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SAUNA YOGA'S EFFECTS ON RECOVERY FROM WORK-RELATED STRESS BASED ON HEART RATE VARIABILITY

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Stress and lack of recovery both disrupt the balance of the autonomic nervous system. Measures of heart rate variability (HRV) reflect these disruptions. Earlier research suggests yoga may influence HRV positively. Sauna Yoga is a recently developed Finnish form of yoga that is practiced seated in a dry sauna heated to 40-50 °C.

In this study, the stress-recovery balance of a group of health care workers with varying work schedules who all already practiced Sauna Yoga was assessed using Firstbeat Lifestyle Assessment (FLA), an HRV analysis tool. The study also sought to answer whether Sauna Yoga affected their balance of stress and recovery, including sleep. All participants completed one three-day FLA with a Sauna Yoga session on the second day.

No statistically significant differences were found due to the small sample size and partly because of the heterogeneity of the group. The balance of stress of stress and recovery varied between participants, a small part of the group scored excellently compared to normative values. Daily amounts of stress reactions were in normal range for most participants. While all participants practiced some form of physical exercise in addition to Sauna Yoga, some would benefit from more aerobic physical activity. Amount of recovery during the day (24 hours) varied from poor to good. Most recovery happened during sleep. While only one participant had insufficient length of sleep, amount of recovery varied from poor to good and quality of recovery varied from moderate to good. Some participants did not have periods of recovery during work while others recovered during night shift work. In the long-term, there needs to be a balance between stress and recovery. About half of the group ended up with increased resources at the end of their measurement period while some showed decreasing resources during consecutive work days. However, not all participants' data included days off work.

Sauna Yoga increased all participants' physiological stress level during the Sauna Yoga sessions, most likely through a combination of heat stress and stress from the exercise. Most participants had the day with most stress reactions and all participants had the day with the least amount of recovery on the Sauna Yoga day. Sauna Yoga may lead to better recovery one day later as most participants had their best amount of daily recovery and their best amount of recovery during sleep one day after the Sauna Yoga day. Studies with a larger sample size and more homogeneous group and work schedules are needed in the future to assess Sauna Yoga's effects on recovery.

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CONTENTS

1 INTRODUCTION

This thesis studied, using heart rate variability (HRV) measurement equipment and online software from Firstbeat Technologies, how a single session of Sauna Yoga affected recovery (including sleep quality) from work-related stress. This was assessed using the Firstbeat Lifestyle Assessment, a tool based on almost fully automated analysis of HRV. HRV is a non-invasive marker of autonomic nervous system (ANS) activity which reflects the presence and intensity of both stress reactions and recovery at the level of the ANS. Sauna Yoga is a form of yoga from Finland. It is offered several forms including Adapted Sauna Yoga. This thesis is one of three first Sauna Yoga related studies done by students in the Satakunta University of Applied Sciences.

The theoretical information about HRV in this thesis has been expanded to include some additional information about psychophysical and social factors affecting HRV. Even though yoga is often practiced in the Western world merely as physical exercise and breathing exercises, the philosophy of yoga extends beyond the *asanas*, i.e. the postures (exercises) and the *pranayama*, the breathing exercises. However, this thesis does not answer specifically to the effects of psychophysical and social factors.

A lot is known about the basic physiological effects of and adaptations to heat stress caused by hot climates as well as heat stress caused by physical exertion. Various forms of sauna bathing are special forms of extreme heat stress. The effects of sauna bathing will be described shortly, but since Sauna Yoga is done in a dry and cooler (50 °C) sauna, it bears more resemblance to heat stress generated by working and exercising in hot environments. The latter also includes specific types of yoga such as Bikram yoga.

Seven people who practice Sauna Yoga and work in health care took part in the study. Measurements were done during two weeks. Afterwards, all participants got personal feedback based on their Firstbeat Lifestyle Assessment about the balance between stress and recovery during the measurement period. Their data was then used to assess how a single Sauna Yoga session affects recovery from (mainly) work-related stress of hospital staff.

2 THEORY

This theory part will introduce Sauna Yoga and the measurement tool used in this study, Firstbeat, which uses heart rate variability to assess the load and recuperation of the human organism. Theory part also covers previous research on the structure and function of the heart, how the autonomic nervous system (ANS) regulates the heart and how this affects various aspects of heart rate variability (HRV), what factors are known to improve heart rate variability and specifically, what is known about yoga's effects on HRV. Theory part also looks into research on the effects of heat on the human organism, especially during sauna bathing and exercising in high temperatures, with main emphasis on what is known about doing yoga in heated environments.

2.1 Anatomy and physiology of the cardiac system

The heart is located inside the thoracic cavity, between the lungs inside the mediastinum (OpenStax 2017, 824). The heart is as big as a closed fist and weighs 250-350 g. It beats approximately 100 000 times per day. The heart consists of four chambers: two atria on the top and two ventricles on the bottom (Shaffer, McCraty & Zerr 2014, 1). The anatomy of the heart is shown on top in Figure 1.

The dual system of human blood circulation is depicted at the bottom of Figure 1. There are two separated but linked circuits in the human circulation: the pulmonary and systemic circuits. Both carry blood but have differences when viewed from the point of view of gases. The pulmonary circuit transports blood from the right ventricle of the heart to the lungs. There it delivers carbon dioxide for exhalation and picks up oxygen. The pulmonary circuit returns the oxygenated blood to the heart's left atrium. It is then pumped into the systemic circuit via the left ventricle. The systemic circuit transports oxygenated blood from there to the tissues of the body. It also returns relatively deoxygenated blood and carbon dioxide to the right atrium of the heart from where it's pumped via the right ventricle back to the pulmonary circuit (OpenStax 2017, 827).

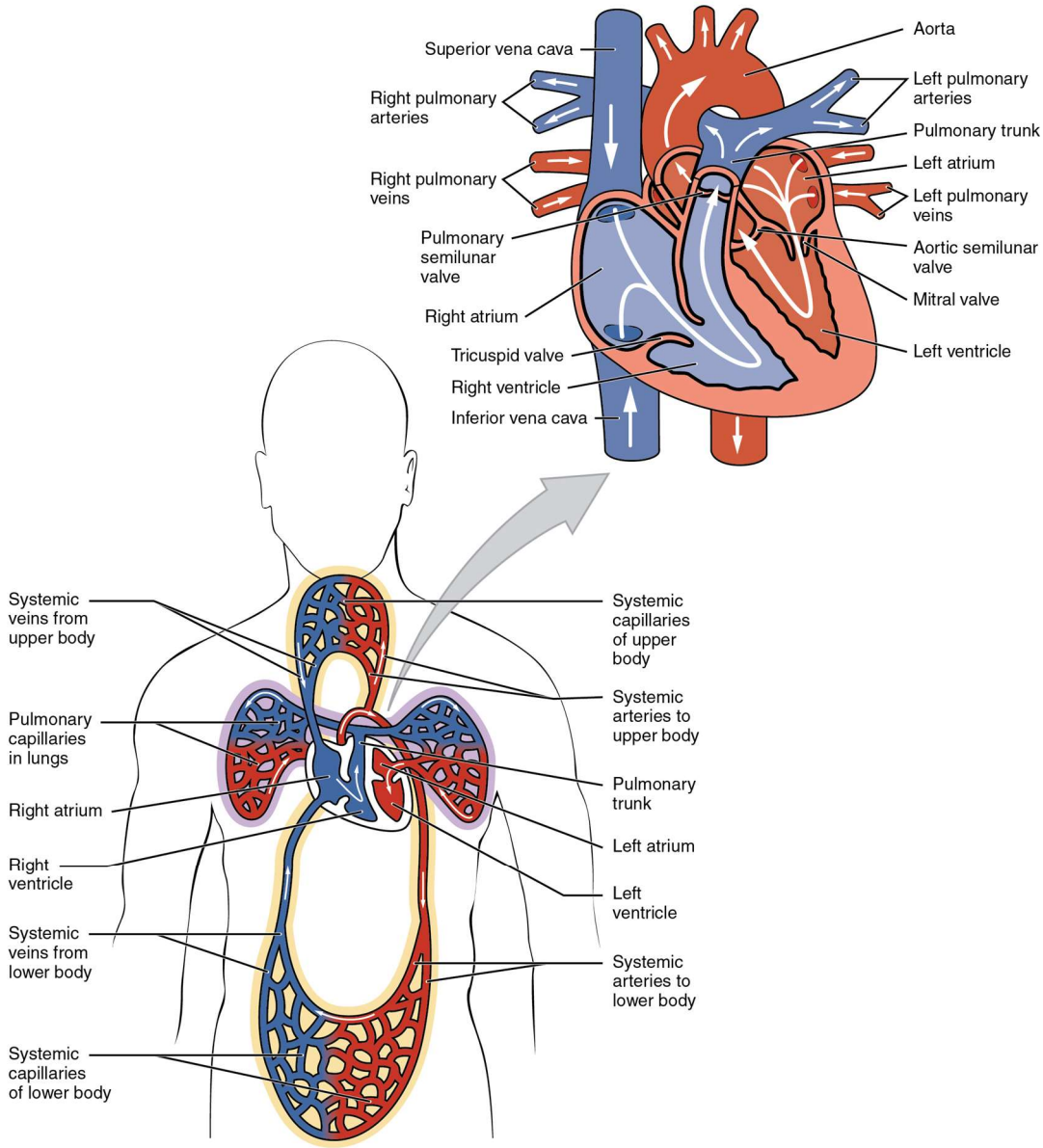

Figure 1. The process of human blood circulation (OpenStax 2017, 828).

2.2 Characteristics of normal electrocardiogram

By carefully placing surface electrodes on the body, it is possible to record the electrical signal of the heart. This tracing of this complex, compound electrical signal is called the electrocardiogram (ECG). In Figure 2, ECG tracing is correlated with the electrical and mechanical events of a single contraction of the heart. This cascade of events goes as follows (numbers correspond to numbers in Figure 2). 1) The whole

conduction system is at rest after the ventricles have fully contracted during previous heartbeat. 2) P wave: The action potential initiated by the sinoatrial (SA) node sweeps across the atria. 3) Between P wave and QRS complex: There is a delay of approximately 100 ms after the impulse reaches the atrioventricular (AV) node. This allows the atria to complete its pumping of blood before the impulse is transmitted to the AV bundle. 4) QRS complex: After the delay, the impulse travels through the AV bundle and bundle branches to the Purkinje fibers. The impulse also reaches, via the moderator band, the right papillary muscle. 5) Between the QRS complex and T wave: Next, the impulse reaches the contractile fibers of the ventricle. 6) T wave: Lastly, ventricles begin contracting (Openstax 2017, 848-856).

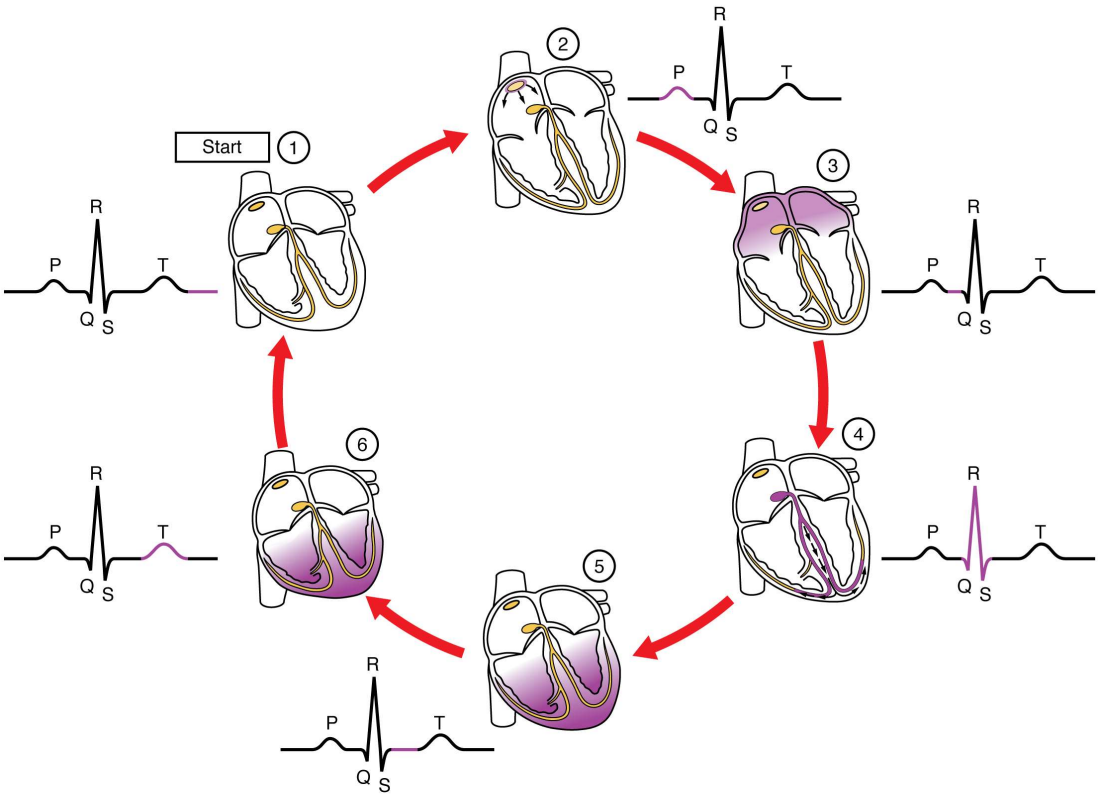

Figure 2. Correlation of ECG tracing with the electrical and mechanical events of a heart contraction. Source: Openstax 2017, 856.

2.3 Cardiac regulation

The cardiac system is controlled by both intrinsic and extrinsic regulation. Intrinsic regulation is accomplished using the autorhythmic cells of the heart. They spontane-

ously generate pacemaker potentials. These initiate cardiac contractions even if all efferent cardiac nerves are severed and the heart is removed from the chest cavity. Initiation of the heartbeat is primarily caused by the electrical activity of the SA node and AV node, the main two internal pacemakers of the heart (Openstax 2017, 846-850).

Without extrinsic cardiac regulation i.e. input from parasympathetic nervous system (PNS) or sympathetic nervous system (SNS), the heart would beat at intrinsic rate of the SA node, on average 107 bpm at 20 years and 90 bpm at 50 years. However, actual heart rate (HR) at any moment represents the net effect of the neural output of the sympathetic nerves, which accelerate HR, and the parasympathetic (vagus) nerves, which slow HR. Even more important is the relative balance of these: is HR appropriate for the context the person is engaged in at any given moment? For example, heart rate can be low during sleep but it must be higher during daytime activities (Shaffer, McCraty and Zerr 2014, 1-2).

2.3.1 Benefits of high vagal tone

Vagal tone represents the contribution of the parasympathetic nervous system (PNS) to cardiac regulation. Vagal tone is linked with many phenomena, including self-regulation at the health, emotional, cognitive and social levels (Laborde, Mosley & Thayer 2017, 2). Shaffer, McCraty and Zerr (2014, 13-15) reviewed five theories that see HRV and especially cardiac vagal tone as useful in the field of psychophysiological research. The reported benefits of high vagal tone are presented in Table 1.

Table 1. Reported benefits of high vagal tone according to five models from psycho-physiological research (Shaffer, McCraty and Zerr 2014, 13-15 and Laborde, Mosley & Thayer 2017, 3).

Theory	Authors	Reported benefits of high vagal tone
The neurovisceral integration model	Thayer et al. (2009)	Better executive cognitive performance, emotional regulation and health regulation
The polyvagal theory	Porges (2007)	Better social functioning and optimal homeostatic regulation
The biological behavioral model	Grossman and Taylor 2007	Higher resting vagal tone "reflects a functional energy reserve capacity from which the organism can draw during more active states"
The resonance frequency breathing model *	Lehrer (2013)	Vagal afferent pathways affect brain areas known to be involved in affect regulation. Vagal efferent pathways inhibit sympathetic tone.
The psycho-physiological coherence model **	McCraty and Childre (2010)	Increased vagal afferent traffic effects inhibition of pain signals and sympathetic outflow

* Breathing slowly at a specific frequency (6 breaths per minute) for 15 minutes leads to higher positive mood, a significantly higher LF/HF HRV ratio and lower systolic BP (Steffen et al. 2017)
** Coherence through slow breathing combined with deliberately shifting to positive emotional state

As an example of the aforementioned five theories, Porges (2009) states in his Poly-vagal theory that there are actually two branches of the vagus nerve. The evolutionarily older dorsal vagal complex is unmyelinated and mainly regulates subdiaphragmatic organs. All mammals have also a newer ventral part to the vagus which is myelinated and linked to both the striated muscles of the head and face and the organs above the diaphragm as well as prosocial behaviours. Porges calls this a face-heart connection that enables visceral states to be regulated via social interaction. For example, when this social engagement system is activated, sympathetic influences to the heart are in-hibited and the hypothalamic-pituitary-adrenal (HPA) axis is dampened.

2.3.2 Thermoregulatory cardiac control

Homeothermic animals such as humans regulate their body temperature. Defending the thermal homeostasis from environmental thermal challenges is a fundamentally important process. It is governed by the central nervous system. Skin thermoreceptors sense environmental temperature and send feedforward thermosensory information on it through the spinal cord and via the lateral parabrachial nucleus to the preoptic area

(POA). Two other sources of feedback to the POA are signals from local thermosensitive neurons and pyrogenic signals of prostaglandin E2 produced in response to infection (Nakamura 2011).

Skin warming leads to cutaneous vasodilation. This heat-defensive response increases skin blood flow which helps body heat dissipate from the body surface. The tonicity of cutaneous sympathetic nerve activity regulates skin blood flow. Even when the environment is thermoneutral, most of cutaneous vasodilation is elicited through attenuation of this cutaneous sympathetic nerve activity. The warming of the skin also leads to warming-induced tachycardia i.e. increased heart rate. Combined with the heat-dissipation achieved through cutaneous vasodilation, it helps to optimize the increases in cutaneous blood flow by maintaining a sufficient level of cardiac output and arterial pressure (Nakamura 2011).

