress persist too long.

Psychological implication of stress such as feelings of anxiety, ineffectiveness and lower self-esteem are typically triggered after it seems that an individual is unable to cope with the stressors (Figure 1). Initially, stress viewed as stimulus or response based physiological reactions. In recent practice, stress is considered as a "dynamic process" that depends upon both internal and externals factors. This includes specific environmental situations (e.g. threat) and personal characteristics (e.g. beliefs, training to meet challenges). In this view of stress, cognitive factors constitute important part of the response mechanism as well as perceiving stress in the first place (McVicar 2003 & Yoder-Wise 2013).

Physiological regulation of stress is mediated by brain functions. Stress is essentially regulated through Autonomic Nervous System (ANS) that is part of Central Nervous System. ANS is self-regulated system and responsible for two opposite sets of activities: Sympathetic (arousal) and Parasympathetic (relaxation). Sympathetic system mainly activates in the presence of stress stimuli (e.g. threat or challenge) and results in increased heart rate (HR) and decreased heart rate variability (HRV) these changes leads to ‘fight or flight’ response. In contrast, the Parasympathetic system calms the body and associated with decreased HR and increased HRV (Seaward 2015, 37). Activation of both systems result in associated physiological changes (Table 1).

Parasympathetic System	Sympathetic System
Constricted pupils	Dilated pupils
Increased salivary secretion	Decreased salivary secretion
Decreased heart rate	Increased heart rate
Constricted bronchioles	Dilated bronchioles
Increased intestinal secretion	Decreased intestinal secretion
Contract bladder	Relax bladder
Stimulate elimination	Inhibits elimination
Stimulates genitals	Stimulates genitals

Table 1: Physiological changes during activation of parasympathetic and sympathetic systems.

2.3 Stress and workplaces

Work is an essential part of individual’s life that helps the person to meet his/her objectives. Work has different sets of challenges and difficulties and everyone deals with them differently and reacts accordingly and even within a specific profession individuals may experience different stressors. Research studies found that extended periods of stress may pose a health risk. For example, Cox et al. mentioned that “over the past two decades, there has been an increasing belief that the experience of stress necessarily has undesirable consequences for health” (2000, 16).

Furthermore, it has been highlighted that professionals that deal with the human subjects/services suffer from more stressful situation than the others as they were dealing with the clients and come across with range of stressful emotions on ongoing basis (Johnson, Cooper, Cartwright, Donald, Taylor, & Millet 2005).

Nursing is one of the professions that deal with the emotions on regular basis and hence, personnel working in this profession are prone to be stressed. According to Milczarek, Schneider, & González (2009) 25% of Finnish worker reported work-related stress. Furthermore, in the same report, they underlined that UK nurses reported higher level of stress as compare to other professions.

2.3.1 Sources of stress at workplaces

Over the centuries, human evolved complex social environment that helped them attain great achievements and it is highly interdependent environment. Working in such a complex environment offers many challenges on constant basis and this may lead to stress. Not all the stressors are harmful (distress) and in fact they are helpful in maintaining the pace of work, meeting challenges and deadlines known as 'eustress' (McVicar 2003 & Yoder-Wise 2013, 553). However, when a person lives in a constant state of stress, it may leads to psychologically and physiologically negative outcomes (Figure 1).

According to the Leka, Griffiths, and Cox (2003) the sources of work stress can be categorized into work content and work context. Work content includes job content, workload, working hours and participation/control. Work context may include factors like career development, job status and titles as well as pay and allowances. Employees' satisfaction with working conditions, feelings of job related security could all constitute stress sources.

Cox et al. described two broad categories of stressors in medical professions. In first category there are physical hazards that may include biological, biomechanical, chemical and radiological factors. Second category is psychosocial hazards that may include "aspects of work design and the organisation and management of work, and their social and environmental contexts, which have the potential for causing psychological, social or physical harm" (2000, 14).

2.3.2 Stress in Intensive Care nursing staff

Hospitals are workplaces that includes stressors from both categories mentioned above and usually all the staff members working across hospital units are exposed to it. However, nursing staff in particular exposed to these stressors on a constant basis due to demanding nature of job, hence, they consistently reported more stress (Golubic et al. 2009; Hall 2004; Milutinovic et al. 2012; Poncet et al., 2007).

Excessive or unhealthy stress may leads to lower quality of work. Milutinovic et al. reported that unhealthy stress "decreases the quality of nursing and nursing care, negatively affects job satisfaction, increases psychiatric morbidity (high rate of anxiety and depression), and triggers the development of some physical disorders, particularly cardiovascular and locomotor diseases" (2012, 172). Another study conducted in Brazil found that 90% of nurses working in ICUs mentioned that it is stressful, wearying, and tiring. (Preto & Pedrão, 2009).
Various research studies identified major sources of stress among nurses depending upon their nature of work and hospital unit where they are working, it includes:

1. Facing death and dying
2. Involvement with end-of-life care

3. Professional conflicts with physicians/colleagues/families.
4. Inadequate preparation to meet emotional needs of patients and their families
5. Lack of support
6. Conflicts with other nurses and supervisors
7. Labour standards
8. Uncertainty concerning treatment
9. Fear of making mistakes
10. Limitations on organisational level
11. Work in shifts
12. Disproportion between work and reward
13. Trauma-related injuries
14. Inadequate nurse to patient ratios

Relevant research results on major sources of stress along with their methodologies and country of origin are summarised in the Appendix 1.

Stress amongst nursing staff working in ICU is more evident as they have to deal with the diverse range of situations: dealing with critical patient and their families, encountering with death and dying on constant basis. These situations were reported as the leading cause of stress (Golubic et al. 2009; Hall 2004; Milutinovic et al. 2012; Poncet et al. 2007). Often when patient is dying, the role of ICU nurses changes from "curative to comfort measures" (Vanderspank-Wright, Fothergill-Bourbonnais, Malone-Tucker, & Slivar 2011, 22). This also leads to very stressful condition for the concerned staff. Heavy workloads and understaffing are also found as important stressors (Cadwell & Weiner 1981; Milutinovic et al. 2012).

Poncet et al. (2007) conducted large cross sectional study (n = 2392) to identify determinants of burn out syndrome in critical care nurses in France. They found that one-third of ICU nursing staffs have severe burn out syndrome that may leads to stressful conditions. Burgess et al. (2010) argue that personality and coping strategies for stress play significant role in perception of stress. They concluded that nurses with better coping strategies may perceive less stress as compare to their colleagues. However, their study sample was small and only from one UK hospital. Golubic et al. (2009) conducted a cross-sectional study of 1086 nursing staff in various Zagreb University hospitals in Croatian capital. They found that higher educational levels play important role in improving nurses' work abilities. Also, general source of stress amongst nurses in Croatia is derived from financial issues and work organisation.

Physical environmental factors (e.g. light, noise, machine beeps) are also considered as an important source of stress in ICUs. These factors along with sudden changes in patients' conditions create constant sense of urgency that nursing staffs have to tackle on daily basis.

Riemer, Mates, Ryan, & Schleder (2015) found that reducing intensity of light is significantly correlated ($p < .001$) with reported reduction in stress levels of ICU nurses. They also found that noise reduction is also correlated with reduction of stress, although the finding is not significant ($p = .08$).

2.4 Impact of stress on personal and work characteristics

Some studies report positive correlation between stress and personal characteristics such as BMI. Block, He, Zaslavsky, Ding, & Ayanian conducted longitudinally study over the period of nine years in nationally representative cohort of US adults. They found that psychosocial stress was positively associated with "greater weight gain among both men and women with higher baseline body mass indexes if they experienced job-related demands, had difficulty paying bills, or had depression or generalized anxiety disorder" (2009, 184).

Milczarek et al. (2009) found that in Finland 25-39 age group reported the smallest amount of high-level stress that is 9.4% as compared to 40-54 and 55-64 groups where the stress prevalence is 9.6% and 10.2% respectively. Golubic et al. (2009) found that older age was associated with lowering in work ability causing frustration and stress. However, study done by Winwood, Winefield and Lushington (2006) in Australia with a large sample ($n = 846$) reported that effect of age on stress and work fatigue is ambiguous as in their study youngest age group reported the highest fatigue and poorest recovery compared to the oldest group, who reported good recovery and better wellbeing. Nonetheless, it is noted that all these studies were based on self-reported accounts of stress.

Nursing care is shift-based work and the work timings and length are also important factors that contribute towards stress. Nurses with longer working hours combined with overtime and different work-shifts, are at risk for fatigue, impaired sleep and burnout which may leads to compromise patient care and patient dissatisfaction. (Karhula, Härmä, Sallinen, Hublin, Virkkala, Kivimäki, Vahtera, and Puttonen 2013; Rogers, Hwang, Scott, Aiken, & Dinge 2004 & Stimpfel, Sloane, and Aiken 2012).

2.5 Measuring stress

Most of the research studies on stress are based on self-reports of nursing staff using different psychological tools. For example, Expanded Nursing Stress Scale (ENSS), Maslach Burn-out Inventory (MBI), Centre for Epidemiological Studies Scale, General Symptoms Distress Scale (GSDS) and the interpersonal work relations scale (ERIT). Few studies used approaches like interview and Visual Analogue Scale to measure stress when implementing any intervention (Hall 2004; & Riemer et al. 2015).

As mentioned earlier, stressful conditions also causes the physiological arousal that may lead to the release of hormones which are cortisol and catecholamine (epinephrine and norepinephrine). Several studies are done to measures stress through blood or saliva sample. (Centre for Studies on Human Stress 2007; Choi, Kim, Yang, Lee, Joo, & Jung 2014 & Rydstedt, Cropley, Devereux, & Michalianou 2008).

Among other measures, heart rate variability (HRV) is considered as reliable and consistent indicator of stress as it reveals essential information about changing physiological functions in a real time. (Acharya, Joseph, Kannathal, Lim, & Suri 2006; Clays, Bacquer, Crasset, Kittel, Smet, Kornitzer, Karasek. & Backer 2011; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1998).

HRV is defined as the variability between two consecutive R-R intervals (peak point of PQRST wave of ECG) and it varies from beat to beat (Figure 2). Higher HRV reflects the activation of parasympathetic that leads to relaxation and lower HRV reflect the stimulation of sympathetic activity that points to stressful conditions (Chandola et al. 2010).

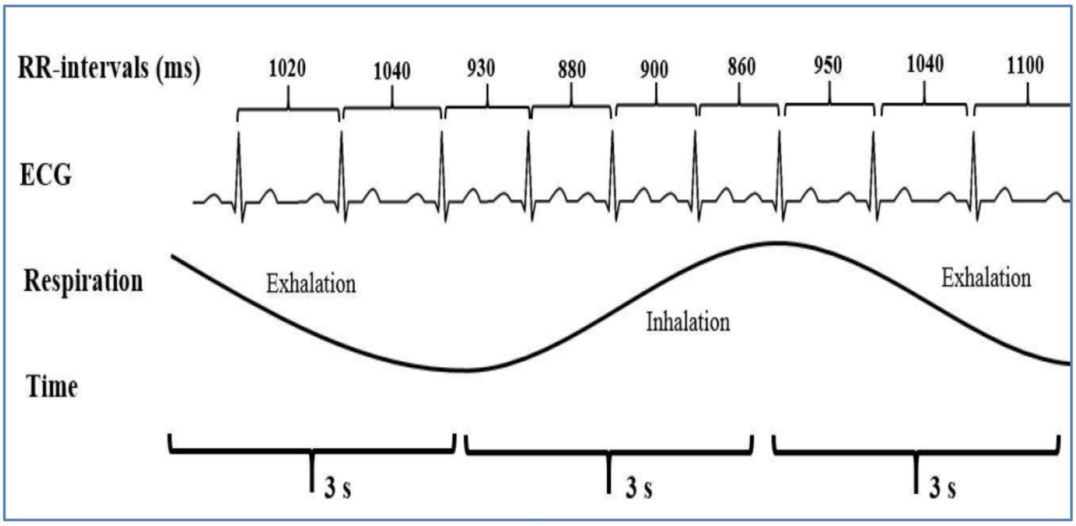


Figure 2: ECG showing RR-intervals in milliseconds. (Firstbeat Technologies Ltd., 2014, p. 3)

HRV has been used to detect both psychological and physiological disorders and has gained importance as a technique to explore the function of the autonomic nervous system (Firstbeat Technologies Ltd. 2014). However, measuring HRV requires electrocardiogram device (ECG) attached to an individual on a constant basis which is impractical.

Recent advancement in the wearable technology made it possible to measure and record real-time HRV in response to the stressful conditions. (Teisala, et al., 2014; Föhr, et.al, 2015). Commercially available devices, such as Firstbeat's Bodyguard 2 HRV recording device can measure and record HRV in real time that later analysed using a software (Firstbeat Technologies Ltd., 2014). Analysis reports not only report stress situation but also other physiological functions as well. (Relevant studies and technical reports can be accessed at www.firstbeat.com/en/science-and-physiology/).

2.6 Reducing stressful condition

Founding figures of modern nursing, Florence Nightingale and Jean Watson emphasised on creating healing environments that may help patients as well as nursing staff. For this purpose, there have been various attempts to reduce stressful conditions particularly in the ICUs. One of the study by Riemer et al. (2015) found that reducing intensity of light is significantly correlated ($p < .001$) with reported reduction in stress levels of ICU nurses. They also found that noise reduction is also correlated with reduction of stress, although the finding is not significant ($p = .08$). Human interactions at the workplace are usually one of the leading cause of stress and incorporating “healthy practice environment” may help nursing staff to lowering “perceived stress” (Kahnen, Gerard & Qin 2016, 12).

