RECOVERY OF RESCUERS FROM A 24-HOUR WORK SHIFT AND ITS ASSOCIATION WITH PHYSICAL FITNESS

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ABSTRACT

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The work of rescuers can be physically and psychologically very demanding so it is important for them to have sufficient recovery between work shifts. The purpose of this thesis was to study recovery of rescuers and to see if physical fitness is associated with recovery from work shifts. Heart rate variability (HRV) recordings reflect changes in the autonomic nervous system, and they were used for the analysis of stress and recovery. HRV was recorded for 96 hours, from the beginning of a 24-hour work shift to the beginning of the next shift. Physical fitness assessment included VO_{2max} estimation with a submaximal bicycle ergometer test, and maximal strength testing (isometric bench press and leg dynamometer). Salivary cortisol samples were collected 0, 15, and 30 min after awakening on the three resting days. Some HRV parameters showed enhanced autonomic control after the work shift. Stress percentage decreased from the work day to the 2nd rest day ($p<0.05$) and relaxation percentage increased after the work shift, but this increase was non-significant. Enhanced autonomic control did not extend to the last resting day in all variables. Square root of the mean squared differences between successive normal-to-normal intervals (RMSSD) and total power decreased with increasing rest. Maximal oxygen uptake (VO_{2max}) was associated with enhanced parasympathetic cardiac control. The effects of lower- and upper-body strength on recovery were less consistent, although increased lower body strength was in many cases associated with enhanced recovery. Cortisol awakening response was attenuated right after the work shift. In conclusion, some parameters reflecting autonomic control were enhanced after work shift and aerobic fitness was associated with increased recovery, but some of the results were inconsistent.

Keywords: firefighters, stress, recovery, heart rate variability, autonomic control, cortisol awakening response, physical fitness

ABBREVIATIONS

ANS	autonomic nervous system
ATP	adenosine triphosphate
BP	blood pressure
BMI	body mass index
CAR	cortisol awakening response
CNS	central nervous system
ECG	electrocardiography
HFP	high frequency power
HR	heart rate
HRV	heart rate variability
LFP	low frequency power
LF/HF	ratio of low frequency power to high frequency power
PCr	phosphocreatine
PPE	personal protective equipment
PSD	power spectral density
RMSSD	square root of the mean squared differences between successive normal-to-normal intervals
RPE	rating of perceived exertion
SCBA	self-contained breathing apparatus
SDNN	standard deviation of normal-to-normal intervals
TP	total power
ULF	ultra low frequency power
VLF	very low frequency power
VO_{2max}	maximal oxygen uptake

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1 INTRODUCTION

Firefighters, referred to “rescuers” in Finland, have a highly demanding occupation, where they are under heavy stress on a regular basis. They have to perform at physically demanding tasks but also have to face many psychologically challenging situations during rescue. Stress occurs when environmental demands exceed the adaptive capabilities of the organism resulting in psychological or physiological changes. If stress is prolonged or very intense, it can interfere with cognitive tasks and can affect performance negatively. (Barling et al. 2005, 220).

Rescuers work in 24-hour shifts, having one work shift and three full days of recovery (24 hours work – 72 hours recovery). During leisure time rescuers carry out different types of activities and some may even have a second job. The demanding nature of the occupation makes it necessary for rescuers to have adequate recovery during the days off from work. There have not been investigations on the whole 72-hour recovery period of rescuers after a 24-hour shift. Thus, the purpose of the present study is to find out what kind of changes in autonomic control can be seen during work shift and the recovery period in Finnish rescuers. To investigate stress and recovery, a 4-day HRV measurement and salivary cortisol measurements were conducted in rescuers from the Central Finland Fire Department in Jyväskylä. Also, physical fitness assessment was conducted to find out whether or not there is an association between physical fitness and recovery from the challenging shift work. This assessment included a submaximal bicycle ergometer test to determine aerobic fitness and isometric bench press and leg press tests to determine muscular strength.