2.4 Heart rate variability

Heart rate variability (HRV) is the beat-to-beat variation in time intervals between two consecutive heart beats or R-R intervals. HRV reflects the complex interactions of the ANS: cardiac parasympathetic nerve fibers decrease heart rate and cardiac sympathetic nerve fibers increase it. Heart rate also responds to changes in blood pressure (baroreceptor reflex sensitivity) and it synchronizes markedly with respiration (respiratory sinus arrhythmia) (Billman 2011, 1, 9). According to the review by Posadzki, Kuzdzal, Lee & Ernst (2015, 240), HRV can be used as a proxy measure for the ANS activity of the heart. It reflects the physiological and endocrine as well as psycho-emotional equilibrium of the body. HRV has also been proven to be an independent predictor of mortality in both healthy individuals and patients.

2.4.1 Measuring HRV data

HRV has been a focus of psychophysiological research since 1996 thanks to accessible technology and the then-released first standards for measurements. Later, collecting and analyzing HRV data has become very accessible to researchers thanks to progress in both computer science and technology (Laborde, Mosley & Thayer 2017, 2). HRV

can be easily measured with standard ECG devices and suitable software (Posadzki, Kuzdzal, Lee & Ernst 2015, 240). Also, Plews et al. (2017) have demonstrated that compared with ECG, both smartphone photoplethysmography (PPG) and a HR chest strap sensor can provide an acceptable agreement for a typically calculated HRV variable, the root mean sum of the squared differences between R–R intervals (RMSSD).However, actually understanding and correctly interpreting the numerous HRV parameters from ECG data is quite complicated (Laborde, Mosley & Thayer 2017, 2).

First international guideline for HRV standards was the 1996 standardization document from the Task Force of the European Society of Cardiology and North American Society of Pacing and Electrophysiology. In 2015, guidelines for newer methods were presented in the joint position statement by the e-Cardiology ESC Working Group and the European Heart Rhythm Association co-endorsed by the Asia Pacific Heart Rhythm Society. The traditional methods standardized in 1996 remain the most important methods for assessing ANS physiology and modelling pathophysiology (Sassi et al. 2015).

2.4.2 Analyzing HRV data

According to a review by Laborde, Mosley and Thayer (2017), over 70 variables can be calculated mathematically out of HRV analysis. Variations in heart rate can be measured and statistically analysed in time-domain or frequency-domain over short (seconds to minutes) or long periods (traditionally 24 hours) of time. An example of a simple time-domain variable is calculating mean heart rate. An example of statistical time-domain measurement is the RMSSD. Time-domain methods include also so-called geometrical methods. Typical frequency-domain measurements include analysing three spectral components from short 2-5-minute recordings: very low frequency (VLF), low frequency (LF) and high frequency (HF). These reflect various aspects of extrinsic cardiac regulation. LF/HF ratio is also a common parameter for assessing ANS activity (European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). Out of variables that can be calculated from HRV

data the ones recommended as the best in reflecting vagal tone are peak-valley, HF and RMSSD (Laborde, Mosley and Thayer 2017).

2.4.3 Effects of exercise on heart rate variability

One of the basic principles of exercise/training, or physiologic conditioning, is the overload principle: Regularly applying a specific exercise overload will lead to enhanced physiologic function which leads to a training response (McArdle, Katch & Katch, 453). In other words, disturbance of homeostasis of is needed for adaptation to happen, and intensity of exercise looks to be a key factor in achieving it. This disturbance of homeostasis may be evident in the state of autonomic modulation hours after an exercise session has ended (Hynynen, Vesterinen, Rusko & Nummela 2010).

At rest, parasympathetic (vagal) cardiac modulation is dominant. According to Porges (1992), the PNS acts as the modulator of stress vulnerability and reactivity. Hynynen, Uusitalo, Konttinen & Rusko (2008, 557) proposed a name for this condition: “autonomic resource hypothesis". This hypothesis proposes that a person’s individual cardiac vagal reactivity varies according to their baseline vagal activity. Higher parasympathetic modulation at rest, before a stressor, leads to a greater vagal response (adaptability) during the stressful event. Their study compared the HRV response of overtrained and non-overtrained athletes to a cognitive task. The overtrained athletes could not decrease their HRV during the task like the non-overtrained athletes did, and this was related to a worse performance in the task.

Evidence for the autonomic resource hypothesis has been provided for example Hynynen, Vesterinen, Rusko & Nummela (2010, 430-432) with male marathon runners training 7±2 h/week. In this study, prolonged dose-response effects on autonomic modulation during sleep after endurance exercise was found. The researchers state that “these findings extend previous knowledge on acute HRV responses to stress of physical exercise indicating prolonged parasympathetic withdrawal hours after” exercise. Support has also been provided by Martinez-Navarro et al. (2012) with 600-m running test and by Blasco-Lafarga, Martínez-Navarro & Mateo-March (2013) with a submaximal judo test.

Buchheit, Laursen, Al Haddad & Ahmaidi (2009, epub page 2) review earlier research by others, noting that after an acute period of exercise (at normal temperatures) HRV markers initially fall rapidly. According to Stanley, Peake & Buccheit (2013) metaboreflex stimulation (e.g., muscle and blood acidosis stimulating sympathetic nerve activity in skeletal muscles) is likely a major factor controlling parasympathetic reactivation in the first 90 minutes after an aerobic exercise session. According to studies referenced by Buchheit, Laursen, Al Haddad & Ahmaidi (2009, epub page 2) it takes one to three days before parasympathetic resting values have returned to baseline or higher levels. This delay in the recovery of vagal-related HRV indices may be due to increased sympathetic activity which restores homeostasis of muscle glycogen and system stress metabolites.

According to Stanley, Peake & Buchheit (2013) arterial-baroreflex stimulation, caused most likely by exercise-induced changes in plasma volume, mediates cardiac parasympathetic reactivation 1−48 h after high-intensity exercise. Buchheit et al. (2009, epub pages 7-8, 10) found evidence for this hypothesis. They showed that two days after a single supramaximal exercise session, all calculated vagal-related HRV indices (11 in total; including $RMSSD_{5–10min}$) had increased and the sympathetic-related index (LF/HF ratio) decreased. They found strong correlations between changes in vagal-related HRV indices and plasma volume (e.g., r = 0.85 for $RMSSD_{5–10min}$).

Al Haddad, Laursen, Ahmaidi & Buchheit (2009) researched nocturnal heart rate variability following supramaximal intermittent exercise (15 second runs with 15 second recovery periods at slower pace). They found that this type of high intensity exercise, with session lasting at maximum 12 minutes, could perturb the ANS for about 36 hours. The duration at high intensities does not seem as important as the intensity, according to the researchers their results were almost comparable to Niewiadomski, Gasiorowska, Krauss, Mroz, and Cybulski (2007) whose subjects only did two all-out 30-s Wingate efforts.

Stanley, Peake & Buccheit (2013) studied how aerobic exercise at three different intensity levels affects recovery as measured by HRV for three groups of subjects: inac-

tive (untrained), moderately-trained and highly-trained. The intensity levels were divided by the first (VT1) and second (VT2) ventilator thresholds. According to Thompson (2017), VT1 is a marker of intensity that can be identified by the increase in person's breathing rate. This happens because blood lactate begins to accumulate. It leads to the person only being able to speak a few words at the time. VT2 is also observable in breathing rate: when the person's blood lactate level raised over its maximum steady state i.e. it begins to accumulate quickly, the person needs to start breathing so heavily that he or she cannot speak anymore.

Stanley, Peake & Buccheit (2013) found that complete cardiac autonomic recovery after a single session of aerobic training requires up to 24 h for low-intensity (below VT1) exercise. Recovery takes 24−48 h for ventilatory threshold intensity (between VT1 and VT2) exercise. After high-intensity (over VT2) exercise, at least 48 h is needed for recovery. Exercise intensity is the key factor in cardiac parasympathetic reactivation (returning to pre-exercise levels of HRV). To be more specific, according to Seiler, Haugen & Kuffel (2007), VT1 appears to be a definite threshold for parasympathetic recovery: recovery is faster at intensities below VT1 but increasing intensity beyond VT1 does not cause any further slowing down of parasympathetic recovery.

According to Stanley, Peake & Buccheit (2013), with low-intensity aerobic exercise, cardiac parasympathetic activity i.e. HRV is moderately suppressed 1 h after the exercise, has risen above pre-exercise levels at 24 hours, and has returned to below pre-exercise levels at 48 hours. Recovery from higher intensity aerobic exercise happens differently. With threshold-intensity exercise, the suppression of parasympathetic activity (i.e. HRV) still remains very large at 48 hours. By contrast, with high-intensity exercise, the suppression of HRV is stable at 24 hours but raises above pre-exercise levels within 48 hrs.

Fitness / training status affects recovery during the first 90 minutes significantly. HRV was only moderate suppressed in elite endurance athletes (the high fitness group) but extremely suppressed for inactive subjects. Highly-trained subjects recovered the fastest (about 15 minutes) to or very near pre-exercise HRV levels. For moderately-trained athletes, the same happened in about 40 minutes. Inactive individuals still had large

suppression of cardiac parasympathetic activity at 90 minutes (Stanley, Peake & Buccheit (2013).

2.5 Heat acclimation

Humans can adapt remarkably well to heat. With enough water and protection from the sun, humans who are heat-acclimated can tolerate virtually all naturally occurring hot-weather conditions for extended time. During health acclimation (adaptation to purposeful heat stress exposure in controlled environments such as saunas) and heat acclimatization (adaptation to changes in the natural environment) similar biological adaptations (integrated changes in thermal, cardiovascular and body fluid regulation) occur. In this thesis, the abbreviation HA will be used for both heat acclimation and heat acclimatization. The benefits of HA are achieved by a reduced core temperature, improved sweating and, in some cases, an increased skin blood flow, better fluid balance and improved cardiovascular stability, and a lower metabolic rate (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

In hot climates, air temperature can exceed skin temperature (about 33°C). This minimizes or reverses dry heat loss (conduction, convection and radiation) which means evaporative cooling will bring most of heat dissipation. When a person adapts to such a climate, his/her physiological strain (core temperature and heart rate) during heat exposure is reduced and he or she secretes more sweat. Fluid homeostasis may be challenged by sweating, especially in hot dry climates (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

In hot temperatures, skin temperatures become more uniform with the air temperatures. This happens at first by heat being gained from the environment, and then by cutaneous vasodilatation. This change toward uniform temperatures leads to reduced exogenous heat gain, and also increases water vapor pressure at the skin surface which enhances evaporation. While resting at an air temperature of 35°C and 70% relative humidity), a rise of 1°C in a person's skin temperature (from 33 to 34°C) leads to a 35 % reduction in the required evaporative heat loss (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

2.5.1 Effects of exercise on heat acclimation

Some HA occurs during rest in the heat but physical exercise in heat is the most effective way to achieve HA. The following information is from studies where exercise and heat are combined. HA to a climate begins on the first day of exposure after which the incidence of heat syncope decreases. HA progresses rapidly during the next 2–4 days of exposure. About 80% of the adaptive responses and performance / exercise tolerance improvements occur during the first 7 days of exposure. The time needed for achieving HA is about the same for hot-dry and hot-humid conditions (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

Submaximal exercise-heat performance is markedly improved during the HA process. For example, out of 24 subjects attempting 100 min of treadmill walking at 49°C and 20% relative humidity for 7 consecutive days, none could complete the task on the first day. By day 3, 40% were successful, and by day 5, 80%. On day 7, all but one subjects were successful (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

In studies with male subjects, physically fit individuals acclimate faster than less fit individuals and may be less susceptible to heat illness. Maximal oxygen uptake can explain 42–46% of the variability in the HA day at which core temperature plateau is attained, and of the core temperature measured after 3 h of exercise in high temperature. To improve thermoregulatory responses during exercise in the heat, endurance training must produce substantial increases in sweating rate and core temperature (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

To develop full exercise-heat acclimation one does not need daily 24-h exposure to heat. In dry heat, daily 100-min exposures appear to be the optimal way to achieve HA (Tipton, Pandolf, Sawka, Werner & Taylor 2002). The individual differences in HA are large, therefore, for athletes doing a purposeful HA program, some may achieve complete HA in less than 10 consecutive days but others may more time (Daanen, Racinais and Périard 2017). Also, daily exposures are not necessary for achieving HA. Adaptation to 10 days of heat exposure leads to equal results in the end whether one does the exposures 10 days in a row or every third day i.e. during a 27-day period (Tipton, Pandolf, Sawka, Werner & Taylor 2002).

2.5.2 Heat acclimation decay and heat re-acclimation

Heat acclimation decay (HAD) will happen unless HA is maintained by heat re-acclimation (HRA) i.e. more exposures to exercise-heat. Individual differences in the retention/decay of heat acclimation are dramatic. For example, the benefits remain longer for physically fit individuals. Also, the decay of the benefits to heat acclimation is slower if one has acclimated to hot-dry conditions instead of hot-humid conditions (Tipton, Pandolf, Sawka, Werner & Taylor 2002, 390). According to Daanen, Racinais and Périard (2017, 410), about 2,5% of the adaptations in HR and body's core temperature (Tc) are lost per one HAD day.

Heat re-acclimation undertaken within a month of HA is much faster for inducing adaptions in HR and Tc compared to HA. This is especially true for end-exercise HR and Tc. In one study, just 4 days of HRA were needed to compensate for a month of HAD (Daanen, Racinais and Périard 2017, 424).

2.5.3 Health effects of traditional Finnish sauna

Traditionally, Finnish sauna has a recommended temperature of 80-100 °C at the level of the bather's face. The air is dry (humidity 10-20 %) but humidity is usually temporarily increased by throwing water on the hot rocks of the sauna heater. Mean ± SD frequency of sauna bathing for a group of randomly selected middle-aged (42-60 years) men from Kuopio, Eastern Finland was 2,1 ± 1,1 times per week, but 201 of the 2315 subjects went to sauna 4-7 times a week (Laukkanen, Khan, Zaccardi & Laukkanen 2015, E1-E2).

Sauna bathing in the traditional Finnish way may increase heart rate up to 100 beats per minute in moderate sessions and up to 150 beats per minute in intense sessions. These correspond to low and moderate intensity physical exercise, respectively. The proposed functional improvements of sauna bathing are similar to the benefits from regular physical exercise (Laukkanen, Khan, Zaccardi & Laukkanen 2015, E5).

Laukkanen, Khan, Zaccardi & Laukkanen (2015, E1, E4) found frequent sauna to have bathing positive long-term health effects. Compared to infrequent sauna bathing (1 session per week), frequent sauna bathing (4-7 sessions per week) decreased the risk of sudden cardiac death (SCD), fatal coronary heart disease, fatal cardiovascular disease and all-cause mortality in a sample of 2315 middle-aged (42-60 years of age) men from Eastern Finland. They also found that long sauna bathing sessions (>19 minutes) decreased the risk of SCD compared to short sessions (<11 minutes). The researchers also cite several previous findings of the health benefits of sauna bathing, including sauna bathing two times a week lowering blood pressure and enhancing left ventricular function.

Laukkanen, Khan, Zaccardi & Laukkanen (2015, E5) did not report any harmful effects from sauna bathing even though some have been reported in previous studies. They attribute this possibly to the type of conditions and temperatures used. Dry sauna bathing seems safe. Individuals prone to orthostatic hypotension need to be cautious. Also, alcohol take together with sauna bathing has been a major factor in adverse events from sauna bathing.

Laukkanen et al. (2018, epub pages 1-2) found beneficial acute effects from sauna bathing on parameters of blood-based biomarkers and cardiovascular function. They did measurements pre-sauna as well as immediately after and 30 minutes after of a session of sauna bathing at 73 °C and 10-20 % humidity for 30 minutes. 102 Finns (65 male) aged 51,9 ± 9,2 years (mean ± SD) participated in the study. A single session in a sauna lead to lowered systemic blood pressure and improved arterial compliance. Some hematological variables also changed significantly during the sauna session. The researchers recommend sauna bathing for a population with cardiovascular risk factors because of it benefits cardiovascular function.

2.5.4 Combined effects of exercise and sauna

Combining exercising and post-exercise sauna to achieve heat acclimation is a relatively new area of research in sports science. Stanley, Halliday, D'Auria, Buchheit & Leicht (2014) studied the effects of post-exercise sauna bathing on heat acclimation

on plasma volume (PV) expansion and heart rate and HRV. With well-trained cyclists, only four sessions of sauna bathing following normal training were needed for largely expanded peak PV expansion. According to several previous studies, this translates improved physical performance in all environmental conditions. However, tracking HR and HRV indices did not reveal clear correlations to PV so they may be unsuitable to track heat acclimatization.

Leicht et al. (2018) studied post-exercise sauna with 10 male cyclists and found the changes to HR and HRV over a 10-day period to be unclear. A single sauna bathing increased HR acutely by 32 % on average (from 109 to 143 bpm) and acutely reduced lnRMSSD on average by 62%. These changes are indicative of enhanced sympathetic and/or reduced parasympathetic modulations. However, these changes were not clearly impacted by repeated sauna exposures over 10 days i.e. HR and lnRMSSD did not change by the protocol. These athletes, who had high HRV, tolerated the post-exercise sauna bathing protocol. According to the researchers, the effects of repeated post-exercise sauna remain unclear.

2.5.5 Forms of heat injury

Rising core temperature, Tc, best predicts heat injury occurring (Bynum et al. 1978). Heat stroke is a severe form of heat injury, defined as hyperthermia in the setting of central nervous system (CNS) dysfunction. In heat stroke, Tc is typically from 40°C to 44°C. However, heat stroke can occur even if Tc is < 40 °C (Glazer 2019). Heat stroke can cause greater consequence to vulnerable people, for example children and the elderly (Bynum 1978).

Heat cramps are a mild form of heat injury which can happen when salts and fluids are not replaced during intense and long exercise sessions in the heat. Heat syncope and heat exhaustion (from water depletion or salt depletion) are moderate forms of heat injury. Heat syncope causes weakness, fatigue, and fainting after water and salt lost through perspiration are not replaced. Heat syncope can occur in people with pre-existing heat illness or people taking diuretic medication (The American Academy of Orthopaedic Surgeons 2016). Unlike heat stroke, heat exhaustion does not cause CNS

dysfunction. Typically in heat exhaustion, Tc is elevated to 37-40 °C (Glazer 2019). Heat exhaustion due to water depletion is caused by heavy sweating. It leads to extreme weight loss, decreased perspiration, and rise of skin and body temperatures. Weakness, excessive thirst, headache, and sometimes unconsciousness can also be caused by heat exhaustion due to water depletion. Heat exhaustion due to salt depletion often leads to nausea, vomiting, dizziness, muscle cramps. Risk for this form of heat exhaustion increases if body salts and minerals are not replaced fast enough. This can also happen if only water is used to replenish fluids so electrolyte fluid drinks can prevent this form of heat exhaustion (The American Academy of Orthopaedic Surgeons 2016).