There are several technological and traditional interventions or strategies that can be used in reducing the stressful condition and may be applicable to the wider society. One of the study regarding the benefit of using Binaural Beat Technology (BBT) in healthy adult concluded that “regular listening to binaural beats including reduced stress and anxiety, and increased focus, concentration, motivation, confidence, and depth in meditation.” (Wahbeh, Calabrese, & Zwickey 2006, 25).

In another US study, researchers conducted quasi-experiment to observe the effects of essential oils in lowering stress (Pemberton & Turpin, 2008). The study found that using essential oils may help ICU nurses in reducing stress. However, researchers also noted that there could be multiple factors that might act as stress-reducers (e.g. nurses’ characteristics, their working environment, work load).

3 Research Questions

The goal of the current study is to investigate interaction of personal characteristics and various work situations contribute to stress, relaxation and heart rate patterns. Hence, the main research questions are:

1. Are there difference in stress based on personal characteristics (age, BMI, activity)?
2. Are there difference in stress based on work-shift times?
3. Is there a relationship between objectively measured stress, relaxation, heart rate and stress risk?
4. Is there a relationship between self-reported wellbeing and stress risk?

4 Methodology

Research design provides a roadmap for conducting the study by outlining selection process for research subjects, measurement tools, data collection and analysis plans (Burns, Gray and Grove 2015). So as suggested by Burns et al. (2015), this chapter describes the study setting, participants, data collection tools and procedure, and analysis plan.

4.1 Study setting

Data was collected from intensive care unit (ICU) of South Ostrobothnia Hospital District (EPSHP). The hospital was built in 1977 and facilities have gone through only minor renovations over the years. The hospital facilities are considered inadequate in terms of available space, building services, and modern care culture. Under the EVICURES project, proposed new facility will consist of single-patient rooms with private bathrooms in ICU and also redesigned intermediate care rooms. There will be 24 beds in total. To address any concerns and ensuring support for new design, hospital staff and patients were involved in the project from the beginning (Nykänen et al. 2016).

Currently there are 11 beds (seven ICU beds and four beds for neurological intermediate care patients). Patient-nurse ratio at the unit varies according to the work shift and occupancy of the ward. For example, in the morning and evening shifts a nurse may have to care for 1-2 ICU patients or 1-4 intermediate patients. But at night shift a nurse may take care of 1-4 ICU or 1-4 intermediate care patients. Nurses work as team pair with another nurse or assistant nurse (Hämäläinen 2017. Personal communication).

4.2 Data collection

This study made use of the data including statistics and digital diary collected as a part of EVICURES research project with the assistance of technology developed by Firstbeat Technologies Oy. So, methodology was selected based on the previously collected data and the author did not personally collect the data. Data acquisition process is briefly described below.

4.2.1 Acquisition of existing data

First of all, permission was sought from three stakeholders: first the South Ostrobothnia Hospital District (EPSHP) that owns the data and also the employer of nursing staff members who participated in the study; secondly, Firstbeat Technologies Oy that stores data and other technical reports; finally and most importantly, the study participants who were informed about the aims of present study and written consent was sought. (Appendices 2 and 3 for details). After receiving the consents, permissions and the data, formal analysis process was started.

4.2.2 Study participants

There were total 37 nursing staff including both permanent and substitute nurses at EPSHP's ICU unit. (Hämäläinen 2017. Personal communication). The EVICURES research project included 10 nursing staff members (9 females, 1 male) that represents 27% of the staff members. Their ages ranged from 28 to 59 years with average age of 45.1 years (SD =10.18).

Participation in the study was voluntary and before commencing the study, participants were provided with detailed information of the study and their role as a participant. Written consent was obtained and the participants were trained in using the data collection device before starting the study (Nykänen, et al., 2016).

The data was collected in 24-hour cycles over four-day period (totalling about 96 hours). This period consists of various combinations of work and rest so it gives overall picture of shift based work in the ICU. For example, some participants worked three days and one day off, while some other worked two days and two days off. One individual worked all four days. The ICU have several different kinds of shifts. The most common shifts are summarised in Table 2. Study participants worked in all these shifts. (Hämäläinen 2017. Personal communication).

Shifts	Timings	Total Hours
Morning	7:00–14:00	7
	7:00–15:00	8
Evening	12:00-21:00	9
	13:00-21:00	8
	14:00-21:00	7
Night	20:30-7:15	10.75
Long (double) shift	7:00-21:00	14

Table 2: Shifts at Intensive Care Unit of study hospital

Participants also kept a digital diary to indicate time spent on working, sleeping, and other activities. Some of them also mentioned medication they have taken during the four day data collection period.

4.2.3 Data collection tools

Main tool of data collection was Firstbeat Bodyguard 2 R-R interval recording device (Figure 3). The device is commercially available and developed by Firstbeat Technologies Oy based in Jyväskylä, Finland. The device records R-R interval and movement data. This data was collected in the accuracy of milliseconds. The data is then analysed by using a specialised software also developed by the company. The analysis report came in the form of .csv documents that contain various variables.

Figure 3: Firstbeat Bodyguard 2 R-R interval recording device. © Firstbeat Technologies Oy.

Parak & Korhonen (2014) reported that the Firstbeat Bodyguard 2 device is reliable and can correctly detected 99.95% of all heartbeats. After applying the artefact correction, accuracy increase little more to 99.98%.

At the beginning of four-day data collection period, participants also filled out a short questionnaire about subjective perception of wellbeing. It consisted of 10 statements that were rated as 'Completely Agree' (1); 'Somewhat Agree' (2); 'Neither Agree, Nor Disagree' (3); 'Somewhat Disagree' (4); 'Completely Disagree' (5). (Table 3).

Original Statements in Finnish	English Translation
Liikun mielestäni riittävästi terveyden kannalta.	In my opinion, I exercise enough to keep myself healthy.
Liikuntani teho on mielestäni riittävä kohottamaan kuntoani.	In my opinion, my activity is sufficient to elevate my fitness.
Syön mielestäni terveellisesti.	In my opinion I eat healthy.
Koen käyttäväni alkoholia kohtuudella.	I think that I use alcohol reasonably.
En koe olevani stressaantunut.	I do not feel stressed.
Päiviini sisältyy palauttavia hetkiä ja taukoja.	My day includes moments of recovery and breaks.
Olen yleensä virkeä ja energinen.	I am usually lively and energetic.
Nukun mielestäni riittävästi.	I think I sleep enough.
Koen, että voin vaikuttaa omaan terveyteeni liittyviin asioihin.	I experience that I can affect the matters which are related to my own health.
Voin mielestäni hyvin tällä hetkellä.	I feel well, in my opinion, at the moment.

Table 3: Subjective perception of wellbeing questionnaire.

Results of the questionnaire were reported with the help of statements and smiley faces (Figure 4) in Wellbeing Analysis reports for every participant.

KYSELYN TULOKSET

Liikun mielestäni riittävästi terveyden kannalta.	Jokseenkin eri mieltä
Liikuntani teho on mielestäni riittävä kohottamaan kuntoani.	Täysin eri mieltä
Syön mielestäni terveellisesti	Jokseenkin samaa mieltä
Koen käyttäväni alkoholia kohtuudella.	Täysin samaa mieltä
En koe olevani stressaantunut.	Jokseenkin eri mieltä
Päiviini sisältyy palauttavia hetkiä ja taukoja.	Täysin samaa mieltä
Olen yleensä virkeä ja energinen.	Jokseenkin samaa mieltä
Nukun mielestäni riittävästi.	Jokseenkin eri mieltä
Koen, että voin vaikuttaa omaan terveyteeni liittyviin asioihin.	Jokseenkin samaa mieltä
Voin mielestäni hyvin tällä hetkellä.	Jokseenkin samaa mieltä

Figure 4: An example of a result of a subjective feelings questionnaire. © Firstbeat Technologies Oy.

4.2.4 Data files and reports

Processed data files were received in .csv format from Firstbeat Technologies Oy. There were three data files per participant per day, so total 12 data files per participant for four-day data collection period and total 120 data files for all ten participants. The original data files were named according to the participants details like name, date and time of data collection. Therefore, it was not possible to use the original data file names in this report. Hence the data file were named as First Data File (FDF), Second Data File (SDF) and Third Data file (TDF).

The FDF, Figure 5) contained original and corrected R-R interval vectors in milliseconds and artefact vector that tells if the R-R interval was modified with artefact correction.

1	Firstbeat Analysis Server 6.6.2.18807		
2	Start time: 12.09.2015 06:58:28		
3			
4	VECTORS		
5	RRVector	ArtifactCorrectedRRVector	RawArtifactVector
6	568	568	0
7	743	743	0
8	754	754	0
9	739	739	0
10	748	748	0
11	778	778	0
12	811	811	0
13	845	845	1
14	877	877	0
15	875	875	0
16	874	874	0

Figure 5: An example of First Data File (FDF). © Firstbeat Technologies Oy.

The Second Data File (SDF, Figure 6) contained Root Mean Square of Successive Differences (RMSSD in R-R intervals) in five and one minute sampling frequency.

1	Firstbeat Analysis Server 6.6.2.18807				
2					
3	VECTORS				
4	RMSSD5MinVector	RMSSD1MinVector	CumulativeSecondVector	JournalMarkers	Splits
5	18,81	18,39	0		1
6		0	60		1
7		18,53	120		1
8		13,32	180		1
9		15,75	240		1
10	14,33	14,67	300		1
11		11,26	360		1
12		12,38	420		1
13		15,91	480		1
14		17,01	540		1
15	16,41	14,58	600		1
16		15,93	660		1

Figure 6: An example of Second Data File (SDF). © Firstbeat Technologies Oy

The Third Data File (TDF, Figures 7 & 8) contained the most essential analysis results and the TDF was used for this study.

4	Date of birth	[redacted]	
5	Gender	[redacted]	
6	Height	[redacted]	cm
7	Weight	[redacted]	kg
8	ActivityClass	4	
9	Heart beat max	172	times/min
10	Heart beat min	53	times/min
11			
12	SCALAR VARIABLES		
13	SessionStartDate	[redacted]	dd.mm.yyyy
14	SessionStartTime	[redacted]	hh:min:sec
15	SessionTotalTime	1332	min
16	DetectedArtifactPercentage	1	%
17	RelaxationTime	306	min
18	StressTime	867	min
19	TimeBelow20pMETMax	1282	min
20	Time20pTo30pMETMax	44	min
21	TimeOver30pMETMax	5	min
22	Time4MinPeriods30pTo40pMETMax	0	min
23	Time4MinPeriodsOver40pMETMax	0	min
24	AverageHR	73	times/min
25	AverageRespR	12,2	times/min
26	AverageVentilation	8,25	liter/min
27	AverageVO2	3,64	ml/kg/min
28	AveragepMETmax	11,55	%

Figure 7: An example of personal profile and scalar variable in the Third Data File (TDF). © Firstbeat Technologies Oy