Two common methods used to study physiological responses to stress are the measurement of the autonomic nervous system (ANS) using HRV and assessment of serum hormonal concentrations. When stress is present, HRV can be used to detect changes in ANS very rapidly, whereas hormonal changes may take hours or days to be observed. (Huovinen et al.

2009.). HRV measurements and salivary cortisol responses were used in this study to reveal stress and recovery processes in the body.

Stress response in the body. Stress reaction is a normal response of the body to a physically or psychologically demanding situation. During stress response there is an activation of the sympathetic nervous system (SNS) and withdrawal of the parasympathetic nervous system (PNS) (Filaire et al. 2010). The acute responses to stress include elevated blood pressure (BP), increased heart rate (HR), redistribution of blood from the gastrointestinal system to the muscles and the brain, release of energy (fat, glucose), suppression of reproductive functions, increased blood coagulation, suppressed pain sensitivity, and cognitive changes (Lundberg 2005). Also, the secretion of corticosteroids and catecholamines is increased in response to a stressor. A short-term stress response is beneficial, because it prepares the body to perform better in a demanding situation. Rapid shut-off of the stress response is important for rest and recovery. Repeated activation of the stress response without time for rest and recovery as well as prolonged activation will cause overexposure to stress hormones, high BP, and high levels of blood lipids leading to an increased risk of various health problems. (Lundberg 2005.).

Physical stress. Physical activity causes a disruption of homeostasis in the body which can be seen in autonomic modulation even hours after exercise. During hard training period, nocturnal HRV has been shown to decrease progressively up to 40%. There is a rebound during the lighter training period. If training intensity is kept low while increasing amount of physical stress, HRV has been reported to remain constant. Overreaching or overtraining periods have been reported to decrease HRV and diminish athletic performance. Decreases in HRV have also been found during physically demanding periods in occupational work. (Hynynen 2011.).

Emotional stress. Vagal modulation of heart appears to be sensitive to recent experiences of persistent emotional stress regardless of age, gender, respiration rate or cardiorespiratory rate. Chronic work stress and acute pre-sleep stress have been shown to decrease HRV and hence, increase stress levels in the body. (Filaire 2010; Hynynen 2011.).

Recovery. Recently, the importance of recovery from work-related strain has been acknowledged. A good balance between activation and rest is crucial for health and survival. The inability to rest and recover from work demands can have severe consequences. The health and well-being of an individual are dependent on appropriate periods of rest: either short-term periods such as lunch breaks and evenings or longer periods such as weekends and vacations. One of the most important times for rest and recuperation is sleep, when a number of important anabolic processes are activated. (Kinnunen et al. 2006; Lundberg 2005; Ronka et al. 2006.).

Rescuers offer an interesting subject population for this study because of the unique demands of their occupation. All the different stressors combined can challenge the ability to fully recover in an adequate time frame, and this can be studied by looking at the changes in ANS function.

2 REVIEW OF LITERATURE

2.1 Job description of rescuers

Rescuers in Finland undergo training that generally lasts 1.5 years. Half of rescuers’ 24-hour shift is firefighting tasks and half of it is paramedic work in an ambulance. This is why they have to be prepared for a variety of duties and have vigorous training in the classroom and out on the field. During their shift they may have to perform firefighting, surface rescue, underwater rescue diving, deal with storm damages and other natural disasters, hazardous material spills, fire prevention and educating people about it, rescuing animals, patient transportation, giving first aid, inspecting smoke alarms, testing, checking and maintaining firefighting equipment, and exercising at the station (Helsinki City Fire Fighters 2007; Ilmarinen et al. 2008; Smith 2001).

There is no typical shift for rescuers. They never know if they are going to have time to just take it easy and exercise at the station or if there will be alarms throughout the shift. During one shift they may be bored at the station while during another shift they may not get any breaks at all. The Jobs Rated Almanac ranks firefighters as having the most stressful job in the United States. (Boxer et al. 1993.).