Temperature inside cars during summertime (Vanos, Middel, Poletti & Selover 2018) can, due to the greenhouse effect, raise to the levels used in Sauna Yoga (40-50 °C) (Sauna Yoga International Ltd 2017). Vanos, Middel, Poletti & Selover (2018, 1, 13) tested how internal car temperatures raised when the external air temperature was in average 38,8 ± 2,0 °C (range 32,8 – 41,5 °C). At the end of simulated 60 minute shopping trips, the cabin temperature was in average 46,7 °C in sun-exposed vehicles and 38,3 °C in shaded vehicles. The researchers estimated Tc for a toddler staying in such a cars for one hour. The final Tc in the shaded cars (Tc = 38,2 ± 0,29 °C) was significantly lower than for sun-exposed cars (Tc = 39,1 ± 0.41 °C) ($p < 0,05$). Staying in a sun-exposed car for an average of 80 minutes or in a shaded vehicle for under two hours were estimated to cause heat injury to a toddler.

2.6 Firstbeat

Firstbeat Technologies is a global provider of physiological analytics for well-being and sports. The services of the company are used by millions of consumers as their analytics are used in consumer products such as smartwatches. They also offer the Firstbeat Sports solution for hundreds of sports teams (Firstbeat 2018a).

2.6.1 Firstbeat Lifestyle Assessment

Firstbeat Technologies Oy offers the Firstbeat Lifestyle Assessment (FLA) for analyzing the wellbeing and health factors of non-athletic persons via HRV. Typically, the HRV data is collected for 72 hours continuously excluding taking showers etc. as the device is not waterproof. The client also marks journal notes to Firstbeat's online system (Firstbeat 2016a). The device used to collect the data, the FirstBeat Bodyguard 2, is a portable device that can provide reliable R-R-interval data from the ECG data it collects (Parak & Korhonen 2013). After the measurement period, the service provider uses the Lifestyle Assessment online application to analyze the HR data and create reports (Firstbeat 2016a).

During the analysis of the data, the online software detects artefacts and corrects irregular heartbeats and signal noise. The measurement data is divided into coherent data segments. This process requires the software to take into account individual characteristics such as individual levels and scales of HR. The segments are then categorized into different physiological states. They include stress, recovery and physical activity of different intensities. Next, the software detects HRV-based variables which reflect the amount and intensity of stress and recovery during the day (Mutikainen, Helander, Pietilä, Korhonen & Kujala 2014, 3). Many of the HRV variables analysed by Firstbeat software are explained shortly by for example Rönkä et al. (2006, 2-3). New features are added to the FLA analysis and report several times a year (Firstbeat 2018b).

One of the measures of HRV reflective of vagal tone, RMSSD, is calculated in the FLA. There it reflects the quality of recovery, describing the amount of HRV during sleep. The results are categorized in the FLA based on the person's reference group which is affected by the person's gender and age. If the night's average RMSSD value is in the weakest 10% of the group, the result is poor. Moderate result means being between the lowest 10-50 % of the group, and good result means being above the average (>50 %) of the respective age group (Firstbeat 2016a, 9-10). RMSSD values are highly variable. The RMSSD of awake time to RMSSD sleep time difference is also informative. This value, called relative difference value, is categorized as good when it is ≥ 1,5, moderate when it is 1,0–1,5 and poor if the value is <1 (i.e. RMSSD during sleep was not lower than during awake time) (Firstbeat 2014, 37).

A high RMSSD value is related to good recovery because of the high activity of the PNS. RMSSD level can be low level for several reason. During exercise, it is natural for the RMSSD to be low as HR increases. RMSSD tends to lower with age but increased physical fitness is associated with higher RMSSD values. Prolonged stress and overload as well as weak recovery can lower RMSSD. However, also glucose metabolism disorders such as diabetes, or illnesses that affect normal cardiac functioning can lead to lowered RMSSD (Firstbeat 2016a, 38).

Altini (2015) summarized 10 research articles on RMSSD values measured either in supine position at rest or in limited cases during sleep (text in brackets have been added to the quotes): "For young highly trained individuals or athletes, values are higher, in the range 70-120 [ms], still with great variability (40-50 [ms]) … For young (20-40 years old), sedentary individuals, values range from the middle 30s to the 50s, with standard deviation 20-30 [ms] …Healthy, physically active and young (age 20-30 years old) individuals have RMSSD values around 60 with broad standard deviation (20-30 [ms]) … In patients populations, e.g. chronic heart failure patients, RMSSD is in the 20s, with much lower variability (10-15 [ms])".

In the FLA, physical activity is given a score called Physical Activity Index which is given based on the amount and intensity of aerobically taxing exercise during a day. During light physical activity, relative oxygen consumption has risen from the resting level but it is still less than 40% of VO_{2max}. To improve aerobic fitness and gain health benefits, higher intensities are needed. During moderate-intensity physical activity, oxygen consumption is 40 - 60% of VO_{2max}. During vigorous-intensity physical activity, oxygen consumption rises above 60% of VO_{2max} (Firstbeat Technologies Ltd 2018). In the FLA, 30 minutes of moderate physical activity or 20 minutes of vigorous physical activity leads to a Physical Activity Index of 60/100. Light-intensity activities also contribute to the Physical Activity index but require much more time spent exercising. According to Firstbeat data from 155,000 days of activity data from the year 2017, the average Physical Activity Index was 48 (Firstbeat Technologies 2018, 7).

The Physical Activity Index matches closely with the recommendations from WHO (2010, 7-8). According to the recommendations, to produce significant health benefits, 150 minutes of moderate physical activity per week or 75 minutes of vigorous physical

activity per week (or some combination of them) is recommended. For additional health benefits, 300 minutes of moderate or 150 minutes of vigorous exercise is needed.

Excess post-exercise energy consumption (EPOC) i.e. the amount of oxygen consumed in excess after exercise (liters or ml/kg), reflects how big a homeostatic disturbance was caused by the exercise and how high the body's recovery demand is. Increasing exercise intensity and/or duration increases EPOC. Firstbeat Technologies products include an indirect way based on HR for estimating EPOC. The model has been validated (Firstbeat Technologies Ltd 2012).

The validity of the Firstbeat analysis software has been confirmed in several studies such as Rönkä et al. (2006), a study with 17 participants. The researchers used Firstbeat PRO Wellness Analysis Software to analyze R-to-R interval data to relaxation and stress times during sleep and a 15-item questionnaire to assess work stressor variables. The questionnaire consisted of only the work-related questions from the 53-item Daily Hassles and Uplifts scale. Measurement period covered two working days and one day-off. In the statistical analysis using Spearman correlations, increased social stressors at work correlated negative with sleep duration (r= -.564*, p- value .018) meaning the subjects reported less social stressors at work after more sleep. The negative correlation of workload stressors with relaxation time during the night was slightly less (r= -.481, p-value .050).

The validity of the Firstbeat Bodyguard2 device has been studied by Parak and Korhonen (2013) who found the Bodyguard2 and the Firstbeat software to be accurate in measuring RMSSD. Bogdány, Boros, Szemerszky & Köteles (2016) found that the BodyGuard2 showed good overall reliability with respect to respiratory rate, heart rate and two HRV-indices: RMSSD and the standard deviation of NN intervals (SDNN). However, the measurements of two commonly used frequency measures i.e. high frequency component of the total variance (HF) and low frequency component of the total variance (LF) were not reliable. The researchers speculated this to be based on a software issue.

The FLA typically addresses at least four questions: Firstly, does the client sleep long enough and how good is the recovery during sleep? A good night's sleep is recommended to be over 7 hours with over 75 % of the sleep period showing up as recovery. If there are problems with recovery during sleep, it's important to find out the reason(s) for this and also whether this reflects a chronic or temporary situation. Secondly, FLA shows whether the client had some recovery during the day also. Here, the most important aspect to the interpretation is not getting maximal recovery time during the day but to see if recovery happens at those day-time moments when it is appropriate to relax. Thirdly, the FLA shows whether the client engaged in physical activity that provided positive health effects. However, FLA can only assess the benefits of cardiovascular exercise. Lastly, FLA shows if the measurement period had a positive effect on the person's resources. To ensure that resources are replenished, the person's recovery must be of good quality and regular enough. Temporarily it's ok to consume one's resources but recovery period must follow. Things other than sleep that replenish a person's resources include good physical fitness, healthy nutrition and effective stress management (Firstbeat 2015a).

For easy analysis of how the person's resources were affected during the measurement period, the summary page of the FLA includes a Body Resources diagram for the entire measurement period. It also includes the most effective daily period of aerobically taxing physical activity with the Training Effect (TE). TE tells about the degree of homeostasis disturbance caused by physical activity. It is based principally on EPOC values during exercise but scaled based on how fit or active the individual is. The TE scale is 0-5. For sedentary individuals, even one weekly session at fitness-improving level (TE 3,0) combined with two sessions at fitness-maintaining sessions (TE 2,0) can improve fitness (Firstbeat 2015b).

2.6.2 Occupational research

Mutikainen, Helander, Pietilä, Korhonen & Kujala (2014) did a cross-sectional study to assess the intensity and amount of physical activity (PA) of 9554 Finnish employees. They also took into consideration the age, gender and body mass index (BMI) of the employees, who had done the FLA as part of occupational health promotion in the

years 2007-2013. Data was anonymized for the study by Firstbeat. According to the study, out of the studied employees, half of the men and one-third of the women met the current recommendations for aerobic PA. This proportion was especially low among obese men as well as overweight and obese women.

Föhr et al. (2016) used data from FLAs from occupational health care programs provided to 16 275 employees in 2007 – 2015. They assessed more R-R interval-derived information than Mutikainen, Helander, Pietilä, Korhonen & Kujala (2014), including not just physical activity and BMI but also the amounts of recovery and stress. Typical measurement period was three days including one day off work. The data was analyzed using Firstbeat Analysis Server software. 16 % of the women and 32 % of the men belonged to the high PA group (over 300 min/week). Out of the high PA groups, 53 % of men and 18 % of women had overweight (BMI over 25 kg/m^2) (percentages calculated from Föhr et al. 2016 Table S5). For both men and women, high PA (over 300 min/week) was associated with lower stress balance and lower stress percentages during workdays and working hours. Higher BMI (>25 kg/m^2) was associated with higher stress index, lower stress balance and lower recovery index. Both higher BMI and high PA were associated with a lower amount of recovery during sleep. The researchers mention their additional analysis which was not shown in the study. This analysis showed that for high PA individuals, recovery in a day without PA was higher than in a day with PA.

2.7 Yoga

Conceptual background of yoga originates from ancient Indian philosophy. There are several modern schools or types of yoga including Iyengar, Sivananda, Viniyoga etc. Each school of yoga has its own distinct emphasis regarding the relative content of the yoga practice. These include physical postures and exercises (asanas and vinyasa), breathing techniques (pranayama) and deep relaxation as well as meditation practices for cultivating awareness and eventually more profound states of consciousness (Büssing, Michalsen, Khalsa, Telles & Sherman 2012).

2.7.1 Health effects of yoga

The application of yoga as a therapeutic intervention began in early twentieth century. It takes advantage of the psychophysiological benefits of the components of yoga practice. For example, the physical exercises (asanas) component may lead to increased physical flexibility, coordination and strength. And similarly, the breathing practice pranayama) and meditation may lead to a calmer and more focused mind, greater awareness and diminished anxiety and therefore higher quality of life (Büssing, Michalsen, Khalsa, Telles & Sherman 2012).

Majority of the early research on yoga as a therapeutic intervention has been conducted in India. Many such studies have been published in Indian journals. They are not always easy to acquire for Western researchers. Nowadays, there is a growing body of clinical research studies and some systematic reviews on the therapeutic effects of yoga (Büssing, Michalsen, Khalsa, Telles & Sherman 2012). According to a review study by Tyagi and Cohen (2016) associations between yoga and markers of autonomic activity have been reported in several studies. The reported markers include HR, baroreflex sensitivity, galvanic skin resistance, evoked potentials, attention, cognitive ability, emotional regulation, and mental resilience. Other studies report how a wide range of clinical conditions associated with autonomic dysfunction can be improved with regular yoga practice. The conditions reported were hypertension, diabetes, anxiety, depression, and pain. According to their review, two systematic reviews reported yoga practices having profound effects on metabolic and autonomic activities and also reducing cardiovascular risk.

However, Büssing, Michalsen, Khalsa, Telles & Sherman (2012) take a more cautious view in their review on effects of yoga on mental and physical health. They point out that there is a lot of heterogeneity in this growing set studies on yoga: they have different yoga styles, interventions with quite variable durations, varying effect sizes, heterogeneous diagnoses and outcome variables, small sample sizes, often limited methodological quality and varying control interventions. Because of these factors, there is still a lack of solid evidence regarding the clinical relevance of yoga. For many symptoms and medical conditions, there is inconsistent evidence: while several studies report positive effects of the yoga interventions, other studies are less conclusive.

Sometimes, this is because of differences between the study populations (gender, age and health status), differences between the yoga interventions, and follow-up rates (Büssing, Michalsen, Khalsa, Telles & Sherman 2012).

According to Büssing, Michalsen, Khalsa, Telles & Sherman (2012), the strongest evidence for benefits of yoga exists for pain-associated disability and mental health. This is partly because RCTs of relatively high quality have been done in those areas of research. Yoga may well be effective as a supportive additional treatment in some medical conditions and as physical exercise. However, it has not yet been proven to work as a stand-alone curative treatment. Yoga has potential because it's relatively cost-effective, can be done both in groups and as part of self-care and provides a life-long behavioral skill as well as enhances self-confidence and self-efficacy. It is also often associated with additional positive effects (Table 2) Therefore, more rigorous research is needed.

Table 2. Positive specific and nonspecific effects often associated with yoga interventions (Büssing, Michalsen, Khalsa, Telles & Sherman 2012).

	Specific effects	**Non-specific effects**
Cognition	Contemplative states; Self-identity; Self-efficacy; Beliefs; Expectations	Control of attentional networks
Emotions	Emotional regulation / control	Quality of life
Physiology	Vagal afferent activity; Heart rate / Respiration; Relaxation response / Stress reduction	Social contacts
Physical body	Physical flexibility; fitness / endurance	Healthy lifestyle

Indirect evidence for the components of yoga can be found in many studies. As an example, in one Western form of breathing practice, cardiac coherence training, one slows down the breathing frequency to around 6 cycles per minutes (0,1 Hz). A smartphone can be used to provide HRV biofeedback during the practice. This type of breathing stimulates baroreflex sensitivity, increases respiratory efficiency and improves psychological state. According to several studies, this kind of breathing exercise increases vagal tone activity and can be efficiently used as therapy in clinical contexts such as asthma and cardiovascular diseases as well as post-traumatic stress and fibromyalgia (De jonckheere, Ibarissene, Flocteil & Logier 2014).

2.7.2 Yoga in heated environments

All styles of yoga practiced in room intentionally heated for the practice can be called hot yoga. Examples of hot yoga include Bikram Yoga and CorePower Yoga. Temperature of the room range from 29 °C to 41 °C (Yoga Journal 2018). In Finland, many styles of hot yoga are offered. For example, Yoga Nordic has registered several forms of hot yoga including Hot Jooga (done at 38 °C) and Hot Jooga Lempeä (lempeä = gentle) (done at 35 °C) (Yoga Nordic 2010).

According to a review by Hewett, Cheema, Pumpa & Smith (2015), Bikram yoga is a standardized system of hatha yoga developed by Choudhury. It was popular in 2015, with over 600 Bikram yoga studios worldwide. Bikram yoga consists of a set sequence of 26 asanas and two breathing exercises done in a heated environment (40,6 °C and 40% humidity) to an instructional dialogue. Every class lasts 90 minutes.

Hewett, Cheema, Pumpa & Smith (2015) reviewed the existing research on Bikram yoga's effects on health. Only one of the nine studies in the review used a randomized control trial (RCT) design. Bikram yoga has been shown to improve lower and upper body range of motion and lower body strength as well as balance in healthy adults. According to the non-RCT studies, Bikram yoga may improve arterial stiffness, blood lipid profile, glucose tolerance and bone mineral density as well as perceived stress and mindfulness in some populations.

Fritz, Grossman, Mukherjee, Hunter & Tracy (2014) examined the acute physiological responses, including Tc, of experienced Bikram yoga practitioners (N=19, 19-40 years, 9 men and 11 women) to a single 90 session of Bikram yoga in a heated (40,6 °C) and humidified (40 % relative humidity) conditions. The participants' Tc increased during the first 50 minutes. Average Tc after the Tc peaked was 37,7 - 38,2 °C. This is clearly below the lower temperature limit (40 °C) of heat stroke. However, according to Glazer (2005, 2134-2135), heat exhaustion, a more commonly experienced heat-related illness, can happen when Tc is 37-40 °C.

2.7.3 Yoga's effects on HRV

There have been a number of studies suggesting that yoga influences HRV. Tyagi & Cohen (2016) and Posadzki, Kuzdzal, Lee & Ernst (2015) have systematically reviewed studies on yoga and HRV. Tyagi and Cohen (2016) found 59 studies with 2358 participants. Most studies were done in India and involved healthy male yoga practitioners and single laboratory sessions of research. Experimental and cohort studies have been done both during and after various yoga practices, including relaxation, meditation, breathing and integrated practices. They show vagal dominance both in time and frequency domains of HRV.

Tyagi & Cohen (2016) further analyzed 15 randomized controlled trials (RCTs) in their review of yoga and HRV. Six of those had a Jadad score of 3 out of 5. They conclude that these reviewed studies suggest yoga can affect cardiac autonomic regulation. During yoga session, increased HRV and vagal tone have been shown. During rest, regular yoga practitioners also have increased vagal tone compared to non-yoga practitioners, sedentary individuals and individuals who do regular aerobic exercise. Yoga also enhances vagal and inhibits sympathetic activity in congestive heart failure patients and improves vagal outflow in sedentary individuals.