58	VECTORS																						
59	Cumulativ	RealTime\	StateVect	ArtifactCo	METMaxP	VO2Vecto	EPOCVect	RespRVec	Ventilatio	EEVector	EEpFatVe	Resource\	AbsoluteS	AbsoluteR	ScaledStre	ScaledRel	VLFVector	LFVector	HFVector	HF2Vecto	RSAAmplit	Splits	JournalMarkers
60	0	8:00:00	10	67	13,8728	3,12	0,02	13,46	5,57	83	49	0	183,18	71,48	0	0	40,55	116,07	320,75	519,98	1,15	3	Kotiaskareita
61	1	8:00:01	10	67	13,8728	3,12	0,02	13,46	5,57	83	49	0	183,18	71,48	0	0	40,55	116,07	320,75	519,98	1,15	3	Kotiaskareita
62	2	8:00:02	10	67	13,8728	3,12	0,02	13,46	5,57	83	49	0	183,18	71,48	0	0	40,55	116,07	320,75	519,98	1,15	3	Kotiaskareita
63	3	8:00:03	10	67	13,8728	3,12	0,02	13,46	5,57	83	49	0	183,18	71,48	0	0	40,55	116,07	320,75	519,98	1,15	3	Kotiaskareita
64	4	8:00:04	10	67	13,8692	3,12	0,02	13,46	5,56	83	49	0	183,18	71,48	0	0	40,55	116,07	320,75	519,98	1,15	3	Kotiaskareita
65	5	8:00:05	10	67	13,8656	3,12	0,02	13,46	5,56	83	49	0	174,93	71,54	0	0	46,48	144,62	320,53	511,65	1,87	3	Kotiaskareita
66	6	8:00:06	10	67	13,8621	3,11	0,02	13,45	5,55	83	49	0	168,65	71,6	0	0	52,42	173,16	320,31	503,31	2,59	3	Kotiaskareita
67	7	8:00:07	10	67	13,8585	3,11	0,02	13,44	5,54	83	49	0	163,62	71,66	0	0	58,35	201,71	320,09	494,97	3,3	3	Kotiaskareita
68	8	8:00:08	10	67	13,8549	3,11	0,03	13,44	5,53	83	49	0	159,46	71,72	0	0	64,28	230,26	319,87	486,64	4,02	3	Kotiaskareita
69	9	8:00:09	10	67	13,8514	3,11	0,03	13,43	5,52	83	49	0	155,92	71,78	0	0	70,22	258,8	319,65	478,3	4,74	3	Kotiaskareita
70	10	8:00:10	10	67	13,8478	3,11	0,03	13,43	5,51	83	49	0	152,86	71,84	0	0	76,15	287,35	319,43	469,96	5,46	3	Kotiaskareita
71	11	8:00:11	10	66	13,8442	3,11	0,03	13,42	5,5	83	49	0	150,16	71,9	0	0	82,09	315,89	319,21	461,63	6,17	3	Kotiaskareita
72	12	8:00:12	10	66	13,8364	3,11	0,03	13,42	5,49	83	49	0	147,75	71,96	0	0	88,02	344,44	318,99	453,29	6,89	3	Kotiaskareita
73	13	8:00:13	10	66	13,8321	3,11	0,04	13,41	5,48	83	49	0	145,59	72,02	0	0	93,96	372,98	318,76	444,95	7,61	3	Kotiaskareita
74	14	8:00:14	10	66	13,8278	3,11	0,04	13,4	5,48	83	49	0	143,61	72,09	0	0	99,89	401,53	318,54	436,62	8,33	3	Kotiaskareita
75	15	8:00:15	10	66	13,8236	3,11	0,04	13,4	5,47	83	49	0	133,32	72,44	0	0	112,92	602,02	331,06	439,29	10,33	3	Kotiaskareita
76	16	8:00:16	10	66	13,8193	3,1	0,04	13,39	5,47	83	49	0	127,32	72,72	0	0	120	773,97	343,81	450,3	11,62	3	Kotiaskareita
77	17	8:00:17	10	66	13,815	3,1	0,04	13,39	5,47	83	49	0	122,69	73	0	0	127,09	945,92	356,55	461,31	12,91	3	Kotiaskareita
78	18	8:00:18	10	66	13,8108	3,1	0,05	13,39	5,46	83	49	0	118,93	73,26	0	0	134,18	1117,86	369,29	472,32	14,2	3	Kotiaskareita
79	19	8:00:19	10	66	13,8065	3,1	0,05	13,39	5,46	83	49	0	115,76	73,52	0	0	141,27	1289,81	382,03	483,33	15,49	3	Kotiaskareita
80	20	8:00:20	10	65	13,8145	3,1	0,05	13,38	5,48	83	49	0	113,02	73,77	0	0	148,35	1461,76	394,77	494,34	16,79	3	Kotiaskareita
81	21	8:00:21	10	65	13,8268	3,11	0,05	13,38	5,5	83	49	0	110,61	74,02	0	0	155,44	1633,7	407,51	505,35	18,08	3	Kotiaskareita
82	22	8:00:22	10	65	13,8391	3,11	0,05	13,38	5,53	83	49	0	108,46	74,26	0	0	162,53	1805,65	420,25	516,36	19,37	3	Kotiaskareita
83	23	8:00:23	10	65	13,8513	3,11	0,06	13,38	5,55	83	49	0	106,51	74,49	0	0	169,62	1977,6	433	527,37	20,66	3	Kotiaskareita
84	24	8:00:24	10	65	13,8636	3,11	0,06	13,37	5,58	83	49	0	104,73	74,72	0	0	176,7	2149,54	445,74	538,38	21,95	3	Kotiaskareita
85	25	8:00:25	10	66	13,8759	3,12	0,06	13,37	5,6	83	49	0	101,57	74,99	0	0	199,6	2575,57	489,83	585,14	23,46	3	Kotiaskareita
86	26	8:00:26	10	66	13,8882	3,12	0,06	13,37	5,62	83	49	0	100,28	75,03	0	0	215,42	2829,65	521,19	620,9	23,69	3	Kotiaskareita
87	27	8:00:27	10	67	13,9004	3,12	0,06	13,38	5,65	83	49	0	99,17	75,03	0	0	231,23	3083,72	552,54	656,65	23,91	3	Kotiaskareita
88	28	8:00:28	10	67	13,9361	3,13	0,07	13,38	5,71	84	49	0	98,22	75,02	0	0	247,04	3337,8	583,89	692,41	24,13	3	Kotiaskareita

Figure 8: An example of vector variable in the Third Data File (TDF). © Firstbeat Technologies Oy.

Apart from the data files, two sets of reports were also received for every participant. These reports were in Finnish language and parts of it were translated into English with the help of thesis supervisor.

One of the reports included 'Wellbeing Analysis' (Finnish: Hyvinvointianalyysi, Figure 9, identifiable information has been removed). Wellbeing Analysis report contained summarised information that provide overall 24 hour picture of each participant for all four days. This included total work days, work timings, sleeping hours and state vector (stress, sleep, strenuous exercise, light exercise and others) in percentage for each day. It also included the responses of a participant about subjective perception of wellbeing (Table 3 and Figure 4) and formed the basis of calculating Subjective Wellbeing Index (SWI) (section 4.3.5 for details).

Figure 9: An example of Wellbeing Analysis. © Firstbeat Technologies Oy.

The second report included ‘Expert Report’ (Finnish: Asiantuntijan raportti, Figure 10) that provide summary of the participant medication profile and plotted RMSSD values on hourly cycles showing wake and sleep time heart rate variability ratios.

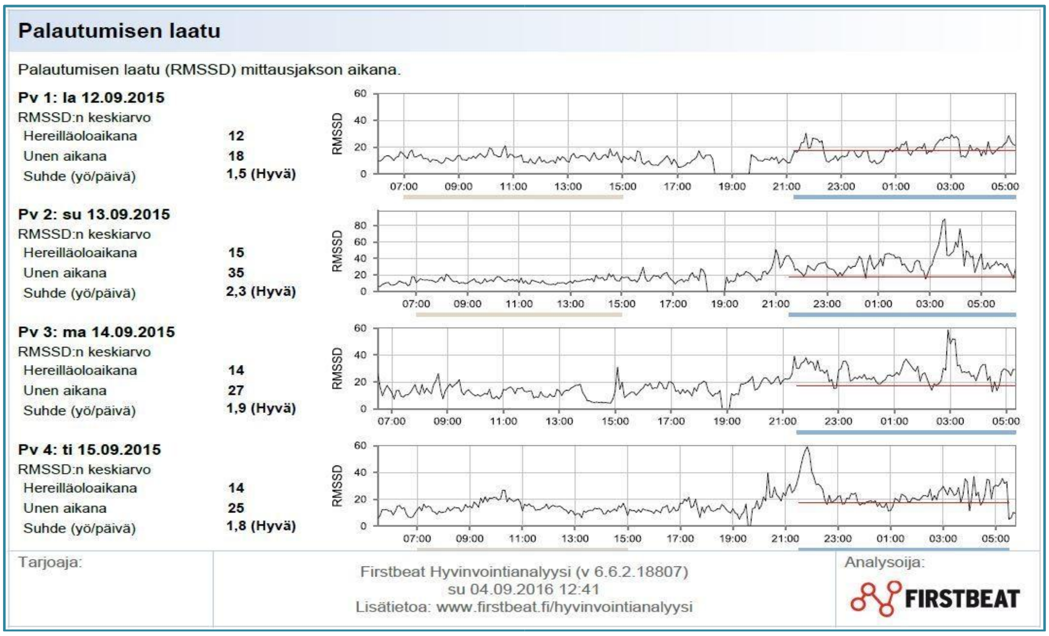


Figure 10: An example of Expert Report. © Firstbeat Technologies Oy.

4.3 Research data analysis

Burns et al. (2015) states that good research have coherent analysis plan that helps answering the research questions in systematic manner. So, the analysis plan below describes step by step process from selection of the data to statistical procedures.

4.3.1 Justification of using the processed data

As mentioned earlier that the FDF contained original and corrected R-R interval vectors only and no other corresponding information was given that helps determining changes in R-R interval against particular activity (e.g. work, sleep or rest). Moreover given R-R interval values were not timed in second-by-second data that could have helped in using the R-R interval values in combination with the TDF.

The SDF contained mean RMSSD values in one and five minute intervals given against particular activity (e.g. work, sleep or rest). This data could have been usefully combined if the time interval was given in seconds that corresponds to the values in the TDF. Hence, only TDF was selected as a main data file for analysis as it contained most complete set of variables that meets objectives of the present study.

4.3.2 Selection of variables in the Third Data File

Variables in TDF were clustered into three categories briefly described in the Table 4.

Personal Profile Variables	Scalar Variables	Vector Variables
Includes personal background information including name, date of birth, gender, height, weight, activity class, max and min heart beats per min.	This category contained 44 variables with single values calculated from the session. It gives overall picture of the participant in given day, for example, mean heart rate and total stress time in 24-hour session. Only stress balance ratio was used to present the stress balance on different working shift. (Table 9)	This category contained second-by-second values for each variable. These values are calculated by the software of Firstbeat Technologies on the basis of R-R interval. For example, for every second the heart rate per minute was given. Similarly, absolute stress and relaxation indices were given.

Table 4: Variables in Third Data File

Personal profile and scalar variables (Figure 7) provided background information on the participants, whereas vector variables (Figure 8) contained essential information that forms the basis of wellbeing report generated by the software of Firstbeat Technologies Oy.

One of the scalar variable, stress balance, was taken into account while presenting the descriptive analysis. Stress balance is calculated by the Firstbeat software and defined as: "Index revealing the balance between stress and relaxation." It values ranges from – 1.00 to 1.00, where negative values indicate that the balance is towards stress and positive values indicates that the balance is towards relaxation. (Firstbeat Technologies Ltd., 2014).

Focus of interest for this study were vector variables that consist of total 23 variables. These variables were further classified into different clusters. (Table 5)

First three clusters (time, activities and physiological state) were kept as it is for further analysis; however, only three variables were selected from the last cluster i.e. heart rate, indices of stress and relaxation. The selection was made keeping the focus of the study on stress and relaxation and their impact on nurses' work and daily lives.

1. Time	2. Activities	3. Physiological State	4. Physiological Variables
Variables indicating time including real time in seconds, cumulative seconds, and the measurement day.	Participants recorded their activities under variable named 'JournalMarkers' (section 4.3.3 and Appendix 5)	Physiological state defined and determined by the Firstbeat Technologies and recorded under the variable named 'StateVector'. (section 4.3.4)	Representing various physiological condition including heart and respiration rates, oxygen consumption, energy expenditure, stress and relaxation indices.

Table 5: Clusters of Vector Variables in Third Data File

4.3.3 Preparing the data for analysis

Data analysis is one of the crucial step in the research and well-defined parameters of analysis helps in achieving overall aims of the study (Burns et al. 2015; Ellis 2013). For the same reason data was prepared for analysis to answer the research questions.

There were total 40 TDFs (one TDF per day per participant) in .csv format. It was not possible to use these Individual TDFs for further analysis. It required modification and reorganisation of the data in such a way that would help answering the research questions. Figure 11 summarises the whole process and steps involved in preparing the data are briefly described here.

(1) All TDFs were explored thoroughly to understand different variables and only four variables of interest were selected: Absolute Stress Vector (ASV), Absolute Relaxation Vector (ARV), Heart Rate (HR), and JournalMarker.

(2) One of the major challenges was to classify 123 activities that were listed under the variable 'JournalMarker' (Appendix 5). Participants were permitted to record anything they were doing under this variable. So, lack of standard coding system made it difficult to make comparison of stress, relaxation and heart rate against a particular activity. So, it was decided to classify all activities under three broad categories: work, sleep, and other activities. Work was further classified based on work shifts: morning shift, evening shift, night shift, and double shifts (Table 2). This classification was done keeping in mind that it would make possible to compare stress, relaxation and heart rate pattern during different shifts, other activities and during sleep. The reliability of the classification of JournalMarker entries (n=123) was performed with the help of an experienced clinical researcher having intensive care background.

(3) TDFs were edited accordingly in the Excel. This included removing irrelevant variables and replacing JournalMarker entries with numeric codes and listed under new variable named 'Activity'. Coding was done as: morning shift= 1, evening shift= 2, double shift= 3, night shift= 4, sleep= 5, other activities=6. This process was done with all 40 TDFs and they were exported into SPSS.

(4) Mean Stress Risk (MSR) was calculated for each participant (section 4.3.5 for details) and added into a merged data file for every individual.

(5) Finally, all individual merged files were compiled into a master data file that contained variables needed for final analysis.

This process was not linear and there were many back and forth cycles of trial and error.

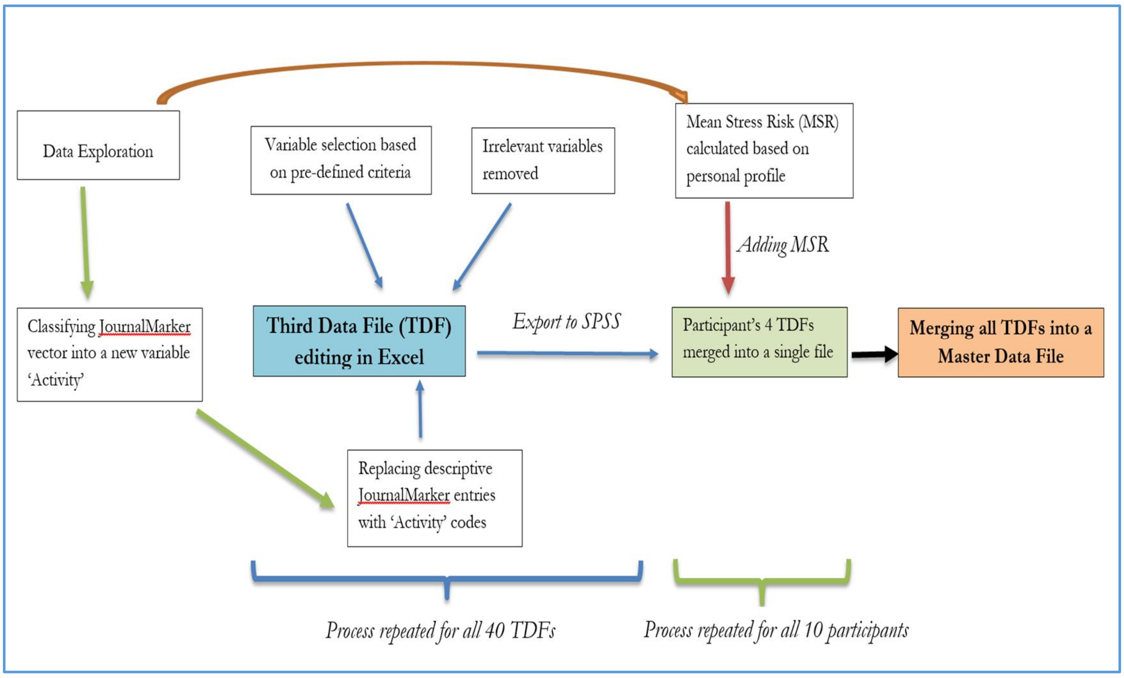


Figure 111: Preparing data for the analysis

4.3.4 Physiological state vectors

Firstbeat software calculate various physiological states of the participants based on their HRV readings and given the values for every second. There are different states recorded under the variable 'StateVector' as:

- Physical exercise (VO_2max >95%)
- Physical exercise (VO_2max 95-75%)
- Physical exercise (VO_2max 75-50%)
- Physical exercise (VO_2max 50-30%)
- Light physical activity
- Relaxation
- Recovery from physical exercise
- Stress
- Unrecognized state

In the Wellbeing Analysis report the physiological state vector of individual participant was compiled under five categories that were used in the descriptive analysis. (Table 6 & Appendices 7 & 8).