There have been numerous studies investigating the health, physical demands, and physical fitness of rescuers. In addition to an increase in illness and a feeling of decreased ability to work in recent years, rescuers have a large amount of mental problems, sleep difficulties, and alcohol use. These reflect a psychologically demanding environment and the problems it brings with it. (Punakallio & Lusa, 2011.).

2.1.2 Physical demands of rescuers

With such a broad range of duties, rescuers encounter many dangers in their work. They do hard physical work and face external physical stress. They have to deal with hot, polluted, and humid environments, toxic fumes, dangerous products of combustion, high radiant heat loads, and an overall chaotic work environment. However, the leading cause-of-death of rescuers is sudden cardiac event (Barger et al. 2009; Donovan et al. 2009; Michaelides 2008, 4; Smith 2011), not injury, as one might expect. Rescuers have high physical demands; good aerobic fitness, anaerobic capacity, muscular strength and endurance, and good control of bodily movements are required for safe and efficient performance (Gledhill & Jamnik 1992; Holmer & Gavhed, 2007; Punakallio & Lusa 2011; Smith 2011). Some of the most physically demanding tasks are smoke diving, extinguishing fires, working on roofs, and carrying patients and victims. Accident risk is also high in these tasks. Changing temperature, dim lighting, difficult passages, and wearing personal protective equipment (PPE) and the self-contained breathing apparatus (SCBA) increase the physical demands placed on rescuers. On top of this, tiredness caused by long shifts adds to the overall stress. (Punakallio & Lusa 2011.).

The many stressors encountered during firefighting result in great physiological strain, above all to the thermoregulatory and cardiovascular systems. The thermoregulatory demands are high because blood is needed in the skin to cool off the body while hard-working muscles need much of the blood at the same time. Rescuers can also have major fluid loss when working hard in hot environments. The insulative properties of PPE can complicate thermoregulation during firefighting tasks. Firefighting activities also lead to near maximal heart rates, while stroke volume decreases (due to fluid loss) and blood pressures can rise and drop quickly below resting values after the firefighting activity. Plasma volume decreases because of sweating, which leads to hemoconcentration. This means that there is an increase in the concentration of red blood cells and blood viscosity. (Smith 2011.).

High heart rates during real-life firefighting may contain a considerable portion of psychological stress (Boxer et al. 1993; Holmer & Gavhed 2007). Nonetheless, studies using heart-rate monitoring during simulated firefighting exercises with limited psychological stress levels show that rescuers easily reach near maximal or even maximal heart rates during simulated tasks. Holmer and Gavhed (2007) studied the metabolic and respiratory demands of firefighting. They found that for an individual with high maximal aerobic capacity a given submaximal work load causes less relative strain compared to an individual with a lower aerobic capacity.

Respiratory demands are linked to the metabolic requirements. In simulated firefighting tasks, researchers have found that at very high activity levels, minute ventilation averaged around 100 l/min with individual extremes as high as 140 l/min. These values are often seen in athletes in endurance sports. (Holmer & Gavhed 2007).

Aerobic fitness. The performed tasks of rescuers, especially smoke diving, put a lot of strain on the cardiovascular system. Maximal oxygen uptake is a well-defined measure of the aerobic power of an individual (Holmer & Gavhed 2007). The National Fire Protection Association (NFPA) Standard on Occupational Medical Programs for Fire Departments recommends that firefighters should have a minimal aerobic capacity of 42 ml/kg/min. Gledhill and Jamnik (1992) analyzed physical demands of firefighting tasks and based on their findings recommend a VO_{2max} of 45ml/kg/min for firefighters. Rescuers with high levels of cardiovascular and muscular fitness can perform their job more effectively and safely and are less likely to jeopardize the safety of their fellow firefighters or the public they serve (Smith 2011).