Posadzki, Kuzdzal, Lee & Ernst (2015) made a more tentative conclusion in their review of yoga and HRV than Tyagi and Cohen (2016). According to them, there isn't convincing evidence from RCTs of yoga for modulating HRV in either healthy individuals or patients. They included RCTs comparing yoga against any type of control intervention in healthy individuals or patients with any medical condition. They assessed the risk of bias using the Cochrane criteria. Fourteen trials met the inclusion criteria but the overall methodological quality was deemed poor with only two studies having acceptable methodological quality. Ten RCTs did report favorable effects of yoga on various domains of HRV. However, nine studies did not report favorable effects and one RCT did not report between-group comparisons. No favorable effects of yoga compared to usual care were shown in the meta-analysis (MA) of the two trials with better methodological quality.

Both Posadzki, Kuzdzal, Lee & Ernst (2015) and Tyagi & Cohen (2016) state that further research needs to overcome the methodological weaknesses in currently available evidence. More rigorous studies are required. The yoga practices need to be reported in more detail because there are big differences in various styles of yoga. Changes in respiration need to be monitored, because without details on the respiratory rate it is extremely difficult to distinguish whether changes in HRV are due to changes in autonomic cardiac control or changes in respiration.

2.8 Sauna Yoga

Sauna Yoga is a licenced sauna fitness system developed by Sauna Yoga International Ltd. Sauna Yoga is practiced under the guidance of a licenced instructor in a 50 °C dry sauna for 30-45 minutes per session. (Saunayoga International Ltd 2017). There are six poses in Sauna Yoga. They are based on poses done in various other yoga styles. Sauna Yoga consists of strengthening, stretching and calming asanas. Almost the full length of a Sauna Yoga session is done in seated position. The original idea behind Sauna Yoga was to bring the slow-paced exercise of yoga to sauna, a space which is truly mobile-free and also free of other audio-visual stimulus. In the Sauna Yoga philosophy this is thought to help calm the mind and focus it on the present moment to alleviate stress (Saunayoga International Ltd 2017).

The six principles of Sauna Yoga are the guideline for doing Sauna Yoga correctly. They are breathing, alignment, midline, core activation, phases and rhythm. The principles have been explained as follows by Tiina Vainio, the developer of Sauna Yoga (quote from Pajukorpi 2017): “Throughout each movement, breathing should flow in and out with natural rhythm. Breathing combines with movement so that they go hand-in-hand. Alignment refers to the sitting position and base of support while exercising. Feet and pelvis should be in contact with the bench so that position is well supported, as if the body would “plant” itself into it. Movements are all started from this position. From the midline, exercises are done bilaterally and equally to both sides. Before starting the movement, core is activated gently, and instructor advises whether the movement starts with inhale or exhale. Movements are carried out in phases, without rush, and with concentration to above-mentioned principles”.

2.8.1 Adapted Sauna Yoga

Sauna Yoga International Ltd has also developed Sauna Pilates and – with help from SAMK personnel - Applied Sauna Yoga, a system developed specifically for individuals with a physical disability or whose mobility is otherwise restricted. Applied Sauna Yoga is done in supported seated position and it is therefore suitable for wheelchair users, people in physical rehabilitation and for people with conditions like fibromyalgia, arthritis or other forms of chronic pain (Saunayoga International Ltd 2017).

2.8.2 Conditions of Sauna Yoga in comparison to other activities

The environmental conditions of Sauna Yoga differ from traditional Finnish sauna bathing in a few ways: the temperature is lower (50 °C compared to 80-100 %), the air stays dry i.e. no water is thrown on the stones, there is physical exertion involved, and the time stayed in sauna is longer, 30-45 minutes. According to Laukkanen, Khan, Zaccardi & Laukkanen (2015, E4), almost half of sauna bathing men reported sessions of <11 minutes. Sauna Yoga can also be compared to other forms of hot yoga. For example Bikram yoga is practiced in a milder temperature (40 °C) but in more humidity (40 %) and for longer (90 min) sessions (Hewett, Cheema, Pumpa & Smith. 2015).

2.8.3 Research on Sauna Yoga

Pajukorpi (2017) studied the effects of Sauna Yoga on patients with chronic pain. For six weeks, participants took part in instructed Sauna Yoga sessions weekly. They filled out a background information form. They also filled out the Brief Pain Inventory Short Form -questionnaire (BPI-SF) before and after the intervention. 6 out of the 8 participants finished the study. Their BPI-SF answers were used to assess sleep and enjoyment of life. The mean values of the scores were lower post-intervention, but the change was not statistically significant. The reason for this was the large individual variation in the results as some patients reported worse results after the intervention. In conclusion, Sauna Yoga may have a slight positive affect on sleep and enjoyment of life in some patients with chronic pain, but the effects are highly individual. More research is needed because of the small sample size.

Lehtola (2017) researched the effects of Sauna Yoga on rheumatic conditions. 113 participants with rheumatic diseases each did one session of adapted Sauna Yoga after which they answered a questionnaire. After their trial of Sauna Yoga, 110 out of the 113 participants answered they "would try it again". In comparison to exercising in regular conditions, most of the participants viewed the higher temperature of Sauna Yoga to have positive effect: 49 % felt it had "a lot of effect", 31 % felt it effected "somewhat" and 16 % answered it had "remarkable effect". 85 % viewed the intensity of the asanas to be "adequate", 14 % as "easy" and 2% as "difficult". 59 % of the participants found the stretching asanas most beneficial. 27% of the participants viewed the calming asanas to be most beneficial for them. 14% felt the strengthening asanas were best for them. In the open question of the questionnaire, participants' most commonly recorded positive aspect was the warmth. However, some participants viewed the heat to be a negative factor. According to Hayes (1993, 157), heat therapy for joints is not recommended in the acute inflammatory phase as it can aggravate the disease process. In the questionnaire, headache and dizziness were also reported. According to The American Academy of Orthopaedic Surgeons (2016), these are symptoms of heat exhaustion i.e. rising Tc without CNS dysfunction. Headache and dizziness are reported with heat exhaustion due to water depletion or salt depletion, respectively.

3 AIM AND OBJECTIVES OF THESIS

The aim of this thesis was to assess how a single Sauna Yoga session affects recovery from (mainly) work-related stress of hospital staff. Heart rate variability measured using the FLA was chosen as the measurement tool. The objectives of the study were to answer the following two questions:

1) What is the balance between stress and recovery of hospital staff?

2) Does Sauna Yoga affect their balance of stress and recovery, including quality of sleep?

4 IMPLEMENTATION PERIOD

Implementation period of this thesis was conducted in cooperation with physiotherapist Erika Santala, who is a certified Sauna Yoga instructor, during March-April 2017. In order to avoid bias, author of the thesis did not take part in planning nor conducting the Sauna Yoga sessions. Since the participants were practicing Sauna Yoga on their free time, no research permit from the organization where the Sauna Yoga group met was needed. The measurement devices (Bodyguard 2) were rented from Firstbeat by Sauna Yoga International. Written permission to use the devices while doing Sauna Yoga was acquired from Firstbeat beforehand.

4.1 Participants

Seven people (all female, age 26-55 years) who all work in health care took part in the study. All the participants already practiced in the same Sauna Yoga group on Tuesdays. The practice sessions last approximately 45 minutes. However, participant B participated in two back-to-back Sauna Yoga sessions on Tuesday (and one on Wednesday).

Initially measurements were planned to be done so that the Sauna Yoga sessions would be after a working day but because some of the participants do shift work and because of time constraints, this was not used as an exclusion criteria. No other exclusion criteria were created. This means that there was marked heterogeneity between the participants. All seven participants who had expressed interest in the study completed their measurement periods and took part in Sauna Yoga during them.

All participants worked at least one day during the measurements. The participants' total working hours per day are shown in Figure 3. Work days were on average 8 h 24 min long and the range from 5 h 26 min to 11 h 0 min, the longest ones being night shifts. Participants B, C and D worked on all three days and their work schedules did not include night shifts. Participant E worked during the day on Monday and Tuesday and had an off day on Wednesday. B, C, D and E all participated in the Sauna Yoga after work. Two participants (F and G) worked a night shift on Monday and Tuesday i.e. they worked after the Sauna Yoga session. They had an off day on Wednesday.

Participant A had an off day on Tuesday worked a night shift on Wednesday. Therefore, participants B, C and D form one group with fairly similar daytime work schedules, as do F and G, who did night shifts.

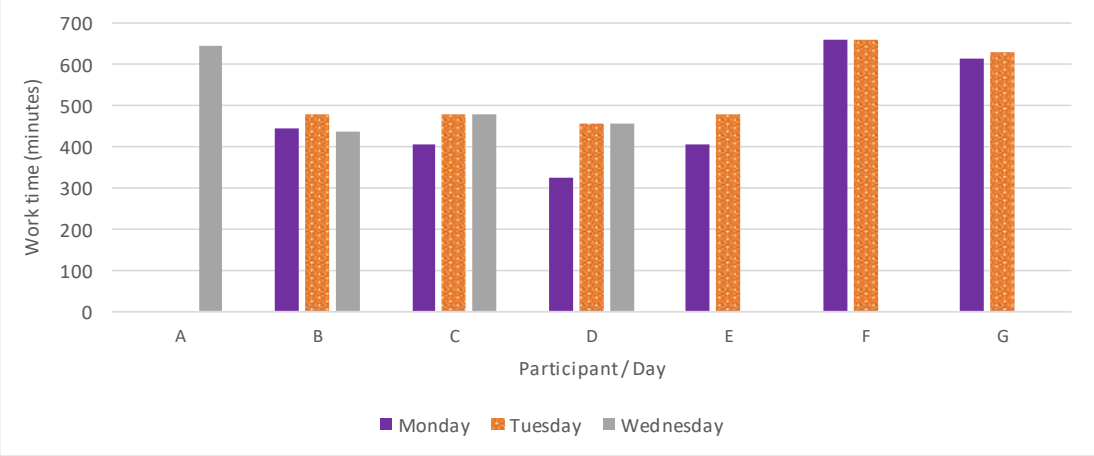

Figure 3. Work time (in minutes) per day per participant.

4.2 Data collection and analysis

HRV data measurements were done in March of 2017 during two weeks. All participants signed a written consent form (Appendix 1) for the measurements and their use in this thesis before beginning their measurement. Each participant also received written instructions on how to use the device (Appendix 2) and any questions from the participants were answered by email.

If possible, the measurements were done so that the day of the Sauna Yoga session was after a working day, but this wasn't possible in all cases because some participants did shift work. Each participant filled the online diary of the FLA during the measurement period. The researcher asked for clarification if the finding in the FLA did not seem to match the diary entries (for example, particularly stressful periods with no explanations in the diary).

The researcher handled the preparation of the device, data extraction and uploading of the data to the Firstbeat server as instructed in the Firstbeat Lifestyle Assessment Guide for Professionals (Firstbeat 2016b). The online version of the Firstbeat Lifestyle Assessment software was used to analyse the data. The software outputs a report which

the service provider then interprets and explains to the client. More information about the FLA, including the reliability and validity of the device and the software, is provided in Chapter 2.6. Personal feedback and a copy of the Firstbeat Lifestyle Assessment report was given individually to all participants in April of 2017.

4.3 Reliability and validity of the data

For participant A, Monday's measurement started late, giving only 16 h 34 min of data for the first day. Therefore A's data for Monday except for sleep time data has been excluded from the thesis. Participant C's Monday's data only covers 18 h 5 min likely also leading to less valid results for describing what happened during the 24-h period after waking up. Participant B had missing data on Monday both during an aerobically taxing physical activity session and about 25 % of the duration of sleep leading to lowered reliability and validity of the assessment of physical activity and sleep, and to a lesser extent the assessment of daily amount of stress reactions and recovery. Both participants F and G have approximately one hour of missing data right after the Sauna Yoga because of spending time in sauna and shower. One hour is approximately 4 % of the daily data so the daily data is slightly less valid. Also, it made it impossible to visually assess their immediate recovery after Sauna Yoga from the graphs available in the FLA.

4.4 Further data analysis based on FLA results

The first objective of the study – answering the question of what is the balance of stress and recovery of the participating hospital staff members – was answered by first interpreting the individual FLAs of each participant as instructed by Firstbeat's guide for professionals (2016), and secondly, by assessing the same factors as a group. The following quantitative statistics were calculated from the entire data set using Microsoft Excel: lowest and highest value, average and standard deviation. The numerical values collected from the Lifestyle Assessment reports were: amount of stress reactions during the day, amount of recovery during the day, amount of recovery during work, length of sleep, amount of recovery during sleep, quality of recovery during sleep (i.e.

average RMSSD during sleep) and physical activity index. The additional values collected from the Specialist report were average RMSSD during awake time and the relative difference of the awake time and sleep time RMSSD values.

The categories in the FLA reports were to evaluate the results. For example, on given day, did a participant have more than usual (>60%), normal (40-60%) or less than normal (<40%) of amount of stress reactions? The other variables with categories were amount of recovery, amount of recovery during work, length of sleep, amount of recovery during sleep, quality of recovery during sleep (heart rate variability) and physical activity index.

Additionally, as fitness level affects variables such as RMSSD, the data about the amount and intensity of physical activity were collected. Three categories were formed to categorize these results: Did the participants do enough moderate and/or vigorous exercise to achieve significant health benefits or even additional health benefits? The WHO's (2010, 7-8) weekly limits for these (150 min moderate / 75 min vigorous exercise, or 300 min moderate / 150 min vigorous exercise, respectively) were used to divide the categories.

The second objective of this study – does Sauna Yoga affect the balance of stress and recovery – was evaluated mostly using the same measures as for the first objective of the study. In addition, single subject research design (SSRD), also known as the n-of-1 i.e. single subject clinical trial, was used. An SSRD trial considers a single individual as the sole unit of observation. N-of-1 can be used to investigate the efficacy of different interventions. Multiple n-of-1 studies can be combined (Lillie et al. 2011).

In SSRD, one or more intervention periods are combined with one or more non-intervention periods i.e. baselines. It is crucial to find out how stable the data within the baseline phase is before starting the intervention (Logan, Hickman, Harris & Heriza 2008, 100). In this study, this would have required completing several measurement periods for each participant. This was not done due to time and monetary constraints.

The analysis of single subject research is done by using statistical techniques or visually assessing the trends, slopes and levels in graphs of the results. Trends can either

increase, decrease or not change. A pronounced slope in the trend is stronger evidence for a change than a gentler slope. By comparing the level of a variable before and after the intervention is also important in determining how significant the change was (Williams 2001). In this study, levels of variables were observed in graphs. The SSRDs possible in this study based on the work schedules of the participants are shown in Table 3.

Table 3. Single subject research designs (SSRDs) for individual participants. A single session of Sauna Yoga (SY) was considered the intervention (B also had an intervention with 2 back-to-back SY sessions). Only working during the day, working during the night, having days off work and SY sessions were considered in forming the designs because of the short measurement periods with single SY sessions.

Participant(s)	**SSRD design**	**Explanation**
C, D	A-B-A (withdrawal)	A: Daytime (ending before 19.00) work without SY B: Daytime work before SY
F, G	A-B-C	A: Night shift without SY B: Night shift before SY C: Day off work without SY
A (Tue, Wed)	A-B	A: Day off work with SY B: Night shift without SY
B	A-B-C	A: Daytime work without SY B: Daytime work before 2 sessions of SY C: Daytime work before SY
E	A-B-C	A: Daytime work without SY B: Daytime work before SY C: Day off work without SY

N-of-1 analysis was only done with the data from participants C and D as they were the only ones with repetitions of the baseline measurement (Table 3). Specifically, the A-B-A (withdrawal) study design was used with them, A being a work day without Sauna Yoga and B a work day with one session of Sauna Yoga. However, participant C only had 18 h 5 min data from Monday, decreasing the reliability and validity of the 24-hour measures. C's sleep time data for Monday was reliable and valid. All outcome measures with numerical values were visually observed from graphs made with Microsoft Excel.

5 RESULTS

The numerical results from the FLAs and the FLA Specialist reports are summarized in this chapter in graphic form. If differing values (of maximum of 1 %) were found in pie graphs and the separate categorized results in the FLA's daily pages titled Lifestyle Assessment, the values from the pie graphs were used. The Body Resources graphs from the FLA Summary pages are shown in Appendix 3 which also show the periods of physical activity that were analyzed to be affecting physical fitness. Other than that, parts of individual FLAs are not duplicated in this thesis. Results from background information survey are available in Appendix 4. To ensure privacy, measurement dates, ages, heights and weights are not shown. The results are summarized and the study questions answered in Chapter 6 (Conclusions).

5.1 Overview of measured physiological states

Figure 4 shows the daily distributions of time spent in states analyzed by the FLA to be either stress reactions, recovery, various levels of physical activity or other states. For participant A, Monday's data was excluded from the analysis except for the sleep time data. Compared to others, participant A spent significantly higher portion of the day in state of recovery, even on a workday (Wednesday). Participants E and D were most physically active in terms of aerobic exercise, both partly due to cycling to work and back home.

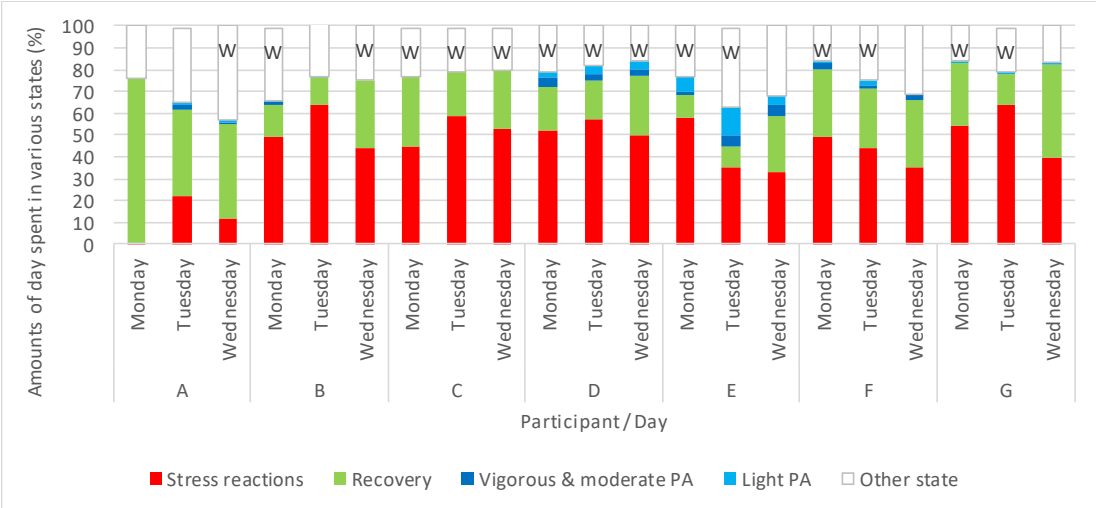

Figure 4. Daily amounts (%) of stress reactions, recovery, physical activity and other states by participant. Working days are marked by a "W". Participant A's measurement for Monday (16 h 34 min) is shown here but excluded from further analysis.