4.3.5 Computing composite variables

Two new variables were computed based on the values of other variables. These are Mean Stress Risk (MSR) and Subjective Wellbeing Index (SWI) described briefly here:

Mean Stress Risk

Both the TDF and Wellbeing Analysis reports contained personal profile variables such as weight & height (BMI), age, and activity class. These variables were classified in to three levels and were used to calculate the MSR. (Appendix 4)

MSR = (BMI level + Age level + Activity Class level) / 3

MSR values were ranked from 1 (representing lower risk and healthier lifestyle such as normal BMI) to 3 (representing higher risk).

Subjective Wellbeing Index

The Wellbeing Analysis report included subjective perception of wellbeing questionnaire filled by the participants (Table 3 & Figure 4), that was utilised to observe any relationship between subjective perception of wellbeing and MSR. To do that, all the statements were evaluated to make sure that they measure same thing i.e. wellbeing. Cronbach's alpha is considered as a good measure to check for internal consistency of the questionnaire. (Gray, Grove, & Sutherland 2017; Roberts, Priest & Traynor 2006). The Cronbach's alpha of the subjective perception of wellbeing questionnaire was 0.797 that reflects good internal consistency. After ensuring high internal consistency, mean value of all ten statements was recorded in new variable named 'SWI' (subjective wellbeing index) where 1 represents perception of wellbeing is high and 5 represents perception of wellbeing is low.

4.3.6 Statistical Procedures

IBM SPSS (version 24) was used to run various statistical procedures and tests to analyse data and answering the research questions. Assumptions for the statistical tests were also checked as described below.

First, the characteristics of participants were described using descriptive statistics including age, weight, height, BMI, activity class, heart rate, work and sleep hours, physiological state vector i.e. what proportion of time they spent in different situations (e.g. stress, recovery, strenuous or light exercise) and stress balance ratio of the day. This is followed by mean values for stress and relaxation vectors.

Second, the relationships between various variables were explored using Pearson correlation: MSR in relation with HR, ASV and ARV. According to Lund and Lund (2013), Pearson correlation test should be performed on a data set that meet following assumptions:

1. Variables of interest should be measured continuous (i.e. measured at interval or ratio level).
2. The variables should have a linear relationship.
3. Data should not contain significant number of outliers.
4. The variables should be distributed normally.

Hence, assumptions were checked: the variables of interest were already measured at continuous scale and meeting the linear relationship. After removing the outliers it is found that data is approximately normally distributed (Appendix 6).

Relationship between MSR and SWI was also performed using Spearman correlation due to small number of observations (n=10) and data was recorded on ordinal or ranked scale. Hence, non-parametric test was done as recommended in the literature. (Lund & Lund 2013; McDonald 2008).

Finally, comparison of mean scores of stress, relaxation and heart rate based on different groupings of age levels, BMI levels, activity class, and work shift timings was done using one-way ANOVA test. For performing ANOVA, the data must meet two assumptions. First the assumption of normality that was already checked but second assumption of homogeneity of variances was checked using Leven's test and found that it had been violated.

In such case when the assumption of homogeneity of variances has been violated, using Welch's ANOVA has been recommended (Kohr & Games 1974; McDonald 2008). Lund & Lund (2013, 1) suggest that "for most situations it has been shown that the Welch test is best."

5 Results

This chapter summarises the results of statistical analysis. First the characteristics of the participants are described with the help of descriptive statistics followed by exploring relationship between various variables and inferential statistical procedures for comparing means.

5.1 Descriptive Statistics

This summarized the descriptive statistics of the study participants.

5.1.1 Personal characteristics and physiological state vectors

There were ten participants in the study (one male, nine female). Wellbeing Analysis reports provided basic demographic information of the participants (e.g. name, gender, age, height, weight, BMI) and other characteristics (e.g. activity class, heart rate, physiological state vectors).

Due to small number of participants, specific personal details (e.g. weight, height, age, BMI) are not reported here to preserve their identity. Age, BMI and activity class are classified into three levels and participants' number were mentioned against the levels (Appendix 4). Appendix 7 describes the basic information about the participant number, MSR, activity class, minimum and maximum heart rate during the whole data collection period and physiological state vectors mean values of all four day data collection period.

Furthermore, Appendix 8 presents mean values of physiological state vectors for all four days separately for each participant. It also presents the day of data collection, sleep hours, duty hours, and duty shift (coded as M= Morning shift, E= Evening shift, D= Double shift, N= Night shift and O= off day). In the last row of the table, cumulative mean values for all physiological state vector were presented. Hence, the table provides clear picture of each participant's physiological state during a given day of the data collection period.

5.1.2 Description of main measurement variables

Collectively all ten participants spent 3 495 848 seconds (about 971 hours) in various activities that were recorded under JournalMarker. These activities were classified as described previously (section 4.3.3). Mean values for HR, ASV and ARV are given in Table 6 against classified activities.

It is important to note that all six categories of activities were unequal in a way that 'night shift' consists of only 2.2% of all data and 'other' consists of major part of the data (41.6%). The measured stress of intensive care nurses varied according to activities so that the mean HR was highest (82.06) during "other activities" and lowest (63.60) during the sleep. The mean absolute stress vector was highest (151.68) during morning shifts and lowest (104.77) during night shift. The mean absolute relaxation factor was highest (78.41) during sleep and lowest (60.16) during the other activities (Table 6).

Table 6 shows observed data for all participants performing different activities for the whole study period. Whereas, Appendix 9 presents same data for every participants for each day of data collection. In addition to that two more variables are presented. First the MSR for each participant and second, the stress balance for each day. It is observed that stress balance of majority of participants was on the negative side that shows the participants tend have weak recovery. (Firstbeat Technologies Ltd., 2014; Fohr 2015).

Activities	Recorded data in seconds	Heart Rate (SD)	Absolute Stress Vector (SD)	Absolute Relaxation Vector (SD)
Morning Shift	444660 (12.7%)	78.71 (SD = 12.35)	151.68 (SD = 70.90)	65.90 (SD = 14.54)
Evening Shift	113400 (3.2%)	76.91 (SD = 11.72)	139.70 (SD = 69.31)	67.77 (SD = 17.03)
Double Shift	345720 (9.9%)	80.48 (SD = 11.82)	139.81 (SD = 63.57)	66.47 (SD = 15.02)
Night Shift	78300 (2.2%)	75.23 (SD = 11.78)	104.77 (SD = 36.09)	70.68 (SD = 14.71)
Sleep	1058925 (30.3%)	63.60 (SD = 8.52)	112.78 (SD = 52.27)	78.41 (SD = 16.35)
Other**	1454843 (41.6%)	82.06 (SD = 16.72)	133.30 (SD = 91.86)	60.16 (SD = 23.38)

Table 6: Mean values of Heart Rate, Absolute Stress Vector and Absolute Relaxation Vector for all participants against different activities.
** ‘Other’ included off days as well as other activities after or before work shifts.
SD=Standard Deviation

5.2 The relationships and differences between stress indices parameters and background factors

In order to answer the research questions, two sets of the statistical tests were conducted.

First, the relationships between stress risk and mean values of Heart Rate, Absolute Stress Vector and Absolute Relaxation Vector was investigated using Pearson correlation. Spearman correlations was done to see the relationship between stress risk and subjective wellbeing.

Second, the differnces in values of Heart Rate, Absolute Stress Vector and Absolute Relaxation Vector based on age, BMI, Activity levels and shifts were compared by one-way ANOVA between groups.

5.2.1 Relationship of Mean Stress Risk with Heart Rate, Absolute Stress Vector and Absolute Relaxation Vector

Mean Stress Risk (MSR) is a composite variable. Relationship of MSR with heart rate, stress, and relaxation was explored using Pearson correlation (Table 7). Statistically significant negative correlation was found between MSR and HR, MSR and ARV. This means when stress risk is low, relaxation and heart rates tend to be on higher side. Similarly, statistically significant positive correlation was found between MSR and ASV. This means higher the stress risk, higher the stress will be and vice versa.

	Heart rate r=	Absolute Stress Vector r=	Absolute Relaxation Vector r=
Mean stress risk	-0.055**	0.176**	-0.159**
Sig. (2-tailed)	0.000	0.000	0.000
n*	3495848	3272724	3301184

Table 7: Relationship between stress risk and, stress and relaxation measured by Pearson correlation coefficient).

* ‘n’ represents seconds as the data was recorded in the interval of seconds.

** Correlation is significant at the 0.01 level (2-tailed).

5.2.2 Relationship between stress risk and subjective wellbeing

SWI variable was calculated based on subjective questionnaire. The relationship between MSR and SWI was explored using Spearman’s rho. Result showed that there was no statistically significant relation between stress risk factors (age, physical activity, and BMI) and subjective perception of wellbeing (Table 8).

Tests		Subjective Wellbeing index
Spearman’s rho (sig. values)	Mean Stress Risk	–0.096 (0.792)
n*	10	10

Table 8: Relationship between stress risk and subjective wellbeing measured by Spearman’s rho.

* ‘n’ represents total participants.

5.2.3 Differences in values of Heart Rate, Absolute Stress Vector and Absolute Relaxation Vector based on age, BMI, Activity levels and Shifts by ANOVA

Participants were divided into different groups based on their age, BMI, activity class and work-shift times. These grouping was used to investigate if the values of stress, relaxation and heart rate differed significantly between groups.

It was found that HR, stress and relaxation values differed statistically significant on the basis of age, BMI, activity class and work-shift times when one-way ANOVA test was performed (Appendix 10). To investigate which groups differed significantly, Post Hoc tests of Games-Howell was performed and it was revealed that there is statistically significant difference between all groups, except in work-shifts where stress difference between evening and double shifts is not statistically significant.

The results showed that with increasing age, heart rate was decreasingly gradually and stress and relaxation vectors were increasing nominally. Statistically significant differences in the physiological indictors was found based on BMI. Stress was found increasing steadily as BMI increased, and relaxation was decreasing suddenly but heart rate patterns were not as prominent. On the activity level, it was observed that more active participants tend to had lower heart rate and stress but higher relaxation. Analysis also revealed statistically significant differences exist in the stress level between different work shifts. Higher levels of stress were seen in the morning shifts but no distinct patterns were observed in heart rates and relaxation in comparison to the shift timings.

6 Discussion

This section discuss the results in the context of theoretical framework and relevant studies followed by limitation of the study, ethical consideration, dissemination of the research findings and conclusion.

The current study found that the overall stress level amongst the participants is 55.5%. This finding is slightly higher than the previously reported level of 51% overall stress amongst Finnish working-age population (Pietilä 2014). However, these finding cannot be generalised to a larger population of ICU nurses in Finland due to small sample size (n=10).

In the present study, there were statistically significant differences in the physiological indictors of heart rate, stress, relaxation and amongst different age group. General pattern was observed that the heart rate was decreasing as the participants' age increased. Umetani, Singer, McCraty & Atkinson (1998) reported similar trend in their research after studying heart rate of 260 people that aged from 10 to 99 years. They also reported that heart rate variability (HRV) decreased as people grew old. Decreased HRV corresponds to increase in stress that also found in the present study and confirmed the results of Mroczek & Almeida (2004) that found strong association between age and daily stress. In the present study sample, as the participants' age increased their need for taking longer period of rest also increased as reflected in the higher relaxation index.

Current study results showed that participants with higher BMI had higher stress but heart rate patterns were not as prominent. Relaxation become relatively better if BMI is low. Likewise, participants' activity levels also showed similar pattern where stress and heart rates were decreasing with higher activity level and increase in relaxation. Mutikainen, Helander, Pietilä, Korhonen, & Kujala (2014) based on 9554 Finnish employees found that physical activity decreased with increasing BMI, results in increasing stress levels. Current study results supports this finding as increased BMI was found closely associated with higher stress levels. Hence, the notion of 'sound body, sound mind' gains credibility. Föhr, Pietilä, Helander, Myllymäki, Lindholm, Rusko & Kujala (2016) in their cross-sectional study (n=16275) reported that increase physical activity is associated lower stress percentages and high stress balance. However, the stress balance in the present study is mostly negative.

Nursing care is generally a shift based work and research studies highlights adverse impact of shift work on nurses' health and performance. Some studies also discussed that stress is associated with working in shift, disturbance of circadian rhythms and also sleep disorder which in turn leads to fatigue, and unpleasant social and family life (Chung & Chung 2009; & Shandor 2012). Cox et al. (2000), Fuller (2010) and Bhatia et al. (2010) reported that nurses working in night shifts or rotating shifts are more stressed than their daytime co-workers, eventually placing them at high risk for compromised health, decreased psychosocial and physiological health of the individual and decreased job performance and work ability. However, one study did not find any relationship between stress and shift work (Cavalheiro et al. 2008). An interesting pattern emerged in the current study that participants' stress levels were higher in the morning shifts as compare to evening and double shifts. One possible reason for this pattern is the fact that more events occur during the morning shifts (e.g. discharge of patients). In the current study, stress levels during night shifts were lowest. This finding is distinct from previous studies and one possible reason for this anomaly is very small data for night shift in present study (only two night shifts performed by one participant in a 40-day data collection period).