Cardiac events are disproportionately related to fire suppression activities, with rescuers having a 10- to 100-fold increased risk of experiencing a fatal cardiac event after fire suppression versus normal duties at the station. Knowing that sudden cardiac events are the leading cause of on-duty-deaths in this profession, rescuers should have a high level of cardiovascular fitness in order to improve performance and decrease the risk of on-the-job fatalities associated with strenuous activity. (Holmer & Gavhed 2007; Smith 2011.).

Anaerobic fitness. Rescuers must also have a high anaerobic capacity to safely and efficiently perform certain tasks. Strenuous firefighting relies not only on aerobic but also anaerobic energy sources, and high lactate values (6-13 mmol/l) have been reported following demanding firefighting simulations (Smith 2011).

Muscular system. It is essential for rescuers to have good function of the muscular system because of the physical demands of firefighting and rescue operations. The tasks, rescuers have to perform, require good muscular strength and endurance, but also the heavy equipment puts an extra load on the body while performing these tasks. Rescuers need to be able to climb stairs and ladders, carry and use heavy tools, and perform difficult rescue operations. The objects which the rescuers need to carry, lift, and pull may often weigh 35-60 kg. Victim rescues also require a lot of muscular strength. (Gledhill & Jamnik 1992; Smith 2011).

Environment and gear. Firefighters work in dangerous environments; they encounter extreme temperatures, toxic smoke, and chaotic conditions that include loud noise and low visibility. The PPE puts a lot of physiological stress on the body not only because of its weight (~22kg), but also because of its insulative properties and restrictiveness. Performing hard muscular work in hot environments leads to thermal strain. Rescuers face hyperthermia (elevated core temperature) and dehydration frequently in their firefighting tasks. These two factors together hasten the onset of fatigue and limit work time, add to cardiovascular strain, lead to fatal heat illnesses, impair cognitive function, and increase the risk of injury. (Smith 2011).

There is great individual variation in energetic requirements for similar type of work in rescuers. Some of it can be explained by the individual variation in body mass. Much of the work involves transportation and movement of the body and the protective equipment. A taller person has a larger body mass and requires more energy for movement at a given speed. But the protective equipment has a larger impact on smaller persons, because the carried weight is relatively higher than on the taller persons. Thus, the physiological strain becomes relatively higher at similar types of work for small persons. (Holmer & Gavhed 2007). Williams-Bell and others (2010) found that only moderate physical demands while wearing full protective gear and SCBA put a lot of physiological strain on firefighters. Punakallio et al. (2003) report that the use of standard European fire-protective equipment (FPE), including fire-protective clothing and SCBA, decreases maximal walking speed and increases working time by an average of 25%. Cheung (2010) found that for submaximal work in a thermoneutral environment, the use of SCBA weighing 15 kg increased cardiorespiratory strain by 20%, and significantly increased thermal strain. The strain caused by SCBA was partly due to the weight of the equipment.

*Ageing***.** There has been a lot of talk about the retirement age of Finnish rescuers. Today Finnish rescuers get to retire at an age of 63-68 (previously 55 years), thus it is important to see what kind of changes occur in the body of a rescuer when they age. According to a study conducted by Statistics Finland the life expectancy of a 25-year old rescuer is 50.5 years. This means that a rescuer is expected to live until 75.5 years. Interestingly, an investigation conducted by the Helsinki Fire Department found that the life expectancy of a Finnish rescuer is only 65 years. (Siekkinen et al. 2008). The current life expectancy of a newborn baby boy in Finland is 76,3 years (“Elinajanodote” 2009). The Finnish Institute of Occupational Health conducted a longitudinal study on rescuers over a 13-year period and looked at changes in health, and physical and psychological functionality in firefighters of different ages. On the average, functionality of muscular and cardiorespiratory systems declined in 13 years and BMI increased. Individually, the decline in aerobic fitness was 4% per year at most. For some, physical fitness remained the same or even improved over years. Regular exercise, and especially weekly exercise predicted well-maintained aerobic and muscular fitness. In 2009, firefighters aged 53-57 had higher fat percentage, fat mass, and BMI than recommended for their health and job demands. Muscle mass was also low.