5.2 Stress reactions

Figure 5 shows the daily amounts of stress reactions (as analyzed by the FLA). The normal range for the amount of stress reactions per day in the FLA is 40-60%. For the whole group, the range for the daily amounts of stress reactions was 12-64 % and the average 46 %. Participant A spent only 12-22 % per day in stress reactions. Participant E also had two days (a night shift and a day off work), and participant F had one day off work with less than normal amount of stress reactions (33-35 %). Participants B and G both had one work day when the amount of stress was over the normal level (64% and 64%). Also, participants C, D and E had one or more day when the stress was normal but relatively high (highest ones being 59%, 57% and 58 %, respectively). The participants' average amounts of stress reaction during days with work ranged from 12 % (participant A) to 59 % (participant G).

For five of the seven participants, Tuesday (the Sauna Yoga day) had the highest amount of stress reactions (Figure 5). Also on Tuesday, all participants had the 15 minutes with the strongest stress reactions as analyzed by the FLA (not shown here) during the Sauna Yoga session. For all participants, the amount of stress was lesser on Wednesday than on Tuesday. Comparing participants who worked on all days (B, C and D), B and D had least stress reactions on Wednesday.

Comparing participants who had Wednesday off from work (E, F, G), all had the least amount of stress reactions on the day off work (Figure 5) although the difference was marginal for participant E who exercised on all three days and went winter swimming and sauna on Monday and Wednesday. Participant E also had the lowest amounts of recovery overall (Figure 8). For participant E, the continuously measured RMSSD values (indicating recovery) from the FLA Specialist report (graph not shown) peaked to the highest value of the day about one hour after the winter swimming/sauna both on Monday and Wednesday (to about 65 ms and about 80 ms, respectively). The Bodyguard 2 device was not used during the winter swimming/sauna sessions so no RMSSD values during the activity are available. On Tuesday, participant E's RMSSD value peaked (about 90 ms) during a 30 minute nap after work. There was a lower peak (about 60 ms) right after Sauna Yoga. Participant E's stress state was assessed by the FLA to be overloaded on Monday, physically overloaded on Tuesday, and on Wednesday E had delayed nighttime recovery.

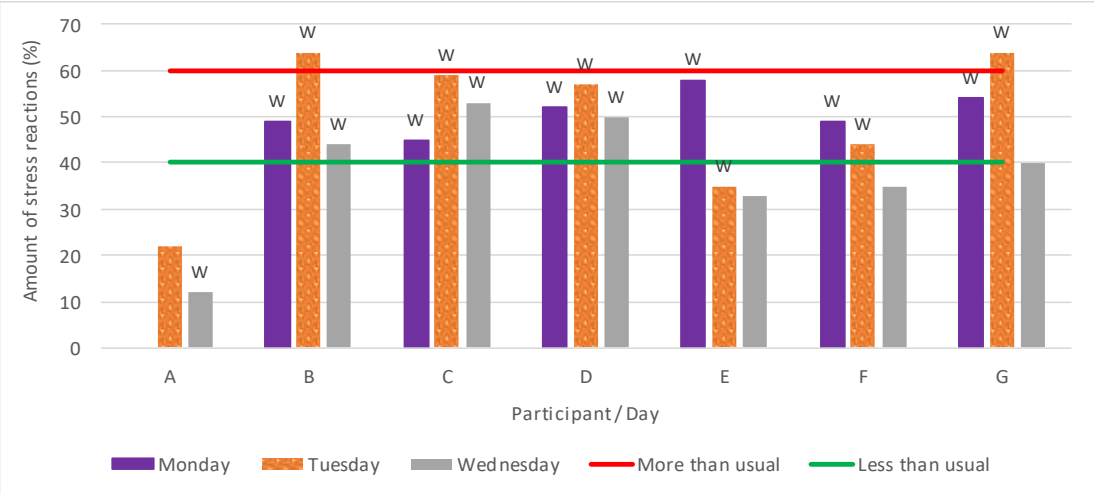

Figure 5. Daily amounts of stress reactions (%). Red line marks the upper limit (60%) and green line the lower limit (40%) for normal amount of stress reactions (according to the FLA). Working days are marked by a "W". Participant A's Monday excluded.

5.3 Physical activity

In the background information (Appendix 4), participants C, F and G had classified themselves to be in activity class 4 (training 2-5 times per week with less than 30

minutes of heavy physical activity per week). Participants A, B, D and E had classified themselves to be in activity class 6 (training 2-5 times per week with 1-3 hours of heavy physical activity per week). The daily amounts of (aerobic) physical activity by participants during the measurement period are shown in Figure 6.

The daily amounts of moderate exercise ranged from 0 to 38 minutes (average 14 minutes). The daily amounts of vigorous exercise ranged from 0 to 47 minutes (average 13 minutes). Participants D and E exercised significantly more and participant F more than the WHO (2010) recommendation for additional health benefits. Participant A did close to the amount of exercise needed for significant health benefits (WHO 2010) on Tuesday and Wednesday. Participants B, C and G did not do the recommended amount of aerobic exercise during their measurement periods.

The daily Physical Activity Indexes calculated by the FLA are shown in Figure 7. A value assessed in the FLA as good (≥60/100) is achieved with 30 minutes of moderate or 20 minutes of vigorous aerobic physical activity. It was reached during all three days by participants D and E, during two days by participant F and during one day by participants A and B. Participants C and G only had low Physical Activity Indexes, even though G did more light physical activity than C.

Participants A, D, E and F all had at least one session with TE per day (not shown). Participant F reached the highest TEs of 4,6 (highly increasing fitness) and 3,7 (increasing fitness). Participants D and E also had one fitness improving session (TE 3,0) each. Rest of the sessions had TEs in the range of 2,0-2,9 (maintaining fitness). The Training Effect is only applicable to aerobic fitness.

Although participants B, C and G did not do the recommended amount of aerobic exercise during their measurement periods (Figure 6), they were physically active otherwise. Participant B had one session with TE on Monday but there was missing data during this session, therefore the TE (2,9) is likely underestimated. B did two Sauna Yoga sessions on Tuesday and one on Wednesday. Participant C participated in work break exercise sessions on all three days and participated in Sauna Yoga on Tuesday and in “regular” yoga on Wednesday. Participant G participated in the Sauna Yoga on Tuesday and in a “deep stretching” class on Wednesday.

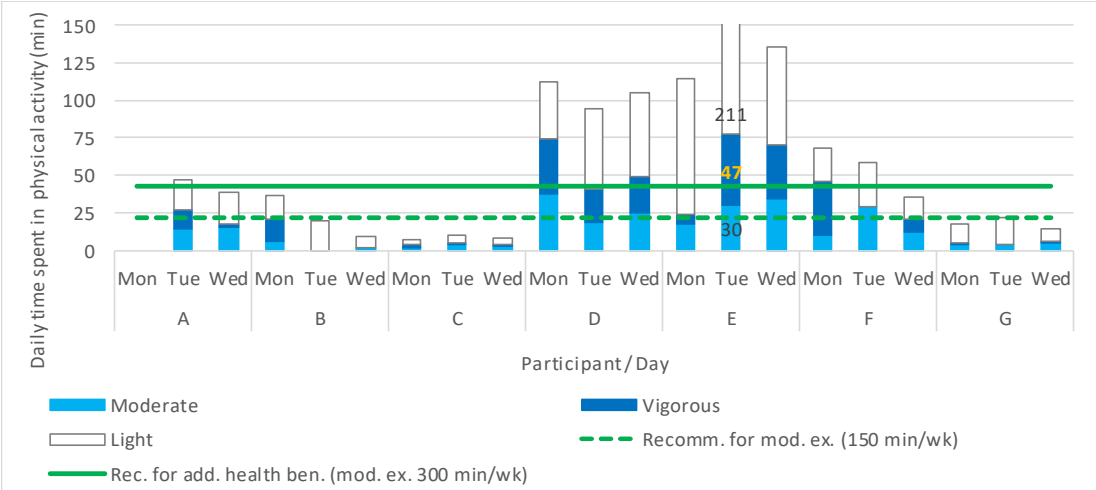

Figure 6. Daily amounts of physical activity (%) in three categories: Vigorous > 60%, moderate 40–60% and light < 40% of maximal aerobic capacity. Dashed green line = significant health benefits, solid green line = additional health benefits (WHO 2010, 7-8). The FLA only analyzes aerobic load from activities. Participant A's data for Monday was excluded.

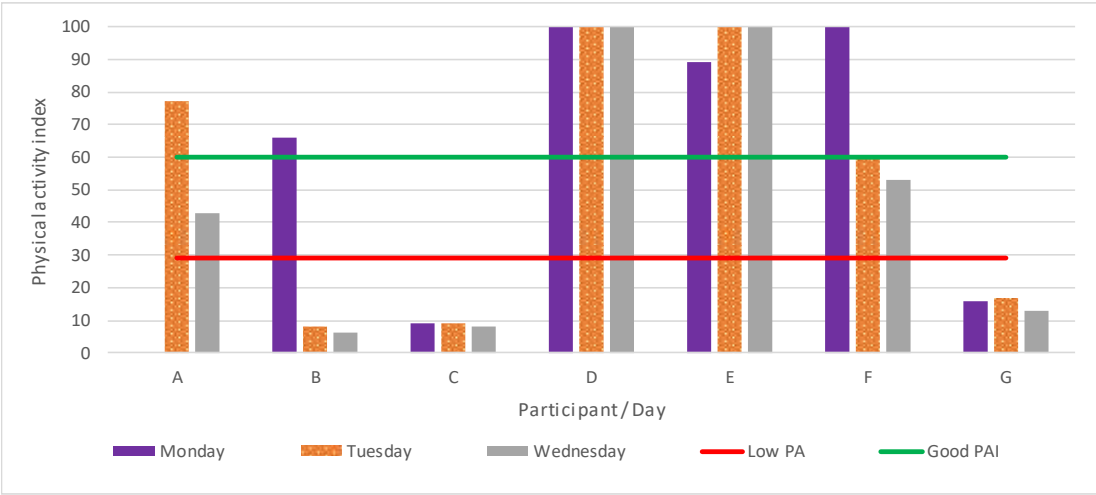

Figure 7. Daily Physical Activity Index (scale of 0-100). The FLA only analyzes aerobic activity. Other forms of exercise done by the participants have not been added to the graph. Participant A's data for Monday was excluded.

5.4 Recovery including sleep

Figure 8 shows the daily amounts (%) of recovery for which the moderate range in the FLA is 20-29%. Figure 9 shows daily amounts (min) of recovery during work for which the moderate range in the FLA is 10-29 min. Participant A's data for Monday

was excluded except for sleep time. Most of recovery happens during sleep (Figure 10, Figure 11 and Figure 12).

For the whole group, the range of daily amounts of recovery was 10-43%, the average being 25%. The three-day averages of daily recoveries were categorized as good (≥30 %) for participants A (42 %) and F (30%), as moderate (20-29 %) for C, D and G, and as poor (≤ 20 %) for B and E. Participant B's amount of recovery (19 %) was better than E's (15 %) although B had no days of work while E had one day off work. Participant G recovered well (42 %) on the day off work (Wednesday) with long sleep (10 hours) with almost good (74 %) amount of recovery during sleep.

In the FLA, recovery time at work is categorized as good when it's at ≥30 minutes, moderate when it's 10-29 minutes, and poor low when it's <10 minutes. Especially participants A and F could recover at work: 182 – 320 minutes of recovery per approximately 11 hour-long night shifts. Participant B also had 47-85 minutes per day to recover at work. Low amount of recovery at work was measured with participants C (0-17 min/d), D (0 min/d), E (0-2 min/d), and G (0 min/d).

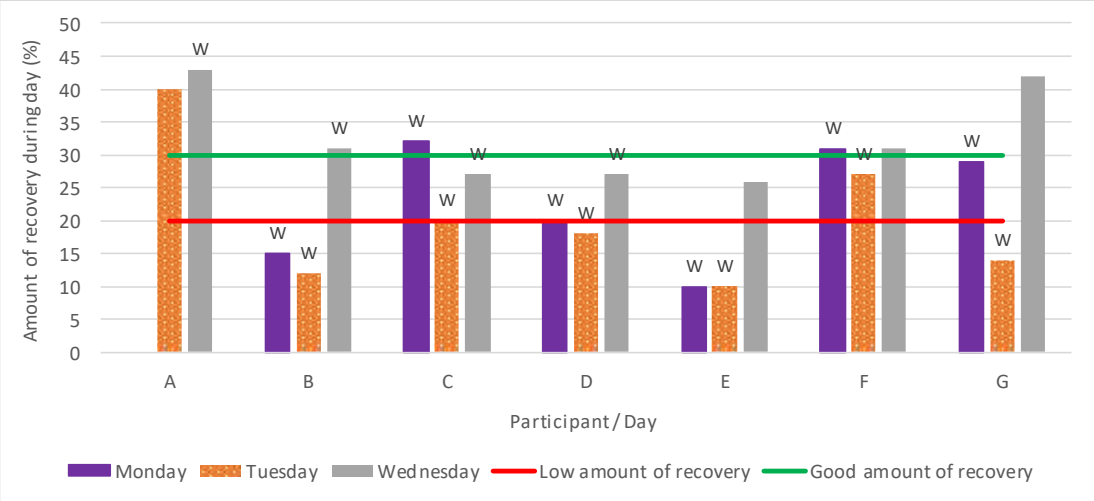

Figure 8. Daily (24-hour) amounts of recovery (%). Lines mark the limits for low (<20%), moderate (20-29%) and good amount of recovery (according to the FLA). Working days are marked by a "W". Participant A's data for Monday excluded.

Figure 9. Recovery (minutes) during work per day per participant. Green columns show work time analyzed by the FLA to be recovery. Green line marks the limit in the FLA for good recovery (≥ 30 minutes). Brown columns show rest of the time at work.

Recovery during sleep is a combination of length of sleep, amount of recovery and quality of recovery. These factors are presented separately in Chapter 5 and summarized in Chapter 6. The summary of the length of sleep (minutes), the amount of recovery during sleep (%), and the quality of sleep (ms; RMSSD) are shown in Figure 10, Figure 11 and Figure 12, respectively. Participant B's sleep measurement on Monday was likely unreliable because of approximately two hours (close to 25 %) of missing data during 7 h 40 min of sleep. However, it has been included in the analysis.

The FLA categorizes ≥ 7 hours as good, and ≤ 5,5 hours as poor length of sleep (Figure 10). The group slept on average 7 h 48 minutes per night (range: 3 h 55 min to 10 hours 16 min). For all participants except F, each night the length of sleep was categorized as good or moderate but still nearly good. Participant F could sleep longer (8 h 33 min) on the day off (Wednesday) but on night shift days the sleep time was only 3 h 55 min to 4 h 40 min.

The FLA categorizes ≥ 75 % as good, and ≤ 50 % as poor amount of recovery during sleep (Figure 11). In average, the group spent 61 % of their sleep in recovery (range 22 – 94 %). In regards to the three-day averages, participants E (37 %) and B (46 %) were in the poor category while A (82 %) was the only one in the good category. The only participants to have good (≥ 75 %) amounts of recovery during sleep were A

(Monday and Wednesday) and D (Wednesday). For participant B, the amount of recovery during sleep was clearly worse on Tuesday (22 %) with two back-to-back Sauna Yoga sessions than on Wednesday (62 %) with one Sauna Yoga session. Her quality of recovery during sleep was also worse (although still categorized as good) on Tuesday compared to Wednesday (Figure 12) Participant B had approximately two hours of missing data at the beginning of the sleep on Monday i.e. the reliability of data is compromised. All participants except F had the best amount of recovery during sleep on Wednesday. Participant F took two doses of alcohol on Wednesday.

Quality of recovery during sleep (Figure 12) is measured in the FLA with the HRV variable RMSSD (ms) and categorized as poor, moderate or good. The categories are age-dependent. The average sleep-time RMSSD was 50 ms but the RMSSD values greatly varied between participants. Participant A had the three highest RMSSD values (98-126 ms) and participant B the next three highest values (51-85 ms) while the other participants had fairly similar values to each other (range 24-43 ms). Participants A, B, C, D and G all had three nights with sleep with good quality sleep. Participant F slept one night (Tuesday) with good quality and two nights with moderate quality. Participant E only achieved moderate quality of sleep. No participants had nights with poor quality of sleep i.e. no one had values comparable to the lowest 10 % of their age group.

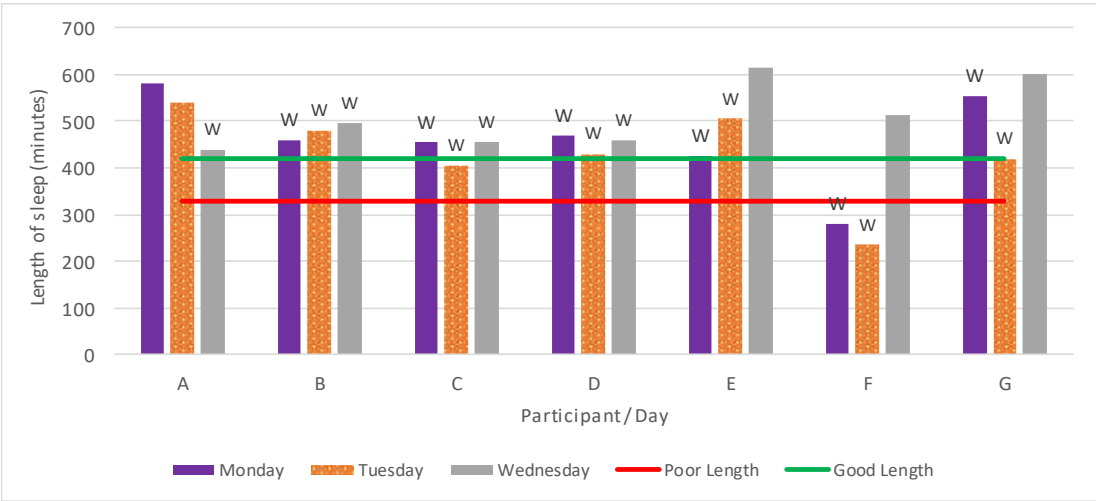

Figure 10. Length of sleep (minutes) per day per participant. The FLA categorizes sleep lengths into poor (≤ 5,5 h; red line), moderate (5,5 – 7,0 h) and good (≥ 7,0 h; green line).