At the individual level, the current study results showed that stress level are higher in longer shifts as compare to standard duration shifts. Similar results were found in a large cross-sectional study of Stimpfel et al. (2012). They reported that working in a 13-hour shifts associated with higher probability of stress, job frustration, and intent to leave the job amongst nurses. Järvelin-Pasanen, Ropponen, Tarvainen, Paukkonen, Hakola, Puttonen, Karjalainen, Lindholm, Louhevaara and Pohjonen (2013) studied impact of ergonomic shift-work schedule (such as fewer shifts in succession, adequate resting time between shifts, no permanent night shifts, shifts rotation and work flexibility as much as possible) on nurses and found that the schedule has a positive effects on HRV and lowering stress.

In past under-staffing was identified as one of the contributing factor in stress amongst ICU nurses (Caldwell & Weiner 1981), however, this does not seems to be a case in the current study as the nurse-patient ratio was good.

The subjective perception of stress was extensively studied and it was reported that stress amongst ICU nurses is high. The current study did not find relation between stress risk factors (age, physical activity, and BMI) and subjective perception of wellbeing. There are two main reasons for this result: (a) the sample size was very small (n = 10) and highly skewed; and (b) the questionnaire for gauging subjective wellbeing was very limited in scope with only ten statements.

6.1 Limitation of the study

As discuss earlier this study was based on the previously collected data, hence, there were several limitations around it.

First, the number of participants were small (n = 10). Although the data consist of 3,495,848 observations measured in seconds, small number of participants mean results cannot generalised in a meaningful way for a larger population. However, the results reported variation of heart rate, stress, and relaxation amongst the study participants.

Second, the data was biased in different ways. For example, there was only one male participant in the sample, so gender comparison was not completed. Similarly, there were only two night-time work shifts (5%). So, these factors made it difficult to do range of appropriate statistical analysis.

Third, there were many missing values for Absolute Stress Vector and Aboslute Relaxation Vector from the data set and no explanation was accompanied why these values are missing. So, missing values, that were no more than 6% of the whole data set, were excluded from the statistical analysis and no replacement for the missing values was made.

Fourth, as already mentioned above (section 4.3.1) that it was practically not possible to use RR and RMSSD values, so main analysis was done using heart rate, absolute stress and absolute relaxation vectors. These variables may not be that precise as the heart rate variability reflected in the readings of RR interval (see Figure 2).

Lastly, original plan was to analyse how physiological indicators of stress relate with various situation at workplaces like performing Cardiopulmonary resuscitation (CPR), medication or caring for intubated patients. This was not possible as the self-reported dairies hardly identified any nursing intervention performed during the whole data collection period (Appendix 5). So, the original plan was reconsidered and adjusted according to the available data set.

6.2 Ethical Consideration

One of the most important element of research ethics is maintaining the confidentiality of study participants. The researcher has a responsibility assuring the participants' anonymity throughout the research and reporting process (Burns 2017; Ellis 2013).

The data was collected during the EVICURES project cycle and necessary consent was obtained by the project team. However, for the current study, the original data was used in a ways that may not be anticipated by the participants when they gave consent for data collection. Hence, a new consent was sought from participants to use their data as per informed consent guidelines of Finnish National Institute for Health and Welfare (Terveyden ja hyvinvoinnin laitos, THL). Anonymity of the participants was assured and necessary precautions were taken to ensure the security of the data (Appendix 2).

Furthermore, written permission was obtained from the Firstbeat Technologies Oy for using copyright materials.

6.3 Dissemination of the Research Report

Once approved, the thesis will be uploaded to the Theseus.fi. It is also planned to report the main results of the study in relevant nursing journals.

6.4 Conclusion

The present study attempted to explore heart rate, stress, and relaxation amongst ICU nurses based on personal characteristics and work situations and the relationship between stress risk and stress indices and subjective perceptions of wellbeing.

It was found that stress indices differ significantly based on personal characteristics (age, BMI, activity class) and different work-shift times, where increased stress levels are associated with higher BMI, older age, low physical activity, and extended work hours. However, this study did not find statistically significant relationship between stress risk and subjective perception of wellbeing.

6.5 Recomendation and future implications

Stress is a complex phenomenon and for futures studies, it is important to collect the data from multiple sources (triangulation) to measure stress from both objective and subjective experiences of a person.

In the present study it was interesting to observe the effect of various work shifts on stress levels of ICU nursing staff. Results may not be generalizable due to small number of participants. However, in future studies with larger and representative sample may allow hospital managers to make informed choices particularly in planning work shifts and providing healthy work environment.

It was also found that stress risk is positively associated with higher stress levels, hence, hospital management may like to take this factor into account while planning and scheduling the staff across different units. For future research studies, stress risk seems a good indicator of stress but it needs to be explored with larger data set and in different work conditions.

The present study was based on the data collected in old ICU environment of South Ostrobothnia Hospital District (EPSHP). It may be educative to conduct a similar study in the renovated ICU environment. Such study would provide a basis for comparative analysis.

References

Acharya, U., Joseph, K., Kannathal, N., Lim, C. & Suri, J. 2006. Heart rate variability: a review. Medical & Biological Engineering & Computing, 44, 1031–1051.

Andolhe, R., Barbosa, R., Oliveira, E., Costa, A. & Padilha, K. 2015. Stress, coping and burnout among intensive care unit nursing staff: associated factors. Journal of School of Nursing USP, 49, 57-63.

Bhatia, N., Kishore, J., Anand, T. & Jiloha, R. 2010. Occupational stress amongst nurses from two tertiary care hospitals in Delhi. Australasian Medical Journal, 3 (11), 731-738.

Block, J., He, Y., Zaslavsky, A., Ding, L. & Ayanian, J. 2009. Psychosocial stress and change in weight among US adults. American Journal of Epidemiology, 170 (2), 181–192.

Burgess, L., Irvine, F. & Wallymahmed, A. 2010. Personality, stress and coping in intensive care nurses: a descriptive exploratory study. Nursing in Critical Care, 15 (3), 129-140. Article from Wiley Online Library. Accessed 12 June 2016. http://onlinelibrary.wiley.com/

Burns, N., Gray, J. & Grove, S. (6th ed.). 2015. Understanding nursing research: building an evidence-based practice. Elsevier.

Caldwell, T. & Weiner, M. 1981. Stresses and coping in ICU nursing- A review. General Hospital Psychiatry, 3, 119-127.

Cavalheiro, A., Junior, D. & Lopes, A. 2008. Stress in nurses working in intensive care units. Rev Latino-am Enfermagem, 16 (1), 29-35.

Centre for Studies on Human Stress. 2007. How to measure stress in human. Accessed 24 October 2016.
http://www.stresshumain.ca/documents/pdf/Mesures%20physiologiques/CESH_howMesureStress-MB.pdf

Chandola, T., Heraclides, A. & Kumari, M. 2010. Psychophysiological biomarkers of workplace stressors. Neuroscience and Biobehavioral Reviews, 35 (1), 51-57.

Choi, S., Kim, S., Yang, J., Lee, J., Joo, C. & Jung, H. 2014. Real-time measurement of human salivary cortisol for the assessment of psychological stress using a smartphone. Sensing and Bio-sensing Research, 2, 8-11.

Chung, C. & Chung, U. 2009. An exploration of quality of life and related factors among female flight attendants. Journal of Nursing Research, 17 (2), 212-219.

Clays, E., Bacquer, D., Crasset, V., Kittel, F., Smet, P., Kornitzer, M., Karasek. R. & Backer, G. 2011. The perception of work stressors is related to reduced parasympathetic activity. International Archives of Occupational and Environmental Health, 84 (2), 185–191. Abstract from Springer link Journals. Accessed 20 January 2017.
https://link.springer.com/article/10.1007/s00420-010-0537-z

Cox, T., Griffiths, A. & Rial-González, E. 2000. Research on work-related stress. Luxembourg: European Agency for Safety and Health at Work.

Ellis, P. (2nd ed.). 2013. Understanding Research for Nursing Students. London: Learning Matters.

Firstbeat Technologies Ltd. 2014. Stress and recovery analysis method based on 24hour heart rate variability. Jyväskylä: Firstbeat Technologies Ltd. White paper from Firstbeat. Accessed 24 June 2016. https://www.firstbeat.com/en/science-and-physiology/white-papers-and-publications/

Foxall, M., Zimmerman, L., Standley, R. & Bene, B. 1990. A comparison of frequency and sources of nursing job stress perceived by intensive care, hospice and medical-surgical nurses. Journal of Advanced Nursing, 15, 577-584.

Fuller, T. 2010. Shift workers give sleep short shrift. American Journal of Nursing, 110 (2), 28-30.

Föhr, T., Pietilä, J., Helander, E., Myllymäki, T., Lindholm, H., Rusko, H. & Kujala, U. 2016. Physical activity, body mass index and heart rate variability-based stress and recovery in 16 275 Finnish employees: a cross-sectional study. BMC Public Health. Accessed 12 April 2017 https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-016-3391-4

Föhr, T., Tolvanen, A., Myllymäki, T., Järvelä-Reijonen, E., Rantala, S., Korpela, R., Peuhkuri, K., Kolehmainen, M., Puttonen, S., Lappalainen, R., Rusko, H. & Kujala, U. 2015. Subjective stress, objective heart rate variability based stress, and recovery on workdays among overweight and psychologically distressed individuals: a cross-sectional study. Journal of Occupational Medicine and Toxicology, 10 (39), 1-9. Article from BioMed Central. Accessed 12 April 2017.

https://jyx.jyu.fi/dspace/bitstream/handle/123456789/47506/s1299501500816.pdf?sequence=1

Golubic, R., Milosevic, M., Knezevic, B. & Mustajbegovic, J. 2009. Work-related stress, education and work ability among hospital nurses. Journal of Advanced Nursing, 65 (10), 2056-2066.

Gray, J., Grove, S. & Sutherland, S. (8th ed.) 2017. Burns and Grove's. The Practice of Nursing Research - E-Book: Appraisal, synthesis and generation of evidence. Accessed 14 August 2017. https://books.google.fi/books?id=oD_UDAAAQBAJ&pg=PA374&lpg=PA374&dq=cronbach+alpha+Burns+and+groves&source=bl&ots=yjSWO9qyjH&sig=DCpAu8WYuv3Tk1l4-qeSmQmbBX0&hl=en&sa=X&ved=0ahUKEwiayLvTj5DWAhWIA5oKHZCsC4EQ6AEIKDAA#v=onepage&q=cronbach%20alpha%20Burns%20and%20groves&f=false

Hall, D. 2004. Work related stress of registered nurses in a hospital setting. Journal for Nurses in Staff Development, 20 (1), 6–14.

Hämäläinen, K. 2017. Registered Nurse and Project secretary EVICURES. Hospital District of South Ostrobothnia. Email to the author. 1 June 2017. Personal communication.

Johnson, S., Cooper, C., Cartwright, S., Donald, I., Taylor, P. & Millet, C. 2005. The experience of work-related stress across occupations. Journal of Managerial Psychology, 20 (2), 178-187.

Järvelin-Pasanen, S., Ropponen, A., Tarvainen, M., Paukkonen, M., Hakola, T., Puttonen, S., Karjalainen, P., Lindholm, H., Louhevaara, V. & Pohjonen, T. 2013. Effects of implementing an ergonomic work schedule on heart rate variability in shift-working nurses. Journal of Occupational Health. 55, 225-233.

Kahnen, D., Gerard, B. & Qin, H. 2016. How does decreasing stress impact the healthy practice environment? Academy of Medical Surgical Nurses, 23 (4), 12-14.

Karhula, K., Härmä, M., Sallinen, M., Hublin, C., Virkkala, J., Kivimäki, M., Vahtera, J. & Puttonen, S. 2013. Job strain, sleep and alertness in shift working health care professionals- a field study. Industrial Health. 51, 406-416.

Kohr, R. & Games, P. 1974. Robustness of the analysis of variance, the Welch procedure and a box procedure to heterogeneous variances. Journal of Experimental Education, 43 (1), 61-69.

Lazarus, R. & Folkman, S. 1984. Stress, Appraisal and Coping. New York: Springer.

Leka, S., Griffiths, A. & Cox, T. 2003. Work organization and stress: systematic problem approaches for employers, managers and trade union representatives. Switzerland: WHO.

Lund, A. & LUND, M. 2013. One-way ANOVA. Accessed 25 August 2017 https://statistics.laerd.com/statistical-guides/one-way-anova-statistical-guide-3.php

McDonald, J., 2008 Handbook of biological statistics. Baltimore, Maryland

McVicar, A. 2003. Workplace stress in nursing: a literature review. Journal of Advanced Nursing. 44 (6), 633-642.

Mealer, M., Shelton, A., Berg, B., Rothbaum, B. & Moss, M. 2007. Increased prevalence of post-traumatic stress disorder symptoms in critical care nurses. American Journal of Respiratory and Critical Care Medicine, 175, 693–697.

Milczarek, M., Schneider, E. & González, E. 2009. OSH in figures: stress at work facts and figures. Luxembourg: European Agency for Safety and Health at Work. Article from BioMed Central. Accessed 12 April 2016. www.stress-lavoro.com/140_stress/TE

Milutinovic, D., Golubovic, B., Brkic, N. & Prokes, B. 2012. Professional stress and health among critical care nurses in Serbia. Arh Hig Rada Toksikol, 63, 171-180.