Moreover, stiffening of arteries was associated with higher age. At least moderate endurance protected individuals from stiffening of arteries. (Punakallio & Lusa 2011).

On the average, there is a 5ml/kg/min decline per decade in maximal oxygen uptake between 25 and 65 years of age. Muscular strength peaks around 25 years of age and remains relatively constant until 35-40 years. There is a gradual decline thereafter. A major decline in maximal performance of muscles can be seen after 50-60 years. Force production decreases, especially, due to inactivity and decreased muscle mass. Adenosine triphosphate (ATP), phosphocreatine (PCr), and glycogen stores decrease and the effectiveness of enzymes decreases, which can lead to exhaustion due to hastened fatigue. Recovery also takes more time as one ages. (Siekkinen et al. 2008.).

A number of studies have examined the relationship between age and safety among firefighters. Tasks requiring high aerobic capacity or significant motor coordination (firefighting, rooftop rescue) were named by older firefighters as the most demanding tasks in the study conducted by the Finnish Institute of Occupational Health (Punakallio & Lusa 2011). An age-related increase in falls is reported by almost all studies that have examined the type of accidents with age. This may be due to an age-related increase in equilibrium disorders or other physiological or cognitive modifications that impede individuals from performing adequately in the required time frames and under critical situations. (Holmer & Gavhed 2007.).

Smoke diving. One of the most physically demanding tasks for rescuers is smoke diving. In smoke diving a firefighter has to make a way into a room filled with smoke gases. A rescuer who wants to be a smoke diver in Finland has to have a VO_{2max} of $\geqq$36 ml/kg/min or $\geqq$3.0 l/min. The average oxygen consumption during smoke diving is 2.8 l/min but occasionally it can be much higher. Good muscular strength and muscular endurance are also required because performing in the heavy smoke diving equipment puts a lot of stress on the human body. (Punakallio & Lusa 2011.).

Although many studies conclude that firefighting has extreme physical requirements, Bos et al. (2004) report that for actual firefighting the energetic intensity is moderate. However, the peak loads can be very high in energetic requirements and can lead to excessive fatigue. Many studies focus on live- or simulated firefighting drills, so they only take into account the firefighting situation. During a 24-hour shift firefighters have time to rest between alarms and this rest is most likely adequate for recovery (Bos et al. 2004). Figure 1 summarizes the stressors encountered in firefighting.

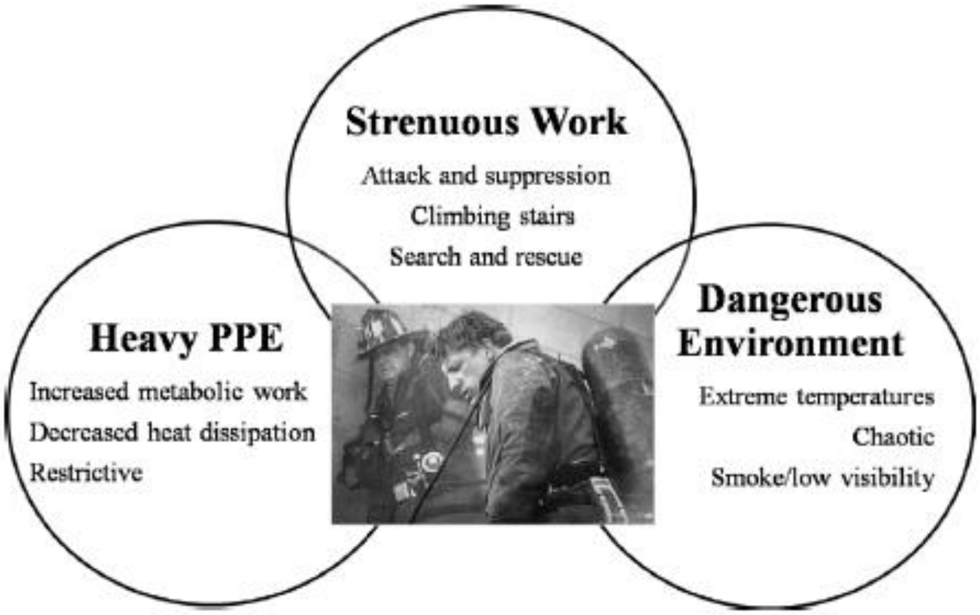


FIGURE 1. Different job stressors in firefighting. (Smith 2011).