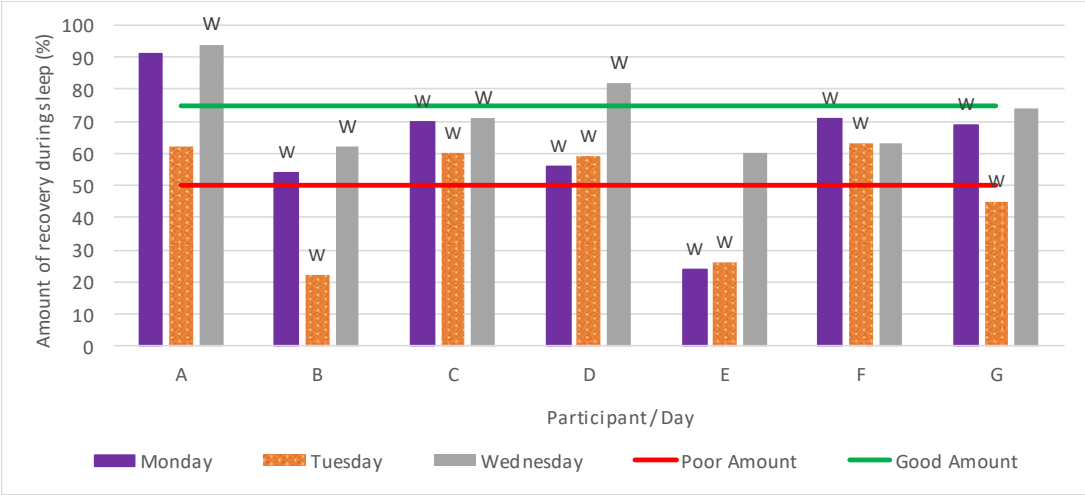

Figure 11. Amount of recovery during sleep (%) per day per participant. The FLA categorizes the amounts of recovery into poor (≤ 50%, red line), moderate (50 – 74 %) and good (75 %, green line).

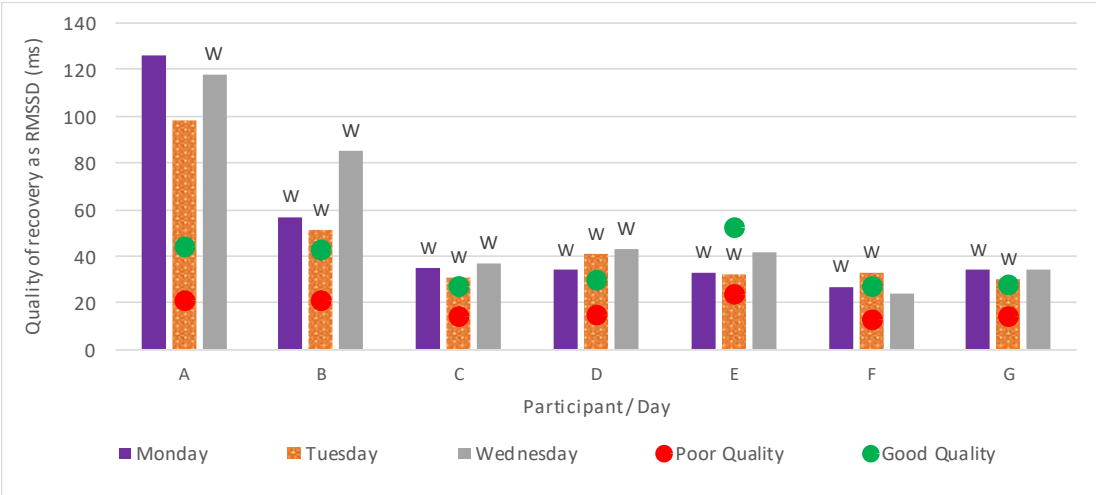

Figure 12. Quality of recovery during sleep measured as RMSSD (ms) per day per participant. The FLA categorizes the quality of recovery into three age-dependent categories: poor, moderate and good. The quality is low below the red dot and good above the green dot.

Average RMSSD values (indicating the activation of the PNS and quality of recovery) and their relative differences during awake time and sleep time are shown in Figure 13 and Figure 14, respectively. Participant A's measurement period for Monday's awake time RMSSD was excluded. The awake time RMSSD values are only available in the FLA Specialist report but the sleep time RMSSD value is also shown in the customer version of FLA as the quality of sleep.

All participants met their age-dependent recommended minimum of average RMSSD (14-25 ms) during sleep each night. There was large variation between individuals. Participant A had the highest awake time values (81-101 ms, Monday's excluded value 118 ms) and the highest sleep time values (98-126 ms). Participant B also had higher values than the rest of the group. B's awake time RMSSD was 43-58 ms and sleep time RMSSD 51-86 ms. For the rest, the range of awake time RMSSD values was 13-33 ms and range of sleep time RMSSD values was 24-43 ms.

Participant D was the only one with the relative difference in the good category (≥1,5). Participant D's awake time RMSSD were the lowest of the group. She only recovered during the awake time on Wednesday when she was lying awake in the morning. Even though participant D had normal average sleep time RMSSD (range 34-43 ms) she also had delayed nighttime recovery on Monday and Tuesday. All other participants had moderate relative differences i.e. everyone had better recovery during sleep time compared to awake time.

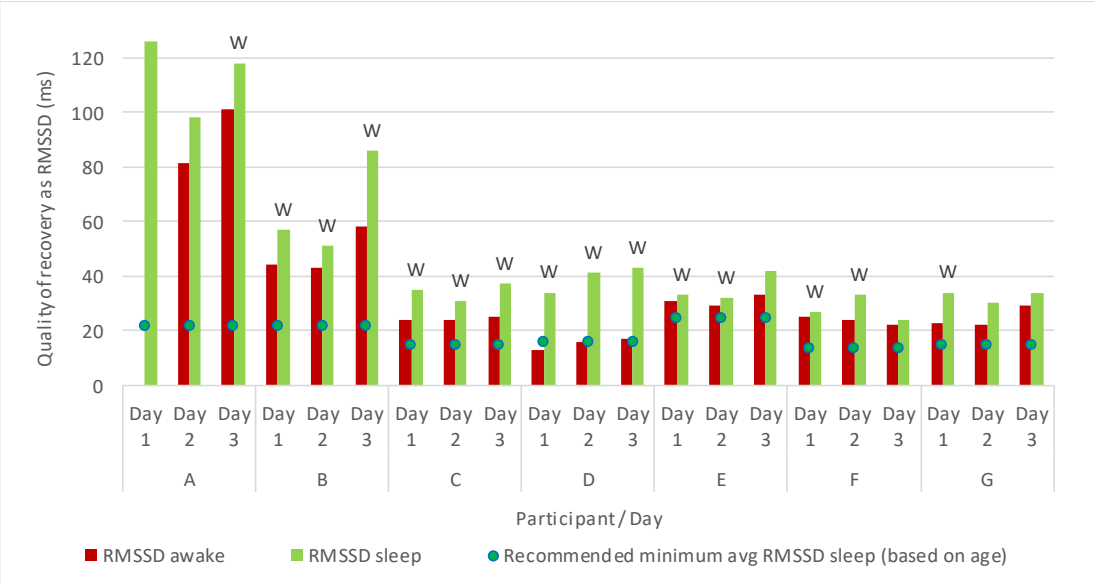

Figure 13. Average RMSSD (ms) during awake time and sleep time per day per participant. The dot marks the age-dependent recommended minimum of average RMSSD during sleep. Work days are marked by a "W". Participant A's daytime data for Monday excluded.

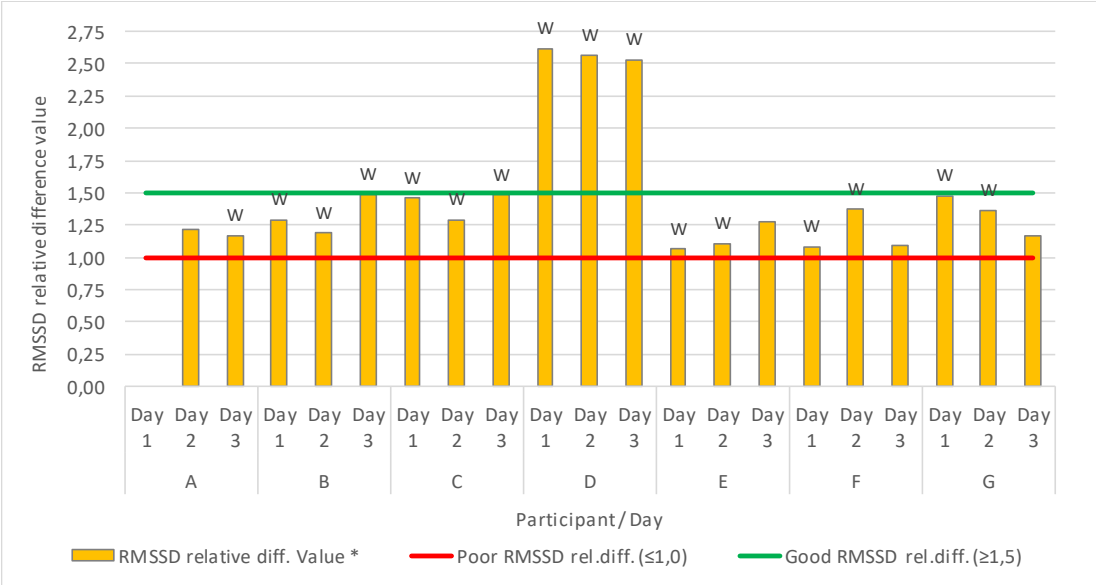

Figure 14. The relative difference value (RMSSD during awake time compared to RMSSD during sleep time) per day per participant. The FLA categorizes the values into three categories poor (≤ 1,0, red line), moderate (1,0-1,5) and good (≥1,5, green line). Work days are marked by a "W". Participant A's data for Monday excluded.

The Body resources graphs of participants are shown in Appendix 3. For participant A, the measurement started late on Monday. Therefore, it does not reflect the resource level after waking up. When comparing the ending levels to the starting levels, Participants A, B, F and G ended up with increased resources. Participants C and D ended up with decreased resources but the measurement periods only had work days. Participant E's measurement ended with decreased resources despite having a day off work on Wednesday. E's sleep during Wednesday increased her resources somewhat but could not compensate for the other nights' short sleep periods with low amounts of recovery.

Participant A's Body Resource graph (Appendix 3) differs from the other participants because her resource level does not descend during the day or the night shift on Wednesday. Participant E's resource graph also differs from the others. It shows descending resources during the daytime and no recovery during night before Wednesday. Participant F recovered also during the night shifts after midnight. Other participants' graphs depict more clearly descending resources during the day and ascending resources during sleep.

5.5 Single subject research

In terms of the single subject research, only results for participants C and D with the A-B-A design are discussed here. No other participants had repetitions in their data. For C, Monday's measurement period was short (18 h 5 min). Therefore the validity of the 24-hour measures was limited but sleep time measurements were valid and reliable.

There were no clear findings from this limited single subject research. Both C and D slept slightly less on Tuesday than on Monday and Wednesday. For both, amount of recovery during sleep was better on Wednesday than Tuesday. Only D had better recovery during Wednesday compared to Monday. For D, this may be due to waking up to throat ache during Monday. There is no clear trend in quality of sleep (average RMSSD during sleep time) or average RMSSD during awake time. C and D both had highest daily amounts of stress reactions per day during Tuesday, and the amount of recovery per day was higher for both on Wednesday compared to Tuesday. However, C's data for Monday is limited in validity.

6 CONCLUSIONS

Considering the first study question, the results show that the balance between stress and recovery varied greatly between the individuals in this heterogeneous group. Four of the seven participants ended up with increased resources at the end of the measurement period. Two of the participants with decreased resources at the end did not have a day off work during the measurement period which might have helped them too to recover their resources.

The participants experienced normal levels of stress during work days. Most participants had the typical pattern of decreasing resources during the day (both at work and during leisure-time) and increasing resources during sleep. During work days, five participants had average daily amounts of stress reactions (47-53 %), one slightly higher but still normal, and one very low amounts with no decrease of resources during work.

Four of the participants reached good level of aerobic physical activity as measured by the Physical Activity Index. Three participants only reached low level and would benefit from more aerobic exercise. The low scores are partly due to non-aerobic forms of exercise, including Sauna Yoga, not affecting Physical activity Index. One participant's Physical Activity Index was likely negatively affected by missing data during an aerobically taxing exercise session on Monday.

In regards to average daily amounts of recovery, two participants were categorized as having good and two as having low recovery, and ensuring more recovery is recommended for the latter two. Three participants reached good recovery time at work, even night shifts. Four participants experienced low amount of recovery at work and would benefit from introducing short breaks.

Recovery during sleep is a combination of length of sleep, amount of recovery and quality of recovery. Four participants had at least one night with poor recovery. Poor sleep length affected one participant after night shifts, and this person would benefit from sleeping more and possibly taking naps. Two participants had one night and one participant had two nights with poor amount of recovery. Quality of recovery during

sleep varied greatly between individuals with two participants having higher values than the others. Five participants had good sleep quality, one participant had moderate sleep quality and one had moderate to good sleep quality.

Participant E had the most problems with the balance of stress and recovery with resources recovering only during Wednesday night after an off day from work. E had two nights with poor amount of recovery. The daily stress states (Overload, Physical overload and Delayed nighttime recovery) reflect these problems which may have been partly due to high amount of PA or due to participating in a combination of winter swimming and sauna on Monday and Tuesday. The other participant with high amounts of physical activity (D), was the only one with above moderate relative difference of RMSSD values due to having low awake-time RMSSD compared to sleep-time RMSSD. She only recovered during the awake time on Wednesday while she was lying awake in the morning. D also had delayed nighttime recovery on Monday and Tuesday. Ensuring less stress (possibly via less PA or winter swimming) and introducing recovery time before sleep and during work would likely improve the balance of stress and recovery of both participants.

In regards to the second study question, does Sauna Yoga affect the balance of stress and recovery including sleep, the clearest finding was that Sauna Yoga caused short-term stress reactions: all participants had on Tuesday the day's 15 minutes with the strongest stress reactions during Sauna Yoga. Five participants (all except E and F) had their day with highest amount of stress reactions on Tuesday. There are possible reasons for E's and F's differing results: E woke up during Monday night due to throat ache, and F did an intensive exercise session on Monday and her HR and level of stress reactions were still high two hours afterwards. All participants had the least amount of daily recovery on Tuesday (E had the same amount of recovery on Monday, too). All in all, Sauna Yoga likely has an effect on the stress and recovery balance of the day of the Sauna Yoga session. Stress is needed for beneficial physiological adaptations to occur.

Sauna Yoga may lead to better recovery one day later, possible due to heat acclimation. For this heterogeneous group of participants, these findings were not statistically significant. However, five participants (all except C and F) had their best amount of daily

recovery on Wednesday, and six participants (all except F) had their best amount of recovery during sleep on Wednesday. F's recovery during Wednesday night may have been negatively affected by taking two doses of alcohol.

Participant B's poor amount of recovery during sleep on Tuesday was possibly affected by two back-to-back sessions of Sauna Yoga. The amount of recovery and quality of sleep (22 %, 51 ms) were worse than on Wednesday (62 %, 85 ms), a day with just one Sauna Yoga session. However, it is possible that part of the stress happened already on Monday (54 %, 57 ms) but then there were problems with missing data.

7 DISCUSSION

This study showed that a small group of health care workers can have very different balances of stress and recovery. The Firstbeat Lifestyle Assessment delivered meaningful information which the participants could put to use. Most participants had results that were close to the average levels measured by Firstbeat. Their stress and recovery balance was not a cause for concern. However, overload, physical overload, low or no recovery during work, delayed nighttime recovery and short sleep periods are factors that one would be wise to remedy.

No statistically significant changes to the variables measured in the FLA due to a single session of Sauna Yoga were found. This study was small and small sample sizes make it difficult to get statistically significant results. For example, Järvelin-Pasanen, Ropponen, Tarvainen, Karjalainen & Louhevaara (2013, 162) considered a sample of 51 female nurses all doing shift work to be an adequate sample to compare differences in HRV between and within normal and extended work shifts. To decrease the effect heterogeneity, the study could have been done with fewer participants but repeated measurements and utilizing single subject research design. According to Lee & Haegele (2015, 50), when a studied population is heterogeneous or small, single subject design is more suitable for demonstrating internal validity and experimental control than group experimental design. This would have benefited answering the second study question.

In this study, varying working schedules of the participants may have affected their HRV findings. This form of heterogeneity is normal in health care settings so it lead to valid results in case of the first study questions. However, it was a confounding factor in answering the second study question, Sauna Yoga's effects on recovery. According to a systematic review by Togo & Takahashi (2009, 597-598), altered circadian rhythms have been shown in night shift workers in several studies, and these may last and cause adverse changes in HRV later, on a day without night shift work. The cardiac autonomic activity and circadian pattern of HRV are independent of the night-day cycle. Instead, they seem to be mostly related to the level of physical activity or wakefulness (standing) and sleep (supine). Merkus, Holte, Huysmans, Mechelen & van der Beek (2015, 10-11) also point out two other physiological processes, i.e. sleep

deprivation and increased physiological activation that cause health effects for workers with non-standard work schedules.

Varying level of physical fitness and age likely increased the heterogeneity of the group. In comparison to RMSSD values reviewed by Altini (2015), one participant had quality of sleep (sleep time average RMSSD) in the range of young, highly trained individuals, and another in the range of young, physically active individuals. The rest had values measured from sedentary young adults.

Also, HRV values are age age-dependent. Järvelin-Pasanen, Ropponen, Tarvainen, Karjalainen & Louhevaara (2013, 154, 161) found older female nurses had lower overall HRV compared to younger nurses, indicating increased SNS activation. These changes are likely attributable to normal physiological changes caused by ageing. In a study with 1743 participants age 40-100 (Almeida-Santos et al. 2016 according to Shaffer & Ginsberg 2017, 8), RMSSD decreases with age until the age of 60 and started increasing again after age of 70. In this thesis, the age range of the participants was 26-55. Harvey et al. (2016, 390) found postmenopausal women to have lower vagal modulation of HR and delayed recovery of HRV after exercise compared to premenopausal women. These were not restored by estrogen therapy, suggesting the lowered HRV was caused by aging.