Mroczek, D. & Almeida, D. 2004. The effect of daily stress, personality, and age on daily negative affect. Journal of Personality, 72 (2), 355-378.

Mutikainen, S., Helander, E., Pietilä, J., Korhonen, I. & Kujala, U. 2014. Objectively measured physical activity in Finnish employees: a cross-sectional study. Article from BMJ Open. Accessed 6 April 2017. http://bmjopen.bmj.com/content/4/12/e005927

Nixon, P. 1982. The human function curve - a paradigm for our times. Act Nerv Super (Praha), 3 (1), 130-133.

Nykänen, E., Tuomaala, P., Laarni, J., Dhinakaran, K., Saarinen, K., Yli-Karhu, T., Hämäläinen, K., Koskela, T., Eerikäinen, H., Salminen-Tuomaala, M., Hellman, T., Rintamäki, K., Vimpari, K., Kilpikari, J., Jääskeläinen, J. & Kotilainen, H. 2016. A user-oriented, evidence-based design project of the first Finnish single room ICU: Results of EVICURES project. Espoo: VTT Technical Research Centre of Finland. Accessed 6 May 2016 www.vtt.fi/inf/pdf/technology/2016/T252.pdf

Parak, J. & Korhonen, I. No Date. Accuracy of Firstbeat Bodyguard 2 beat-to-beat heart rate monitor. Firstbeat Technologies Oy, 1-2. Accessed 6 May 2016.
https://www.firstbeat.com/en/accuracy-firstbeat-bodyguard-2-heart-rate-monitor/

Pemberton, E. & Turpin, P. 2008. The effect of essential oils on work related stress in intensive care unit nurses. Holistic Nursing Practice, 22 (2), 97-102.

Pietilä, J. (2014). Preparation and processing of a large-scale heart rate variability and lifestyle assessment data. M.Sc. Electrical Engineering. Tampere University of Technology.

Poncet, M., Toullic, P., Papazian, L., Kentish-Barnes, N., Timsit, J., Pochard, F., Chevret, S., Schlemmer, B. & Azoulay, E. 2007. Burnout syndrome in critical care nursing staff. American Journal of Respiratory and Critical Care Medicine, 175, 698–704.

Preto, V. & Pedrão, L. 2009. Stress among nurses who work at the intensive care unit. Rev Esc Enferm USP, 43 (4), 838-45.

Rapoliene, L., Razbadauskas, A. & Jurgelenas, A. 2015. The reduction of distress using therapeutic geothermal water procedures in a randomized controlled clinical trial. Advances in Preventive Medicine, 1-10. Accessed 6 April 2017.
https://www.hindawi.com/journals/apm/2015/749417/

Riemer, H., Mates, J., Ryan, L. & Schleder, B. 2015. Decreased stress levels in nurses: a benefit of quiet time. American Journal of Critical Care, 24 (5), 396-402.

Roberts, P., Priestet, H. & Traynor, M. 2006. Reliability and validity in research. Nursing Standard. 20 (44), 41-45.

Rodrigues, V. & Ferreira, A. 2011. Stressors in nurses working in intensive care units. Revista Latino-Americana de Enfermagem, 19 (4), 1025-1032.

Rogers, A. E., Hwang, W.-T., Scott, L. D., Aiken, L. & Dinge, D. 2004. The working hours of hospital staff nurses and patient safety. Data Watch, 23 (4), 202–12.

Rydstedt, L., Cropley, M., Devereux, J. & Michalianou, G. 2008. The relationship between long-term job strain and morning and evening saliva cortisol secretion among white-collar workers. Journal of Occupational Health Psychology. 13 (3), 105–113.

Seaward, B. (8th ed.). 2015. Managing Stress: Principles & Strategies for Health and Well-Being. Burlington, MA, USA: Jones & Bartlett Learning.

Selye, H. 1950. Stress and the general adaptation syndrome. British Medical Journal, 4667, 1383-1392. Accessed on 3 April 2017. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2038162/

Shandor, A. 2012. The health impacts of nursing shift work. M.Sc. Nursing. Minnesota State University, Mankato

Stimpfel, A., Sloane, D. & Aiken, L. 2012. The longer the shifts for hospital nurses, the higher the levels of burnout and patient dissatisfaction. Health Affairs, 31 (11), 2501–2509.

Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1998). Heart rate variability: standards of measurement, physiological interpretation and clinical use. European Heart Journal, 17, 354–381. Accessed 21 February 2017. https://www.escardio.org/static_file/.../guidelines-Heart-Rate-Variability-FT-1996.pdf

Teisala, T., Mutikainen, S., Tolvanen, A., Rottensteiner, M., Leskinen, T., Jaakko, K., Koleh-mainen, M., Rusko, H. & Kujala, U. 2014. Associations of physical activity, fitness, and body composition with heart rate variability–based indicators of stress and recovery on workdays: a cross-sectional study. Journal of Occupational Medicine and Toxicology, 9 (16), 1-9.

The American Institute of Stress. (2017). What is stress? Accessed 21 February 2017. https://www.stress.org/what-is-stress/

Umetani, K., Singer, D., McCraty, R. & Atkinson, M. 1998. Twenty-four hour time domain heart rate variability and heart rate: relations to age and gender over nine decades. Journal of the American College of Cardiology, 31 (3), 593– 601.

Wahbeh, H., Calabrese, C. & Zwickey, H. 2007. Binaural beat technology in humans: a pilot study to assess psychologic and physiologic effects. The Journal of Alternative and Complementary Medicine, 13 (1), 25–32.

Vanderspank-Wright, B., Fothergill-Bourbonnais, F., Malone-Tucker, S. & Slivar, S. 2011. Learning end-of-life care in ICU: Strategies for nurses new to ICU. Dynamics, 22 (4), 22–25.

Winwood, P., Winefield, A. & Lushington, K. 2006. Work-related fatigue and recovery: the contribution of age, domestic responsibilities and shift work. Journal of Advanced Nursing, 56 (4), 438–449.

Vreeland, R. & Ellis, G. 1969. Stresses on the Nurse in an Intensive Care Unit. 208, 54-56.

Yerkes, R. & Dodson, J. (1908). The Relation of Strength of Stimulus to Rapidity of Habit-Formation. Journal of Comparative Neurology and Psychology, 18, 459-482. Accessed 11 April 2017. http://psychclassics.yorku.ca/Yerkes/Law/

Yoder-Wise, P. (5th) 2013. Leading and Managing in Nursing. Accessed 4 August 2017. https://books.google.fi/books?id=VehOAQAAQBAJ&pg=PA553&lpg=PA553&dq=Eustress+in+nursing+staff&source=bl&ots=imFuSWDxW2&sig=uQIHxYkUUvXCB1IPQv2j5UtP9QA&hl=en&sa=X&ved=0ahUKEwiameSjhITWAhXhApoKHem7COwQ6AEIZDAJ#v=onepage&q=Eustress%20in%20nursing%20staff&f=false

Figures

Tables

Appendices

Appendix 1: Summary Table of Research Studies

Study/Country	Purpose and aim of the study	Design	Data and methods	Results
Vreeland & Ellis, 1969/ Bethesda, Maryland, USA	Stresses identified in this communication are those observed in nurses assigned to a four bed unit in the Clinical Centre,National Institute of Health, Bethes-da, Md.	Qualitative Study	Not discussed in the article. It gives the historical background as this is one of the earliest studies done to identify stress among ICU nurses.	This study concludes that nursing in the ICU encompasses stressful events related directly to individual patient needs and indirectly to pressures within the environment. Nurses' knowledge, working with technical equip-ment, working relationships and effective communications creates tension too. Emo-tional trauma associated with emergencies and deaths are also some of the stress creat-ing factors.
Caldwell & Weiner, 1981/ Dallas, USA	The literature on stresses in ICU nursing is reviewed to help the liaison psychiatrist facilitate nurses' coping with the considerable stresses in their work envi-ronment.	A review	Six formal studies and multiple anecdotal reports make up the literature reviewed. (Gives the historical basis.)	Excessive workloads and understaffing have been found to be the most intense stresses. However, emotional issues related to death and sever illness also constant stress for ICU nurses.

Golubic, Milosevic, Knezevic, & Mustajbegovic, 2009/ Croatia	The study was to determine which occupational stressors are present in nurses' working environment; to describe and compare occupational stress between two educational groups of nurses; to estimate which stressors and to what extent predict nurses' work ability; and to determine if educational level predicts nurses' work ability.	A cross-sectional comparative design. n = 1086	Nurses employed at four university hospitals in Croatia. Occupational Stress Assessment Questionnaire and Work Ability Index Questionnaire.	The study identified six major groups of occupational stressors: Organization of work and financial issues; Public criticism; Hazards at workplace; Interpersonal conflicts at workplace; Shift work; & Professional and intellectual demands. Nurses with secondary school qualifications perceived Hazards at workplace and shift work as statistically significantly more stressful than nurses a with college degree. Four statistically significantly predictors related with low work ability and often leads to stress are: Organization of work Lower education Older age Domestic financial problems

Poncet, et al., 2007/ France	To identify determinants of Burnout Syndrome (BOS) in critical care nurses	Quantitative study n = 2392	Survey Questionnaire	The ICU is a highly stressful environment and therefore associated with a high rate of BOS in staff members. The cost of BOS includes decreased quality of care, absenteeism, high turnover rates and poor communication with families. Perceived conflicts with patients, families, or other staff members increased the risk of BOS in our study. High BOS rates have been reported in staff caring for dying Patients.
Hall, 2004/ Lexington, Kentucky	To identify work-related stressors and coping mechanisms of registered nurses (RNs) within a hospital setting.	Qualitative, explorative n = 10	Grounded theory	Registered nurses identified areas that if not met appropriately, may lead to stress: failure to meet patients' needs, expecting too much from the self, too much workload, and novice colleagues. Suggestion to minimise the stress include in-service education.

Burgess, Irvine, & Wallymah med, 2010/ Northwest England	Explore the relationship between personality of the ICU nurses, their perception of workplace stress and their preferred coping response. Consider the implications of the findings for future retention and recruitment strategies of ICU nurses.	Cross section al cohort study of intensive care unit (ICU) nurses at inner city teaching hospital. n = 46	Convenience sample of critical care nurses complete d three standardised questionnaires during September 2007	ICU nurses did not perceive their workplaces to be stressful. Certain personality traits, openness, agreeableness and conscientiousness, were associated with problem-solving coping strategies such as active planning and reframing. (NOTE: This is the only study in this review that reports stress is not perceive by the ICU nurses.)
Rodrigues & Ferreira, 2011/ Porto, Portugal	The purpose of this study was to identify Stressors for nurses working in intensive care units	Descriptive cross-section al study n = 235 nurses	Three questionnaire were used: 1) Socio-demographic variables, physical aspects of work and variables related to the work context. 2) Interpersonal Work Relations Scale 3) Nurse Stress Index.	The study found that novice nurse have higher stress levels than experienced ones. Inadequate physical work structure leads to higher stress levels their study also highlighted that interpersonal relations with their supervisory also have positive or negative effect on the nurses stress level. There is no significant difference found in the age and the stress level.

Foxall, Zim-merma, Stand-ley, & Bene, 1990/ USA	To compared and rule out any significance in the fre-quency and sources of nurs-ing job stress perceived by intensive care (ICU), hospice and medical surgical nurses	Quantitative study n = 138	44 items Nursing Stress Scale with 4 point Likert Scale was used.	The study found significant difference in three stress subscales among the three groups. ICU and hospice nurses are more stress than medical surgical nurses related to death and dying. ICU and medical-surgical nurses come across more stress than hospice nurses related to floating. Medical surgical nurses perceived significantly more stress than ICU and hospice nurses related to work overload/staffing.

Milutinovi c, Golubovic, Brkic, & Prokes (2012)/ Serbia.	The aim of this study was to identify and analyse profes-sional Stressors, evaluate the level of stress in nurses in Intensive Care Units (ICU), and assess the correlation between the perception of stress and psychological and somatic symptoms or diseases shown by nurses.	cross-sectional study n = 1000	Expanded Nursing Stress Scale (ENSS) was used as the research instrument.	Nurses from ICUs rated situations involving physical and psychological working environ-ments as the most stressful ones, whereas situations related to social working environ-ment were described as less stressful; how-ever, the differences in the perception of stressfulness of these environments were mi-nor. Significant differences in the perception of stressfulness of particular stress factors were observed among nurses with respect to psychological and somatic symptoms (such as headache, insomnia, fatigue, despair, lower back pain, mood swings.) and certain diseas-es (such as hypertension, myocardial infarc-tion, stroke, diabetes mellitus.)

Cavalheiro, Junior, & Lopes (2008)/ São Paulo, Brazil	The present study aimed to identify the presence of stress in nurses working in intensive care units, the stressing agents and symptoms associated to the nurses' perceptions of stress, and to assess the correlation between the occurrence of stress, sources of stress, and symptoms shown by the nurses.	cross-sectional study at Albert Einstein Israelite Hospital n = 75	Self-administrated Questionnaire was used for data collection.	The study showed the presence of stress related to work dissatisfaction, activities regarded as critical situations in intensive care units, symptoms related to cardiovascular, digestive and musculoskeletal disorders.
Mealer, Shelton, Berg, Rothbaum, & Moss (2007)/ Atlanta, Georgia, USA	To determine whether there is an increased prevalence of psychological symptoms in ICU nurses when compared with general nurses.	Emory University Hospital,, Crawford Long Hospital and Grady Memorial Hospital . n = 351 general nurses n = 140 ICU nurses	Posttraumatic Stress Syndrome 10 Questions Inventory (PTSS10), a self report scale based on the Diagnostic and Statistical Manual for PTSD and Hospital Anxiety and Depression Scale (HADS) was used.	24% of the ICU nurses tested positive for symptoms of PTSD related to their work environment, compared with 14% general nurses. ICU nurses did not report a greater amount of stress in their life outside of the hospital than general nurses. There was no difference in symptoms of depression or anxiety between ICU and general nurses. In the second survey of ICU nurses from a metropolitan area, 29% of the nurses reported symptoms of PTSD, similar to the first cohort of ICU nurses.