Exercise. Physical training is encouraged and often allowed during work hours of rescuers (Holmer & Gavhed 2007). Aerobic training provides many health benefits, such as improved body composition, serum lipids, glucose metabolism, and VO_{2max}. Moderate-intensity aerobic exercise is widely recommended for health benefits, but higher intensity aerobic exercise training may promote weight loss and cardiovascular improvements to a greater extent. Given the physical demands of firefighting, and the high proportion of line-of-duty deaths attributed to cardiac events, it is important that firefighters include endurance training in their training regimen.

Muscle strength and endurance are also very important for firefighters. Resistance training develops and maintains muscle mass and function and is associated with a decreased risk of all-cause mortality and enhanced glucose metabolism. Resistance training improves work capacity and is likely to provide protection against injuries, especially muscular strains, on the fire ground. (Smith 2011.). According to the investigation done by the Finnish Institute of Occupational Health, firefighters exercise regularly more than the average population (Punakallio & Lusa 2011). Figure 2 summarizes firefighting-specific benefits of regular exercise.

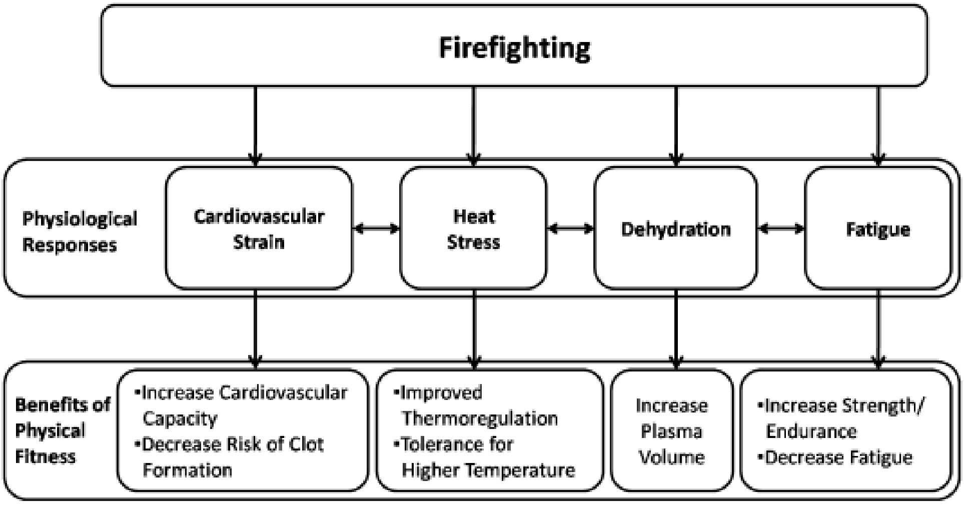


FIGURE 2. Primary physiological responses to firefighting and the benefits of physical fitness. (Smith 2011).

2.1.3 Psychological demands of rescuers

Rescuers experience many psychologically challenging situations in their work. They may have to face devastating rescue scenes, victims of vehicle accidents and fires and perform in dangerous operations. Also, they often have to perform in unknown conditions with time constraint. Knowing that civilians are in danger gives rescuers a critical sense of time urgency. (Michaelides 2008, 12; Punakallio & Lusa 2011; Smith 2011.).