There were some cases of missing data, especially during sleep and during exercise. These were likely connection problems due to one or two of the electrodes being pressed between the body and the bed during sleep, or worsened connection due to sweating. Alcohol rub or shaving the skin at the electrode placement area before placing the electrode might have made the connection better. Two participants could have been delivered the devices personally to ensure the measurements could have been started on Monday morning, increasing the validity of the daily (24-h) variables on Monday.

There is some evidence that yoga does improve HRV. Papp, Lindfors, Storck & Wändell (2013) studied the effects of 8 weeks of hatha yoga. They excluded participants who performed physical activities more than twice a month or who exercised at medium or high intensities. This was done because physical activity is known to increase

HRV. They found, for example, a significant effect of yoga on the HRV variable pNN50 at night (Papp, Lindfors, Storck & Wändell 2013, 1-2). Hanson, Outhred, Brunoni, Malhi & Kemp (2013, 1) found that for females with a low physical activity (less than 30 minutes of vigorous activity at least 3 times a week), getting a single dose of the SSRI-class antidepressant escitalopram improved their cardiovascular stress response (lower HR and higher RMMSD) to a mental stress test to resemble more the response of the females in the study who were used to higher physical activity. These findings could be used in the future to direct research to populations who would most benefit from increased HRV whether via yoga or other forms of exercise.

Future research Sauna Yoga and recovery measured with HRV could be done using single subject research design to decrease the effect of heterogeneity between study participants. It could also be a long term study with measurements before and after an 8-12 week intervention of Sauna Yoga done with participants who have never done Sauna Yoga or any other form of yoga and are physically inactive as changes in their HRV values are likely to be more evident. The participants should also be a relatively homogeneous group. As the HRV variable RMSSD is at its lowest during ages 60-70 (Almeida-Santos et al. 2016 according to Shaffer & Ginsberg 2017, 8), workers nearing their retirement age (over 60 year of age) could be one interesting age group to study.

One participant's amount and quality of recovery during sleep was possibly negatively affected by doing two back-to-back sessions of Sauna Yoga on. Therefore, it could be beneficial for Sauna Yoga instructors with similar work schedules to assess their levels of recovery. One participant took part in winter swimming and sauna on the other days of the measurement period, and this activity resulted high peaks in parasympathetic activity (high RMSSD) afterwards. However, this participant, who was quite active physically, had problems with overload, physical overload or delays in reaching state of recovery during sleep. One topic of further research could be to use HRV measurements to find the optimal weekly amount of Sauna Yoga - or other activities to stress the ANS through heat, cold or a combination of them - to benefit from physiological adaptations such as heat acclimation or cold acclimation. The optimal amount will likely be highly individual. Recovery analysis for athletic training (Firstbeat Technologies Ltd 2015) could be a useful starting point for such optimizing process.

It took longer to finish the thesis than what was originally planned. Not every stress in life can be planned for in advance and they may increase the need for recovery. However, the participants got their feedback on right after the measurement period so they were not negatively affected. Having the opportunity to be a service provider of Firstbeat Lifestyle Assessments was a valuable learning experience. Later, personal interest in the subject matter lead to a rather thorough theory part. On the one hand, researching a lot of theory prolonged the thesis process but on the other hand, it made my personal learning so effective that I felt comfortable coming back to the thesis even after taking breaks due to clinical practices and courses. Also, having once written a Master's thesis made the whole process easier and less stressful.

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Satakunnan Ammattikorkeakoulu

SaunaYoga's effects on recovery from work-related stress based on heart rate variability (SaunaYogan vaikutukset työhön liittyvästä stressistä palautumiseen sydämen sykevaihteluvälin pohjalta arvioituina)

TIEDOTE TUTKITTAVILLE JA SUOSTUMUS OPINNÄYTETYÖHÖN LIITTYVÄÄN TUTKIMUKSEEN OSALLISTUMISESTA

1 Tutkijoiden yhteystiedot

Opinnäytetyön tekijä:
XXXXXXXXXXXXX
Tutoropettaja:
XXXXXXXXXXXXX

2 Tutkimuksen taustatiedot

Tutkimus tehdään osana SAMK:n Physiotherapy (fysioterapeutti AMK) -koulutusohjelman opinnäytetyötä. SaunaYogasta on valmisteilla kaksi muuta opinnäytetyötä toisten tahojen kanssa, mutta ne toteutetaan erillään tästä tutkimuksesta. Mittaukset tehdään maalis-huhtikuussa 2017. Opinnäytetyön laadinta jatkuu kevään 2017 ja syksyn 2017 aikana.

3 Tutkimusaineiston säilyttäminen

Opinnäytetyön tekijä säilyttää kaiken tutkimusaineiston turvallisesti. Aineistoa ei luovuteta ulkopuolisille tahoille.

4 Tutkimuksen tarkoitus, tavoite ja merkitys

Tutkimuksessa selvitetään, miten osallistuja palautuu työhönsä ja muuhun elämäänsä liittyvästä stressistä (kuormituksesta). Erityisesti halutaan selvittää SaunaYogan mahdollisia vaikutuksia työstressistä palautumiseen. Stressitilaa ja palautumista mitataan ympäri vuorokauden FirstBeat-mittauslaitteella. Sen keräämästä datasta saadaan selville autonomisen hermoston tilaa epäsuorasti kuvaavan sydämen sykevaihteluvälin (HRV) vaihtelu mittausjaksolla. HRV pienenee akuutin stressin aikana lyhytaikaisesti ja on kroonistuneessa stressitilassa pysyvästi alhaalla. Aiemmissa tutkimuksissa muiden joogamuotojen on todistettu lisäävän sydämen sykevaihteluväliä, millä on yhteyksiä stressistä palautumiseen ja pitkällä aikavälillä parempaan stressinsietokykyyn ja parempaan terveydentilaan.

5 Menettelyt, joiden kohteeksi tutkittavat joutuvat

Opinnäytetyön tekijä valmistelee mittalaitteiston ja perehdyttää tutkittavan FirstBeat-mittalaitteiston käyttöön ennen mittausta.
Tutkittava pitää kolmen vuorokauden ajan ihollaan laitetta ja sen kahta elektrodia. Tutkittava poistaa laitteiston ainoastaan suihkussa käyntejä, elektrodien vaihtoa, uimista tms. varten. Laitteisto kerää dataa sydämen sykkeestä samalla periaatteella kuin sykemittari eikä vaikuta sydämen toimintaan millään tavalla.
Mittausjakson loputtua laitteisto toimitetaan opinnäytetyön tekijälle, joka hoitaa tiedon purkamisen FirstBeatin onlinepalveluun analysoitavaksi ja esittää myöhemmin tulokset tutkittavalle.

6 Tutkimuksen hyödyt ja haitat tutkittaville

FirstBeat-mittaus kertoo tutkittavan kokonaiskuormituksen mittausjakson aikana. Toisin sanoen, olivatko koko mittausjaksoa tarkasteltaessa palautumis- ja nukkumisjaksot riittäviä kumoamaan stressijaksoista syntyneen kuormituksen vai olisiko työkuormaan ja/tai vapaa-ajan lepoon ja palautumiseen vaikutettava jollakin tavalla. Koska mittausjakson aikana pidetään päiväkirjaa menossa olleista tapahtumista (työvaihe, vapaa-ajan harrastukset, henkisesti stressaavat tilanteet yms.), saa tutkittava myös tietoa esimerkiksi siitä, edistikö SaunaYoga-harjoitus työstressistä palautumista (tutkimushypoteesi).
FirstBeat-laitteisto vastaa sykemittaria eikä sen käyttö täten aiheuta terveysriskejä. Tutkittavan on kuitenkin sitouduttava mittausjakson ajaksi muutamiin hieman aikaa vaativiin toimenpiteisiin kuten pitämään päiväkirjaa, ottamaan laite pois päältään mm. suihkussa käymisten aikana ja asettamaan se päälleen uudelleen sieltä tultuaan.

7 Miten ja mihin tutkimustuloksia aiotaan käyttää

Tutkimustuloksia käytetään tutkittavien anonymiteettia kunnioittaen Antti Leskelän fysioterapian alan opinnäytetyössä, joka tulee olemaan julkisesti ladattavissa SAMK:n WWW-sivujen kautta. SaunaYoga International Oy ja FirstBeat Technologies Oy voivat tiedottaa opinnäytteestä.

8 Tutkittavien oikeudet

Osallistuminen tutkimukseen on täysin vapaaehtoista. Tutkittavilla on tutkimuksen aikana oikeus kieltäytyä mittauksista ja keskeyttää testit ilman, että siitä aiheutuu mitään seuraamuksia. Tutkimuksen järjestelyt ja tulosten raportointi ovat luottamuksellisia. Tutkimuksesta saatavat tiedot tulevat ainoastaan tutkittavan ja tutkijaryhmän käyttöön ja tulokset julkaistaan tutkimusraporteissa siten, ettei yksittäistä tutkittavaa voi tunnistaa. Tutkittavilla on oikeus saada lisätietoa tutkimuksesta tutkijaryhmän jäseniltä missä vaiheessa tahansa.

9 Vakuutukset

Opinnäytetyöhön liittyen tutkittavia ei vakuuteta erikseen.

10 Tutkittavan suostumus

Olen perehtynyt tämän tutkimuksen tarkoitukseen ja sisältöön, tutkittaville aiheutuviin mahdollisiin haittoihin sekä tutkittavien oikeuksiin ja vakuutusturvaan. Suostun osallistumaan mittauksiin ja toimenpiteisiin annettujen ohjeiden mukaisesti. En osallistu mittauksiin flunssaisena, kuumeisena, toipilaana tai muuten huonovointisena. Voin halutessani peruuttaa tai keskeyttää osallistumiseni tai kieltäytyä mittauksista missä vaiheessa tahansa. Tutkimustuloksiani saa käyttää tieteelliseen raportointiin (esim. julkaisuihin) sellaisessa muodossa, jossa yksittäistä tutkittavaa ei voi tunnistaa.

Päiväys	Tutkittavan allekirjoitus
Päiväys	Tutkijan allekirjoitus

OHJEET FIRSTBEAT HYVINVOINTIANALYYSIN SUORITTAMISEEN

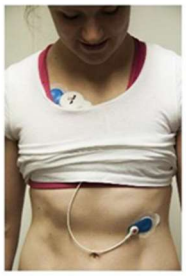
Hei, tässä fysioterapian opiskelija XXXXX SAMK:sta. Tervetuloa Hyvinvointianalyysiin! Sen antama arvio perustuu sydämen sykevälimittaukseen, jonka avulla saadaan tietoa eri hyvinvoinnin osa-alueista. Tulet tämän pohjalta saamaan palautetilaisuudessa tietoa, joka auttaa miettimään jatkotoimenpiteitä hyvinvointisi edistämiseksi. Opinnäytetyön tekijänä minua kiinnostaa erityisesti, auttaako SaunaYoga sinua palautumaan paremmin päivän kuormituksista. Palautumista kuvaa osaltaan myös unenlaatu.

Hyvinvointianalyysin mittausten ja niiden analysoinnin onnistumiseksi pyydän sinua noudattamaan seuraavia ohjeita huolellisesti:

- Käytä Bodyguard 2-mittalaitetta **3 vrk (72 h) yhtäjaksoisesti**. Jos vain mahdollista, aloita mittaus maanantaiaamuna HETI HERÄTTYÄSI ja lopeta mittaus 3 vrk:n (72 h) kuluttua torstaiaamuna HETI HERÄTTYÄSI.
- Mittausaikasi on _____-_____
- Katso mittalaitteen (Firstbeat BODYGUARD 2) käytön ohjevideo:
  - https://www.firstbeat.com/fi/tuki/hyvinvointianalyysi/ohjeet/
  - Sama ohjeistus elektrodien kiinnittämisestä löytyy myös alla kuvina.
- **Mittauksen aloitus**:
  Varmistathan, että elektrodit kiinnitettyäsi **vihreä valo mittarissa vilkkuu**! Luethan lisäohjeet tämän saatteen viimeiseltä sivulta ennen mittauksen alkua

1. Kiinnitä elektrodit laitteen neppareihin.

2. Irrota elektrodin suojakalvo.



3. Kiinnitä laite oikealle puolelle kehoa solisluun alapuolelle. Johdon toinen pää kehon vasemmalle puolelle kylkikaareen.

4. Mittaus alkaa automaattisesti kiinnitettäessä. Tarkista, että vihreä valo vilkkuu. HUOM. valo näkyy parhaiten pimeässä.

- **Mittauksen aikana**:
  seuraathan, että vihreä valo vilkkuu edelleen!

Vihreä valo vilkkuu sykkeen tahdissa.	Laite mittaa ja tallentaa sykettä.
Vihreä ja keltainen valo vilkkuvat sykkeen tahdissa.	Akku on vähissä, mutta mittalaite mittaa edelleen. Mikäli mittaus on vasta alussa, ota yhteyttä yhteyshenkilöösi.
Punainen valo vilkkuu sykkeen tahdissa tai palaa yhtäjaksoisesti.	Akku on loppunut tai laitteen muisti on täynnä ja mittaus on keskeytynyt. Lopeta mittaus ja ota yhteyttä yhteyshenkilöösi.

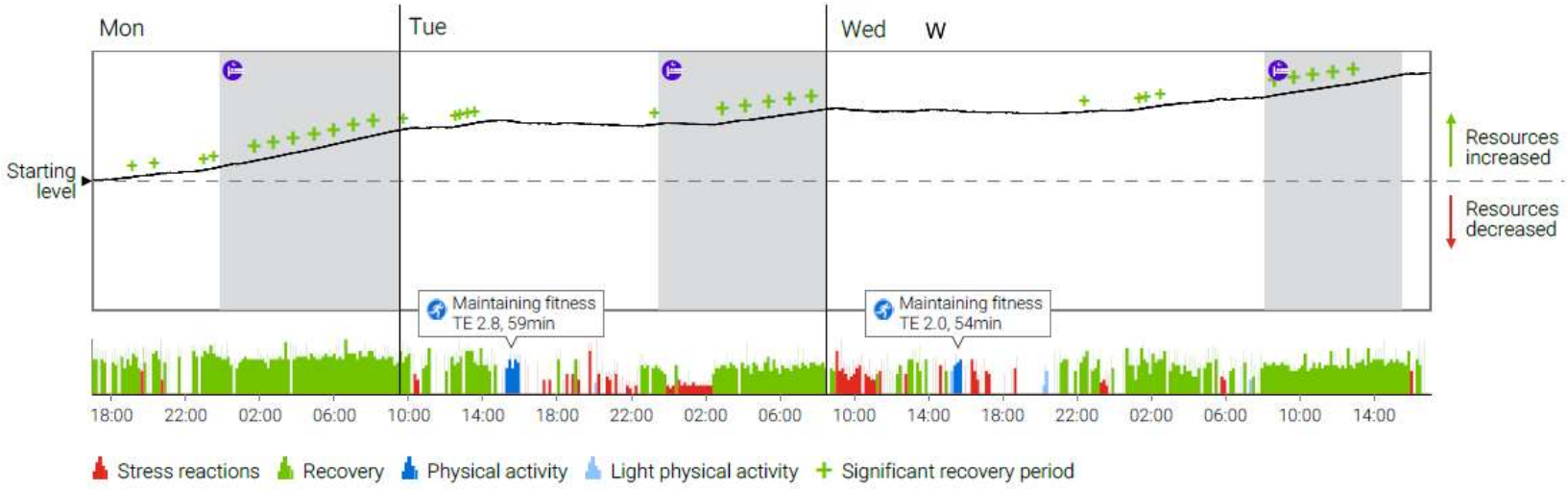
- **Täytä esikysely ja taustatiedot huolella** sähköpostiisi saamasi linkin kautta netissä. Sairaudet, alkoholi ja tietyt lääkeaineet vaikuttavat syketiheyteen. Merkitsethän ne siksi taustatietoihin, jotta mittaustietojen analyysi onnistuu.
- **Täytä päiväkirjaa huolella, se on välttämätöntä luotettavan analyysin kannalta**. Saat sitä varten sähköpostiisi linkin ensimmäisenä mittauspäivänä. Täytä vähintään uni-, työ- ja harrastusajat sekä liikuntasuoritukset, nämä ovat edellytys raportin luomiselle. Myös erityisen stressaavat tai rentouttavat hetket kannattaa merkitä ylös.
- Kirjoita päiväkirjamerkintöjä **pitkin päivää** arjessasi joko 1) **älypuhelimella** suoraan nettiin, tai 2) erilliselle **paperille** ja siitä myöhemmin sähköiseen päiväkirjaan. Ethän yritä luottaa ulkomuistiisi.
- Mittalaitteen kanssa on tarkoitus **elää aivan normaalia elämää** samalla tavalla kuin ilman mittariakin. Mittalaite on kosteuden- muttei vedenkestävä, joten ota se pois suihkun, saunomisen ja uimisen ajaksi. ***POIKKEUS: Tätä opinnäytetyötä varten pidä mittari ylläsi SaunaYoga-harjoituksen aikana***.
- **Vaihda elektrodit** ainakin kerran vuorokaudessa ja aina suihkun jälkeen. Vaihda elektrodit myös, mikäli ne meinaavat irrota. Joillekin elektrodit voivat aiheuttaa **poikkeuksellista ihon ärtymistä**. Tällaisessa tapauksessa voit **keskeyttää** mittauksen.
- Jos sinulle tulee **ongelmia tai kysyttävää**, ota minuun yhteyttä: XXXXX tai puhelimitse XXXXX.
- Mittaukset tehtyäsi **palauta mittalaite** SAMK:n Tiilimäen kampuksen infoon minun nimelläni (XXXXX).
- Järjestämme **palautetilaisuuden** mittatuloksistasi myöhemmin sovittavana ajankohtana. Silloin saat itsellesi henkilökohtaiset raportit ja käymme läpi mittaustulokset. Jokaisen henkilökohtaiset raportit ovat hyvin luottamuksellisia eikä niitä luovuteta muille.