Appendix 2: Informed Consent from the Participants to Use their Data

Research: Measuring stress amongst Intensive Care Unit (ICU) nursing staff of South Ostrobothnia Hospital District (EPSHP) using Firstbeat Technologies: results from EVICURES project.

Researcher:
Munira Prasla, Master's Student at Laurea University of Applied Science
Address: [redacted]
Email: [redacted]
Mobile: [redacted]

Supervisor of the thesis:
Teija-Kaisa Aholaakko, Principal Lecturer, Responsible for the Global Development and Management of Health Care Master –Degree
Address: [redacted]
Email: [redacted]
Mobile: [redacted]

The goal of the research is to produce information in order to promote the wellbeing of the ICU staff and to create positive work environment. The main research question is: What are stress-inducing critical incidences faced by ICU nursing staff as reflected in heart-rate variability provoking critical incidences.

Informed consent:
I am aware that my data (Firstbeat analyses and my notes in the diary) obtained by Firstbeat Technologies Ltd is used by the researcher in her master's thesis and I certify that I have been told of the confidentiality of information and the anonymity of my participation.

I agree that information obtained from this research (the Firstbeat analyses and my notes in the diary) may be used for the analysis purpose only by the researcher and the supervisor of the thesis. The data will not be combined with any other kind of data not mentioned in the study plan or will not be given to any other party. The soft data will be stored in Laurea's secured digital platforms EndNote and in personal computer of the researchers (M.P. & T.-K.A.) securely. It will be combined to the hard data in order to complete the statistical analyses. The hard data will be stored in lock. The soft data will be destroyed by deleting from the personal computers after the publication of the research results and the hard copy will be returned to the owner of the data. The data will be reported in a manner that secures the privacy of all the informants and does not make possible their recognition.

During the data analysis process we will take some assistance from Mr. Markus Mattsson, PhD candidate and quantitative data analysis expert at the University of Helsinki. However, we will make sure the anonymity of the participants.

Two copies of this consent have been signed, one for the researcher and one for the informant.

Name of Participant ____

Signature of Participant _____________________________________

Place and Date ____

Appendix 3: Permission Documents

24th May 2016
Dr. Kari Saarinen
Manager on Intensive Care units
South Ostrobothnia Hospital District ESHP

Dear Dr. Kari Saarinen,

I am Munira Prasla. I am student of 'Master of Health Care: Global Development and Management in Health Care' programme at the Laurea University of Applied Sciences. I am planning to do my master thesis project with EVICURES project under the supervision of Ms Teija-Kaisa Aholaakko.

My intension is to study stress levels in nursing staff of intensive care unit (ICU) of Seinäjoki Hospital and more specifically, heart-rate variability during critical incidences. In this context, I am interested in using the data of ICU nurse that already collected under EVICURES Project by Firstbeat Technology.

I worked on the preliminary plan of my thesis project and developing theoretical foundation of the project. I need data at this point to design specific research questions (based within parameters of the data), and plan for data analysis.

To access the data, I need your permission. I am assuring you that the data will be used only for the research under my thesis project. I along with my supervisor will make sure that data is well protected and confidentiality of the participants is maintained. We also assure you that the data will not be combined with any other kind of data or will not be given to any other party. The soft data will be stored in Laurea's secured digital platforms Optima and EndNote and in personal computer securely if needed. The hard data will be stored in lock. The data will be destroyed by deleting from the personal computer after the analysis and the hard copy will be returned to the owner of the data.

I am looking forward to your cooperation and support.

Regards,

Munira Prasla
Researcher
Laurea University of Applied Sciences

Teija-Kaisa Aholaakko
Thesis Project Supervisor
Laurea University of Applied Sciences

Ok.
Seinäjoki 20.06.2016
KARI SAARINEN
YLILÄÄKÄRI
SEINÄJOEN KS
TEHO

(1) Letter

ETELÄ-POHJANMAAN SAIRAAN-HOITOPIIRIN KUNTAYHTYMÄ | VIRANHALTIJAPÄÄTÖS | Nro

Keskushallinto | 29.8.2016 | 38

Asia	Lupa opinnäytetyölle "Heart-rate variability analysis of nursing staff on South Ostrobothnia Hospital District EPSHP ICU to identify stress provoking critical incidences (working title)", Munira Prasla
Selostus	Laurea ammattikorkeakoulun hoitotyön koulutusohjelmassa opiskeleva Munira Prasla hakee lupaa otsikossa mainitulle opinnäytetyölle. Opinnäytetyön tarkoituksena on "to add knowledge on measuring real-time stress indicators amongst intensive care unit nursing staff by using Firstbeat technology". Opinnäytetyön ohjaajana toimii Teija-Kaisa Aholaakko Liitteenä sopimus opinnäytetyöstä, puoltokirje ja opinnäytetyön suunnitelma.
Päätös	Lupa myönnetty.
Tiedoksi	Opiskelija Munira Prasla Ylihoitaja Niina Herttuala Ylilääkäri Kari Saarinen Ohjaaja Teija-Kaisa Aholaakko
Oikaisuvaatimus viranomainen	Etelä-Pohjanmaan sairaanhoitopiirin kuntayhtymän hallitus Puhelinvaihde Telefax
	Oikaisuvaatimus on tehtävä 14 päivän kuluessa päätöksen tiedoksisaannista. Kunnan jäsenen katsotaan saaneen tiedon kun pöytäkirja on asetettu yleisesti nähtäväksi. Asianosaisen katsotaan saaneen päätöksestä tiedon, jollei muuta näytetä, seitsemän päivän kuluttua kirjeen lähettämisestä, saantitodistuksen osoittamana aikana tai erilliseen tiedoksisaantitodistukseen merkittynä aikana. Oikaisuvaatimuskirjelmässä on ilmoitettava päätös, johon haetaan oikaisua, sekä se, millaista oikaisua vaaditaan ja millä perusteilla sitä vaaditaan.
Paikka ja aika Allekirjoitus Virka-asema	Seinäjoki 29.8.2016 Christina Rouvala hallintoylihoitaja

(2) Permission document from hospital.

Appendix 4: Age, BMI and Activity class BMI Level

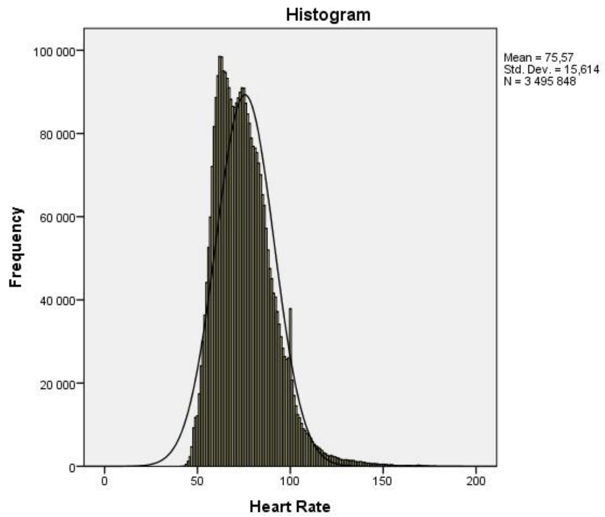
Level	Age	BMI	Activity class
1	< 40 years Participants (7, 9, 10)	< 25 Normal Participants (6, 8)	< 6 Active Participants (7, 8)
2	41-50 Participants (2, 3, 5)	25.1-30 Moderate Participants (1, 2, 3, 5, 10)	3-5 Moderately active Participants (1, 2, 5, 6, 7, 9, 10)
3	> 50 years Participants (1, 4, 6, 8)	>30 High Participants (9, 4)	>3 Less active Participants (3)

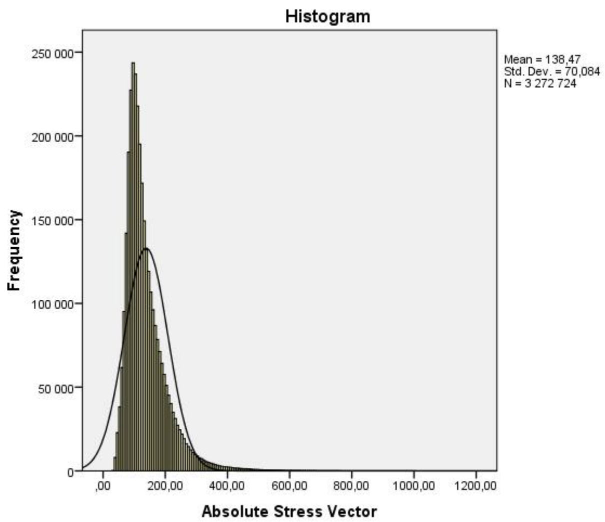
Appendix 5: List of Activities Recorded by Participants under the Variable ‘JournalMarkers’

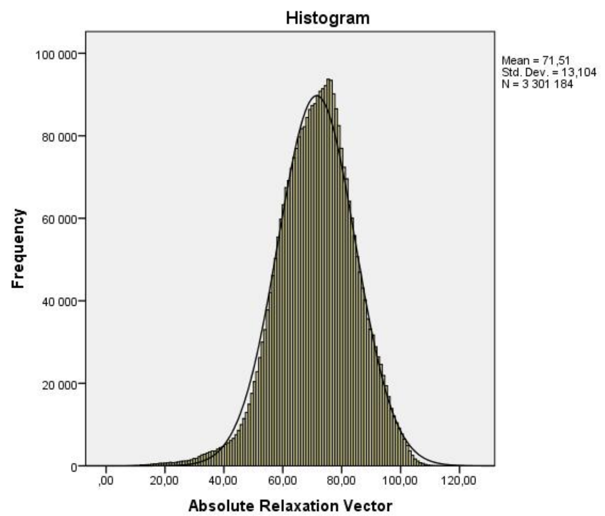
Proper sleep was categorised ‘Sleep’, despite use of different expressions to describe it (e.g. night time sleep, night rest, sleep). Work related activities and other activities are listed below:

Work	Other Activities
1. Work	1. Light exercise
2. Work-Eating	2. Shower
3. Work-Aamukahvilla	3. Relaxation
4. Work-Kahvilla	4. TV
5. Work-iltavuoro alkaa aamuvuoron per	5. TV:n katselu ja neulominen
6. Work-Meeting	6. Pihakalusteinen kantoa varasto
7. Work-Elvytys-harjoitukset	7. Lasten haku hoidosta
8. Work-Driving	8. Kissan kanssa eläinlääkärillä
9. Work-Rauhallinen työpäivä	9. Kaupassa käynti
10. Työmatka autolla/kävellen	10. Eating
11. Work-Rauhallinen työpäivä	11. Pihakalusteinen kantoa varasto
12. Work-Päänsärkyä. Imigran 50mg13. Work-Lapsipotilas, koko päivä	12. Driving
14. Work-Lapsipotilas voi paremmin	13. Aamupala lasten kanssa
15. Work-lapsipotilas teholle,stressi!	14. Reading
16. Work-yökön raportti	15. Kahvilla ystävän kanssa
17. Work- koulutusanomuksen teko	16. Käsityökoulussa
18. Work-ruokatauko	17. Liikunta/kaupoissa kiertely
19. Work-suihkureissu potilaankanssa,	18. Matkustaminen/päiväunet
20. Work-tuote-esittely	19. Mökillä puuhailua
21. Work-hyvin rauhallinen yövuoro	20. Siivous
22. Pientä stressiä työssä	21. Lapsen haku junalta
23. Work-töissä rauhallista	22. Leipominen
24. Work-Rauhallinen työpäivä	23. Puutarhatöitä mökillä
25. Työmatka autolla/kävellen	24. Kutominen pelaaminen
	25. Puutarhatöitä
	26. Saunan lämmitys
	27. Aamupala/lehden luku
	28. Koti- ja puutarhatöitä

Appendix 6: Normality graphs of main variables







Appendix 7: Participants' characteristics and mean values of physiological state vector over the four-day data collection period.

Participant	MSR	Activity Class	Heart Rate		State Vector values in % for four-day data collection period				
			Max	Min	Stress	Recovery	Strenuous Exercise	Light Exercise	Other
1	2.33	4	172	53	64.5	27.75	0.5	1.5	9
2	2	4	182	48	68.5	13.75	0.75	3.25	13.25
3	2.33	2	183	57	59.75	23	0.75	0.5	16
4	2.67	4	160	54	38	45.25	0	0.5	16.25
5	2	4	182	55	59.75	24.25	0.5	3.5	12.25
6	2	4	174	51	62.25	20.25	0.25	1.75	15
7	1.33	6	192	44	49.5	26.75	3	2.5	17.25
8	1.67	6	177	47	30.5	43.5	1.75	1.75	20.75
9	2	4	185	56	72	14.25	1	2.25	11
10	1.67	4	189	57	50.5	19.25	1	5.75	23.25

Appendix 8: Participants' characteristics: Mean values of physiological state vector for each day of data collection period and overall mean value.