Like the emergency situation, also being in the role of a firefighter puts psychological pressure on rescuers. In addition to their own safety, rescuers are responsible for the safety of victims often in very difficult circumstances. Rescuing helpless victims and knowing that there are children in a house that is on fire, are the most psychologically demanding situations in rescue. Shift work adds to the physical and psychological burden of the job. Shift- and night work amplify some environmental stress factors, such as effects of noise and improper lighting. (Punakallio & Lusa 2011; Savusukellusohje 2002.).

2.1.4 Challenges with shift work

Working prolonged shifts and at night challenge the rhythmicity of many physiologic systems, such as sleep, alertness, performance, metabolism and hormones such as melatonin and cortisol. Shift work is associated with decrements in workplace performance, health, and safety. Cardiovascular disease, increased accident risk, disturbed sleep and increased fatigue are all associated with shift work. (Barger et al. 2009; Folkard & Tucker 2003; Harrington 2001; Åkerstedt 2003). Sleep deprivation has been shown to have a causal role in obesity, metabolic syndrome, glucose intolerance/diabetes, and increased accidents and errors (Arendt 2010, see figure 3). Astonishingly, the International Agency for Research on Cancer, a part of the World Health Organization, reported that shift work is possibly carcinogenic to humans (Barger et al. 2009).

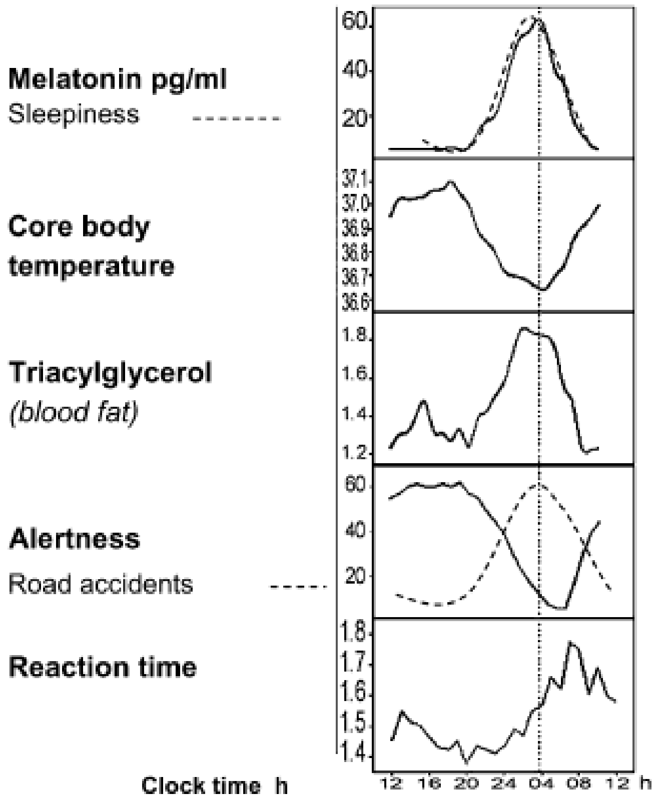


FIGURE 3. Diagrammatic examples of circadian rhythms. (Arendt 2010).

According to Åkerstedt (2003), shift workers report more sleep disturbances than day workers. Also, sleep following a night shift is reduced by 2-4 hours. Increased sleepiness occurs not only during night work but also during days off and is associated with increased risk of accidents. The onset of fatigue is probably the most obvious direct result of working long hours (Spurgeon et al. 1997).

The major health problem with shift work is the conflict between unusual working hours and the biological clock. The circadian pacemaker is located in the suprachiasmatic nucleus of the hypothalamus and is responsible for a 24-hour rhythm in essentially all physiological and psychological functions (e.g. body temperature, respiratory rate, urinary excretion, cell division, hormone production). High performance and alertness are promoted during the day, especially late afternoon. Decrements in alertness and performance can be seen at night, with worst performance decrements between 3:00 and 6:00. Also quality of sleep changes in different circadian phases so even if a shift worker gets to sleep during the day, sleep will be shorter and less consolidated than sleep during the night. (Barger et al. 2009; Harrington 2001; Åkerstedt 2003.).