Elektrodien ja mittarin kiinnittämisestä

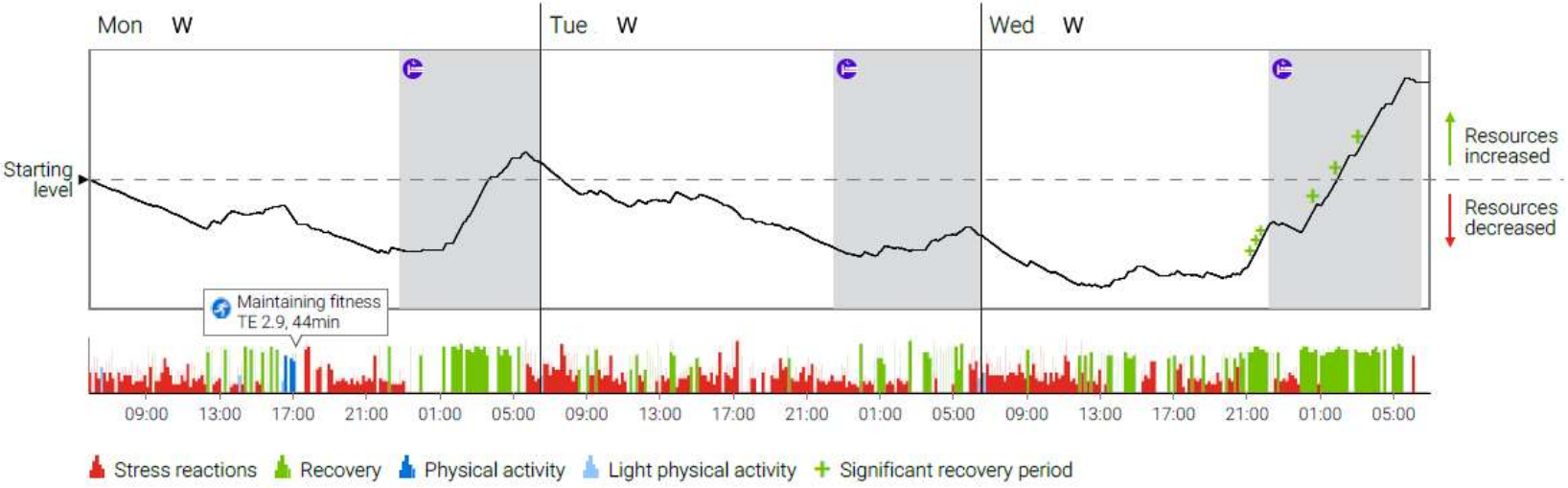
- Jos ihosi on kostea tai rasvainen, pyyhi se alkoholipitoisella puhdistusaineella. Tällöin kuolleet ihosolut irtoavat ja iho kuivuu, minkä ansiosta elektrodi kiinnittyy paremmin.
- Voit tarvittaessa poistaa kontaktia heikentävät ihokarvat elektrodien kohdalta.
- Poista elektrodin taustalevy varoen koskettamasta kiinnityspintaan.
- Älä paina elektrodia keskeltä, vaan liuta sormea elektrodin reunoilta. Näin varmistat sen, ettei märkä pasta tahri kiinnitysaluetta ja elektrodi pysyy hyvin paikoillaan.
- Kiinnitä sitten Bodyguard 2 -laite neppareilla elektrodeihin, kuten tämän saatteen ensimmäisellä sivulla
- Elektrodit ovat kertakäyttöisiä ja käyttöikä n. 24h-30h eli vaihda ne n. kerran vuorokaudessa

APPENDIX 3

Participant A

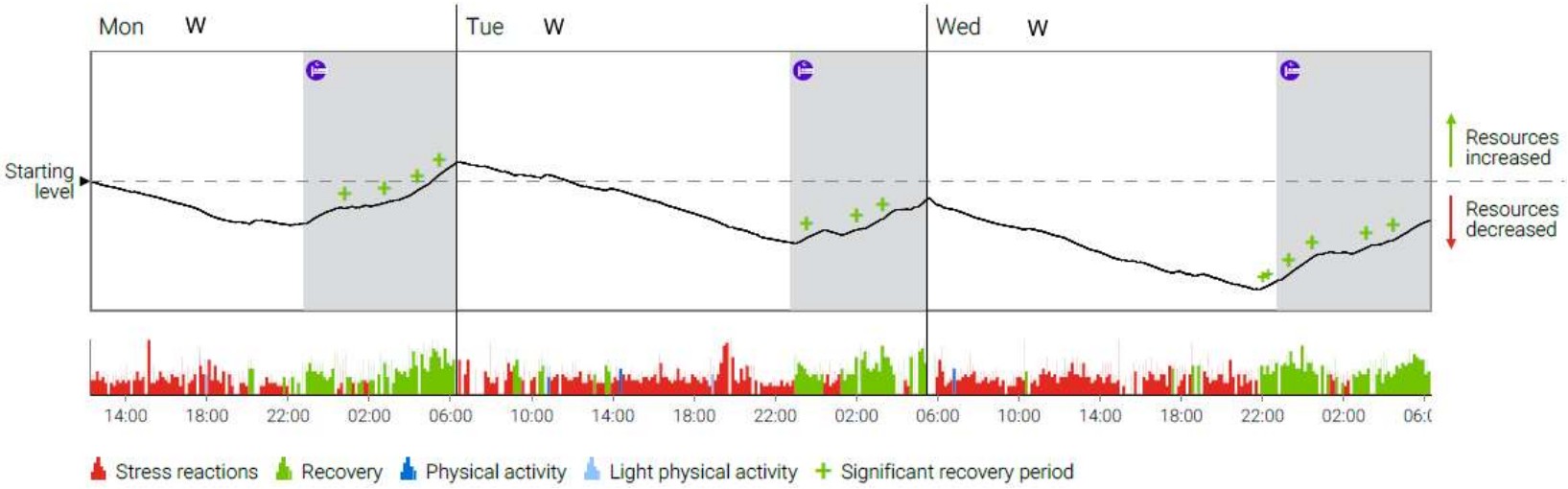


Participant B

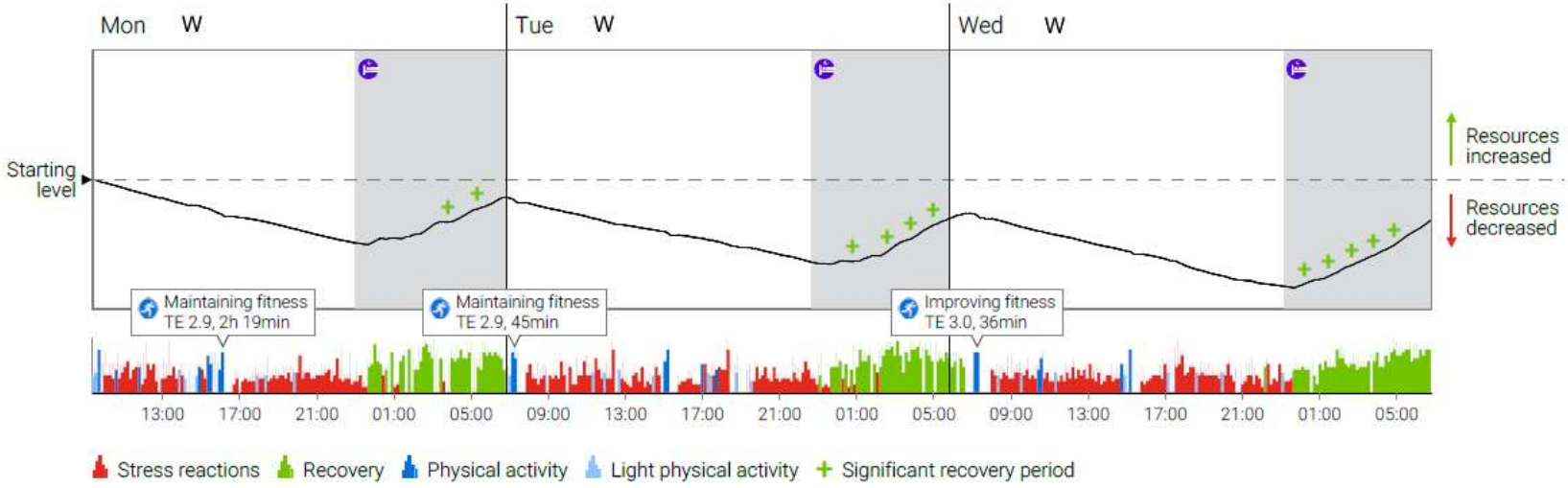


Body resources graphs. Dates of month have been erased. Work days marked with “W”.

Participant C

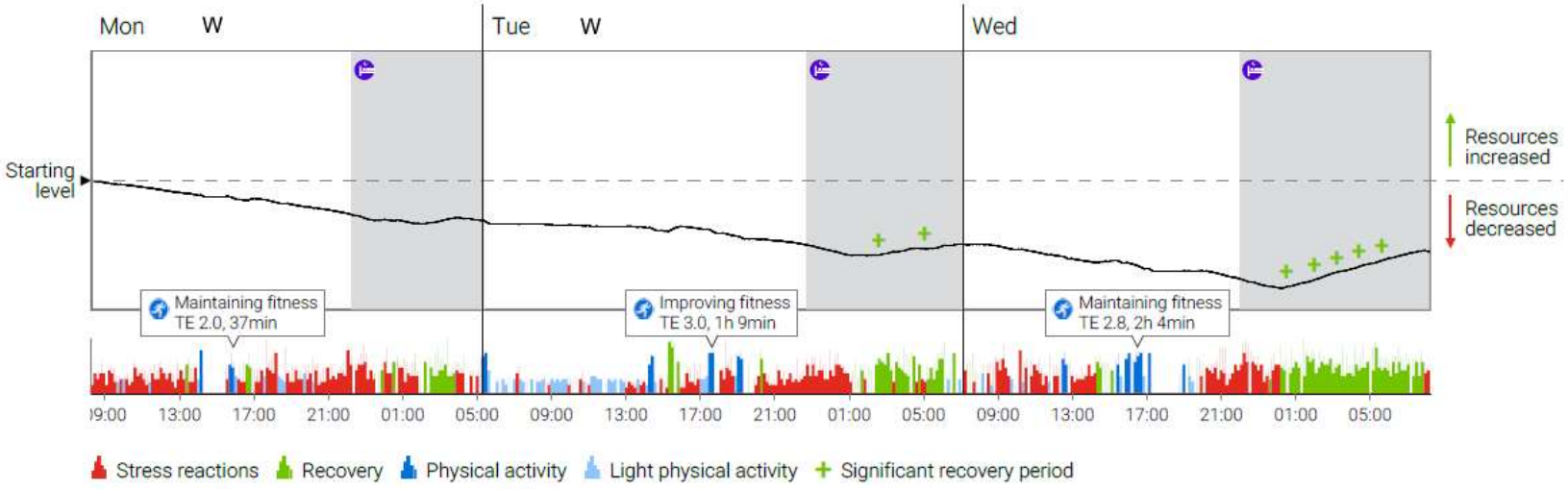


Participant D

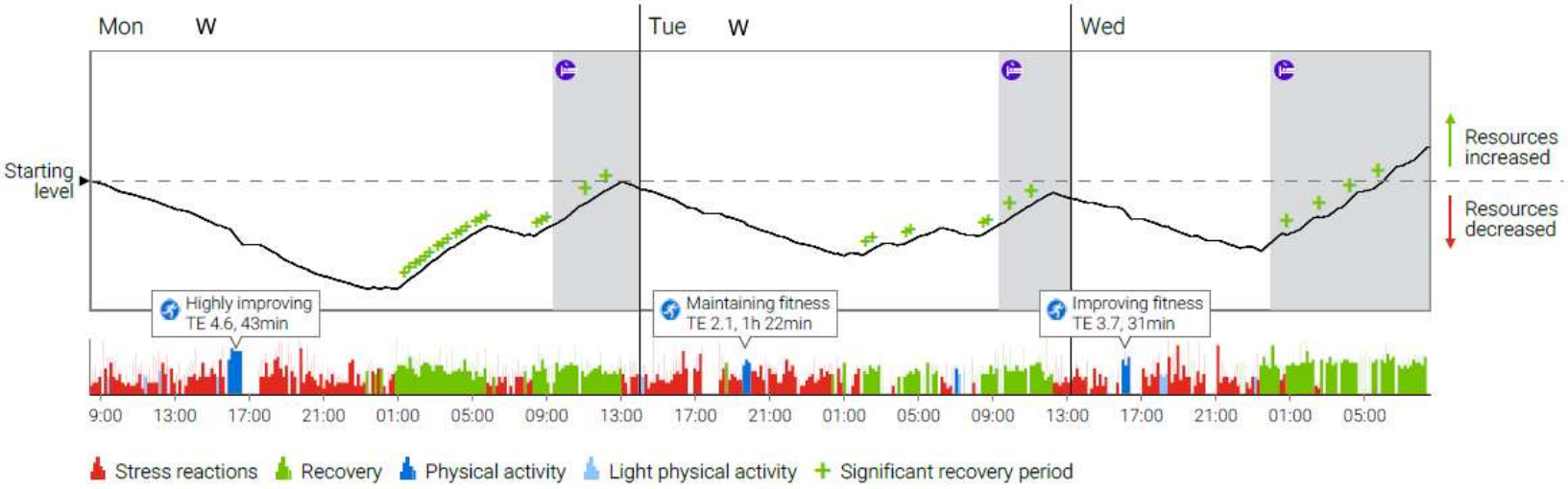


Body resources graphs. Dates of month have been erased. Work days marked with “W”.

Participant E

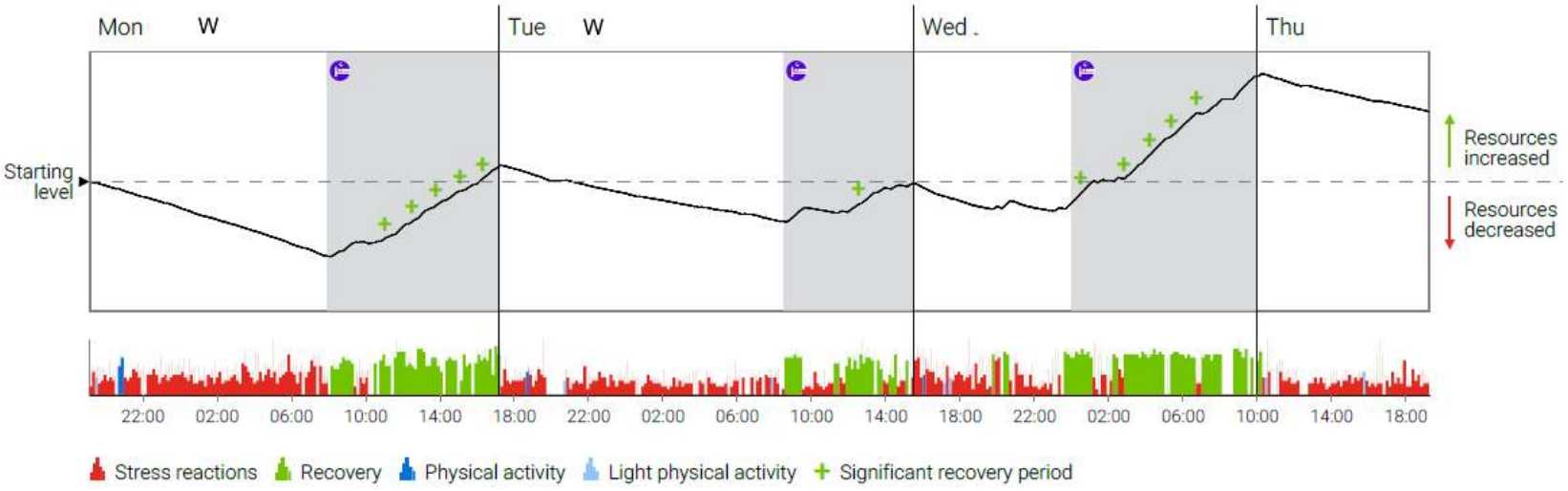


Participant F



Body resources graphs. Dates of month have been erased. Work days marked with “W”.

Participant G



Body resources graphs. Dates of month have been erased. Work days marked with “W”.

APPENDIX 4

PARTICIPANT CODE	Age *	BMI	Activity class value	Activity class classification	HRRest	HRMax
A		24,8	6	Good	37	187
B		23,1	6	Good	38	187
C		30,9	4	Moderate	46	175
D		30,5	6	Good	53	178
E		23,0	6	Good	54	193
F		24,6	4	Moderate	46	174
G		20,9	4	Moderate	40	176

* Age, height and weight omitted.

PARTICIPANT CODE	Day1 Alcohol	Day1 Medication	Day1 Sleep Quality **	Day1 Stress state	Day1 Reliability of detected state	Day1 Work minutes
A	0	0	4	Good recovery	Poor	0
B	0	3	4	Weak recovery	Poor	445
C	0	2	2	Good recovery	Poor	406
D	0	0	4	Delayed nighttime recovery	Poor	326
E	0	0	4	Overload	Good	406
F	0	1	5	Good recovery	Poor	660
G	0	2	3	Good recovery, but no recovery during the day	Good	615

** Sleep quality on a scale of 1-5, 5 being the best. This is marked in the diary / report with smiley faces.

PARTICIPANT CODE	Day 2 Alcohol	Day 2 Medication	Day 2 Sleep Quality	Day 2 Stress state	Day 2 Reliability of detected state	Day 2 Work minutes
A	0	0	4	Good recovery	Good	0
B	0	4	4	Weak recovery	Good	480
C	0	2	4	Moderate recovery, but sleep duration is short	Good	480
D	0	0	4	Delayed nighttime recovery	Good	455
E	0	0	5	Physical overload	Good	480
F	0	1	5	Moderate recovery, but sleep duration is short	Moderate	660
G	0	5	2	Weak recovery	Good	630

PARTICIPANT CODE	Day 3 Alcohol	Day 3 Medication	Day 3 Sleep Quality	Day 3 Stress state	Day 3 Reliability of detected state	Day 3 Work minutes
A	0	0	4	Good recovery	Poor	645
B	0	4	4	Good recovery	Moderate	435
C	0	2	4	Good recovery	Good	480
D	0	0	3	Good recovery	Good	455
E	0	0	5	Delayed nighttime recovery	Good	0
F	2	1	5	Good recovery	Poor	0
G	0	6	5	Good recovery	Poor	0