ID	Day	Sleep hrs	Shifts	Duty hrs	PhysioloState Vector values for 24-hour data collection period (in %)				
					Stress	Recovery	Strenuous Exercise	Light Exercise	Other
1	1	6.16	E	7	65	23	0	1	11
1	2	6.16	D	14	68	28	0	1	4
1	3	6.42	M	8	56	26	2	3	13
1	4	5.00	M	8.1	69	22	0	1	8
2	1	6.58	D	14	76	13	0	3	8
2	2	5.58	O	0	64	6	2	4	23
2	3	8.00	M	8	70	19	0	2	8
2	4	6.50	E	8.5	64	17	1	4	14
3	1	7.00	M	6.4	53	25	1	0	20
3	2	7.25	M	8	55	26	1	1	18
3	3	7.50	D	10.4	69	18	1	1	11
3	4	8.75	O	0	62	23	0	0	15
4	1	6.00	M	8.3	31	53	0	1	15
4	2	6.50	M	7.3	39	46	0	1	14
4	3	8.00	M	5.8	39	41	0	0	20
4	4	8.75	O	0	43	41	0	0	16
5	1	8.25	M	8	77	11	0	1	11
5	2	9.00	M	8	52	32	0	3	13
5	3	8.00	O	0	53	29	1	6	11
5	4	8.00	M	8	57	25	1	4	14
6	1	6.00	M	8	73	8	0	2	17
6	2	9.83	D	14	59	24	1	2	14
6	3	8.33	E	8	58	28	0	1	12
6	4	8.33	O	0	59	21	0	2	17
7	1	5.83	N	10.8	58	20	4	3	16
7	2	5.67	N	10.8	49	30	1	3	16
7	3	8.00	O	0	40	36	3	1	16
7	4	5.40	O	0	51	21	4	3	22
8	1	9.33	M	8	43	30	3	1	16
8	2	6.16	O	0	31	44	1	5	20
8	3	9.75	D	10.3	28	45	3	1	23

8	4	10.5	E	8	20	55	0	0	24
9	1	7.33	O	0	75	9	1	2	13
9	2	9.33	M	8	72	16	1	2	10
9	3	6.50	E	9	69	21	1	2	8
9	4	7.75	M	8	72	11	1	3	13
10	1	6.66	D	10.4	55	18	3	8	16
10	2	6.25	O	0	50	20	0	10	19
10	3	6.25	D	14	69	15	1	3	12
10	4	7.37	M	7	28	24	0	2	46
Over all Mean Values for Physiological State Vector					55.5	25.5	0.95	2.3	15.4

Appendix 9: Mean Stress Risk (MSR) of participants, stress balance of the day and their HR, stress & relaxation vector against various shifts and sleep.

ID	MSR[5]	Stress Balance (day)	Shift Sleep	n*	Mean		
					HR[1] (SD)[4]	ASV[2] (SD)[4]	ARV[3] (SD)[4]
1	2.33	–0.48 (1)	Evening Sleep	25200 22200	77.07 (5.01) 62.64 (3.94)	220.98 (67.62) 169.25 (54.42)	59.65 (9.21) 70.44 15.07)
		–0.42 (2)	Double Sleep	50400 22200	74.24 (5.12) 58.33 (3.3)	204.03 (58.38) 177.04 (53.79)	63.15 (6.70) 72.44 (12.41)
		–0.37 (3)	Morning Sleep	28800 23100	71.71 (5.87) 61.82 (3.40)	185.24 (61.18) 198.49 (58.38)	64.45 (13.45) 69.17 (10.00)
		–0.52 (4)	Morning Sleep	29160 18000	73.07 (5.51) 61.53 (3.76)	199.07 (60.98) 172.62 (42.46)	63.59 (10.06) 72.20 (9.20)
2	2	–0.71 (1)	Double Sleep	50400 23700	83.35 (8.12) 63.67 (8.33)	118.25 (36.15) 64.93 (40.50)	67.21 (8.70) 81.23 (21.42)
		–0.82 (2)	OFF Sleep	21900 20100	81.33 (15.21) 68.28 (6.98)	72.05 (55.73) 80.62 (26.33)	53.84 (33.88) 79.17 (9.20)
		–0.57 (3)	Morning Sleep	28800 28800	79.55 (8.45) 60.62 (8.00)	113.13 (35.19) 58.84 (22.07)	70.73 (8.39) 86.38 (17.44)
		–0.57 (4)	Evening Sleep	30600 23400	86.15 (9.68) 64.51(9.25)	105.83 (34.89) 66.23 (25.70)	66.42 (12.30) 82.26 (17.65)
3	2.33	–0.36 (1)	Morning Sleep	23100 25200	79.03 (7.42) 66.89 (4.55)	115.34 (42.40) 119.13 (24.77)	65.74 (18.30) 78.30 (7.51)
		–0.35 (2)	Morning Sleep	28800 26100	77.50 (9.05) 64.76 (4.87)	124.00 (41.35) 116.93 (28.71)	70.53 (8.46) 78.30 (6.50)
		–0.58 (3)	Double Sleep	37260 27000	81.42 (9.40) 69.84 (5.76)	131.60 (46.76) 135.62 (37.49)	66.14 (11.30) 73.71 (8.25)
		–0.46 (4)	OFF Sleep	24000 31500	81.84 (6.00) 68.34 (4.68)	125.47 (35.91) 131.56 (35.98)	63.70 (11.13) 74.55 (10.06)
4	2,67	0.27 (1)	Morning Sleep	30600 21600	66.48 (7.22) 58.81 (3.83)	109.01 (32.21) 100.24 (31.65)	74.91 (8.17) 81.37 (15.06)
		0.8 (2)	Morning Sleep	27000 23400	68.02 (7.95) 60.88 (3.30)	104.27 (35.84) 117.38 (41.63)	73.62 (12.94) 77.85 (15.97)
		0.3 (3)	Morning Sleep	21600 28800	69.14 (9.21) 59.94 (3.73)	111.76 (34.97) 117.05 (42.60)	72.05 (12.76) 78.35 (16.85)
		–0.3 (4)	OFF Sleep	34200 31500	70.54 (6.83) 61.45 (4.19)	95.89 (40.01) 113.68 (40.84)	65.78 (21.77) 78.08 (16.10)
5	2	–0.74 (1)	Morning Sleep	28800 29700	88.86 (6.04) 69.74 (5.26)	207.90 (60.32) 164.80 (62.96)	57.55 (7.55) 68.62 (8.96)
		–0.24 (2)	Morning Sleep	28800 32400	89.08 (7.43) 64.30 (6.51)	200.52 (56.64) 111.55 (37.84)	58.72 (6.96) 79.24 (9.62)
		–0.29 (3)	OFF Sleep	46500 28800	87.02 (10.89) 64.94 (5.56)	198.52 (114.97) 127.14 (39.70)	54.43 (16.15) 74.94 (11.91)
		–0.39 (4)	Morning Sleep	28800 28800	88.21 (8.67) 66.02 (5.90)	186.55 (58.83) 140.98 (50.08)	60.35 (7.93) 73.67 (10.52)
6	2	–0.81 (1)	Morning Sleep	28800 21600	76.02 (9.01) 66.18 (6.00)	147.15 (44.02) 126.45 (45.75)	67.29 (9.85) 72.41 (12.00)
		–0.42 (2)	Double Sleep	50400 35400	81.34 (9.20) 61.33 (5.97)	148.52 (71.20) 101.38 (33.86)	58.19 (18.67) 78.96 (13.70)
		–0.34 (3)	Evening Sleep	28800 30000	81.40 (8.05) 60.66 (5.05)	147.87 (60.80) 99.46 (28.80)	61.77 (15.13) 79.64 (10.75)
		–0.47 (4)	OFF Sleep	39000 29984	80.64 (9.38) 62.77 (5.36)	137.33 (63.86) 112.03 (37.26)	60.20 (17.49) 76.51 (10.50)

7	1.33	–0.49 (1)	Night Sleep	38700 21000	70.90 (8.51) 56.16 (6.03)	96.00 (29.48) 79.69 (21.20)	74.11 (12.36) 85.02 (9.33)
		–0.24 (2)	Night Sleep	39600 20400	79.45 (12.95) 51.15 (4.50)	113.33 (39.71) 65.06 (18.00)	67.33 (16.00) 88.92 (17.89)
		–0.05 (3)	OFF Sleep	34859 28800	85.72 (26.27) 51.32 (5.63)	100.91 (75.12) 69.44 (20.93)	59.46 (26.03) 89.37 (14.48)
		–0.42 (4)	OFF Sleep	41700 19441	82.29 (21.92) 59.84 (9.11)	112.57 (76.31) 68.72 (29.58)	62.10 (24.79) 76.10 (25.92)
8	1.67	–0.17 (1)	Morning Sleep	28800 33600	65.23 (6.15) 58.16 (5.74)	92.18 (36.67) 88.53 (27.13)	74.61 (26.10) 89.43 (15.75)
		0.17 (2)	OFF Sleep	32100 22200	71.68 (17.40) 57.20 (5.02)	109.69 (71.08) 75.53 (37.97)	74.22 (21.25) 77.61 (34.56)
		0.24 (3)	Double Sleep	37200 35100	61.72 (6.23) 55.91 (4.91)	99.87 (23.33) 77.72 (25.54)	87.41 (11.06) 91.17 (20.71)
		0.47 (4)	Evening Sleep	28800 37800	62.45 (5.90) 54.66 (4.93)	96.41 (31.37) 89.60 (29.10)	82.33 (19.27) 89.22 (16.91)
9	2	–0.79 (1)	OFF Sleep	45000 26400	96.90 (14.11) 73.50 (7.30)	209.48 (140.04) 139.52 (49.71)	49.71 (18.27) 71.46 (12.15)
		–0.63 (2)	Morning Sleep	28800 33600	90.28 (8.41) 72.07 (8.02)	194.54 (74.07) 142.56 47.07)	56.61 (10.72) 72.67 (10.21)
		–0.54 (3)	Double Sleep	32400 23400	90.27 (8.55) 65.36 (6.60)	199.53 (77.17) 114.13 (42.58)	55.30 (10.40) 77.00 (16.69)
		–0.74 (4)	Morning Sleep	28800 27900	96.24 (10.30) 74.58 (8.89)	216.48 (107.43) 163.09 (82.76)	52.63 (12.60) 69.23 (13.62)
10	1.67	–0.51 (1)	Double Sleep	37260 24000	89.05 (11.55)	115.65 (37.53) 102.30 (38.21)	66.44 (11.40) 76.85 (20.61)
					69.35 (7.26)		
		–0.42 (2)	OFF Sleep	34200 22500	83.64 (12.81) 68.92 (6.58)	110.31 (39.52) 101.88 (29.57)	70.81 (11.40) 80.49 (14.37)
		–0.64 (3)	Double Sleep	50400 22500	83.50 (10.13) 70.09 (7.78)	103.43 (33.25) 100.99 (37.57)	69.31 (15.36) 77.51 (20.33)
		–0.07 (4)	Morning Sleep	25200 27000	78.72 (10.81) 75.08 (9.12)	94.47 (32.51) 119.11 (50.07)	73.43 (16.36) 74.88 (16.48)

* ‘n’ represents seconds as the data was recorded in the interval of seconds.

[1]Heart rate, [2]Absolute Stress Vector, [3]Absolute Relaxation Vector, [4]Standard Deviation and [5]Mean Stress Risk

Appendix 10: Difference in the values of Heart Rate, Absolute Stress Vector and Absolute Relaxation Vector based on age, BMI, activity levels and shifts by ANOVA.

Age Levels	n* (%)	Mean (SD)		
		HR	ASV	ARV
1 (<40 yr.)	1046600 (29.9)	80.69 (18.24)	124.50 (82.88)	64.90 (23.21)
2 (41-50 yr.)	1042904 (29.8)	78.60 (13.50)	131.56 (71.38)	67.01 (17.28)
3 (>50 yr.)	1406344 (40.2)	69.5 (12.65)	132.02 (73.20)	69.86 (20.93)
ANOVA	-	[F (2, 3495845) = 203455.5 p = 0.000]	[F (2, 3272721) = 3445.02 p = 0.000]	[F (2, 3301181) = 17750.7 p = 0.000]
BMI Levels				
1 (<25)	717968 (20.5)	69.83 (14.15)	112.94 (59.82)	72.23 (23.44)
2 (25.1-30)	2076816 (59.4)	77.22 (15.31)	130.87 (76.29)	66.64 (19.92)
3 (>30.1)	701064 (20.1)	76.54 (15.58)	143.06 (85.24)	65.34 (19.55)
ANOVA	-	[F (2, 3495845) = 63712.30 p = 0.000]	[F (2, 3272721) = 29182.42 p = 0.000]	[F (2, 3301181) = 24565.00 p = 0.000]
Activity Levels				
1 (>5)	687608 (19.7)	68.75 (19.50)	96.10 (55.72)	75.31 (24.50)
2 (3-5)	2455800 (70.2)	76.99 (14.12)	138.87 (80.44)	65.43 (19.75)
3 (0-2)	352440 (10,1)	78.91 (13.07)	130.68 (55.15)	66.92 (15.40)
ANOVA	-	[F (2, 3495845) = 88146.43 p = 0.000]	[F (2, 3272721) = 89960.86 p = 0.000]	[F (2, 3301181) = 63249.12 p = 0.000]
Shifts				
Morning	444660	78.71	151.68	65.90

	(45.3)	(12.35)	(70.90)	(14.54)
Evening	113400 (11.5)	76.91 (11.72)	139.70 (69.31)	67.78 (17.03)
Double	345720 (35.2)	80.48 (11.82)	139.81 (63.57)	66.47 (15.02)
Night	78300 (8.0)	75.23 (11.78)	104.77 (36.09)	70.68 (14.71)
ANOVA	-	[F (3, 982076) = 5469.45 p = 0.000]	[F (3, 956032) = 112984.77 p = 0.000]	[F (3, 956875) = 111.16 p = 0.000]

* ‘n’ represents seconds as the data was recorded in the interval of seconds.

[1]Heart rate, [2]Absolute Stress Vector, [3]Absolute Relaxation Vector, [4]Standard Deviation and [5]Mean Stress Risk