Rectal temperature has a maximum at 17:00 and a minimum at 5:00. Melatonin has a maximum at 04:00 in the morning and a minimum at 16:00, and seems closely related to temperature and alertness. (Harrington 2001; Åkerstedt 2003.).

The biological clock can be adjusted by exogenous factors such as light-dark cycle, social climate, and work schedules. Some studies report that there is a reduction in complaints of fatigue after objective improvement in physical fitness. Taking care of physical fitness, diet, and sleep of sufficient amount and quality can help with managing shift work. It is important to remember that ageing shift workers do not tolerate shift work as well as younger workers. With age, sleep becomes shorter and more fragmented. (Harrington 2001.).

Issues with sleep. There are four major physiologic determinants of alertness and performance in healthy subjects: 1) circadian phase (time of day), 2) number of hours awake (acute sleep deprivation), 3) nightly sleep duration (chronic sleep deprivation), 4) and sleep inertia (impaired performance upon waking). Each of these four factors has independently been associated with decrements in neurobehavioral performance and an increased risk of accidents. Shift workers experience all of them to some degree, varying according to occupation. (Barger et al. 2009.).

According to Barger and coworkers (2009), there are more industrial and driving accidents at night compared to the day. Acute sleep deprivation causes decrements in alertness and performance. Compared with the first hour, there is more than a 15-fold increase in the risk of a fatigue-related fatal crash after 13 hours of driving. The impairment of cognitive performance has been corresponded to a blood alcohol concentration of 0.05% after 19 hours of sustained wakefulness and a concentration of about 0.10% after 24 hours. Arendt (2010) supports this by reporting that 20-24 hours without sleep can lead to decrements in performance equivalent to an illegal level of alcohol in the blood (see figure 4). Rescuers working a 24-hour shift may not always get to nap during their shifts, so the risk of accidents can occasionally be very high.

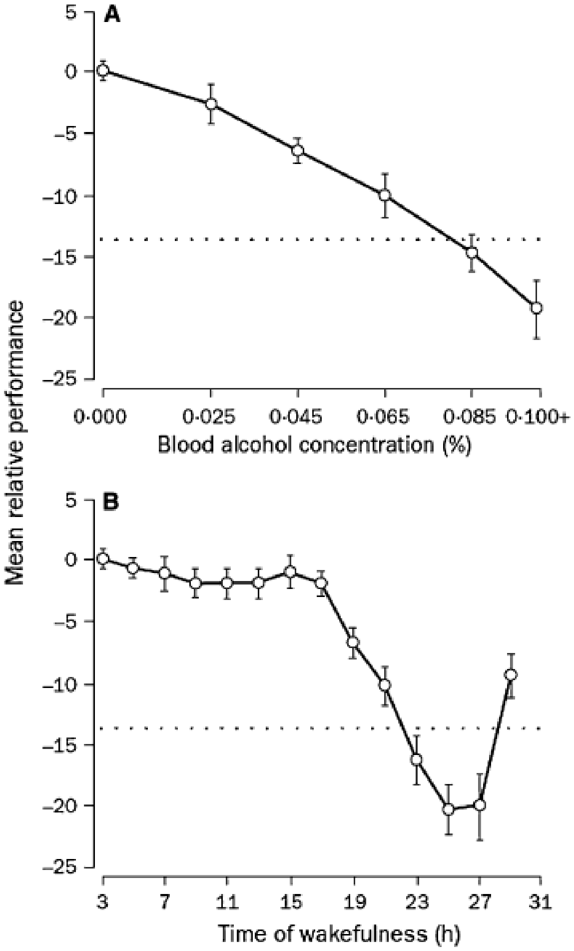


FIGURE 4. Comparison of the effect of blood alcohol concentration and hours of wakefulness on task performance. Higher scores indicate better performance. (Arendt 2010).

The detrimental effects of each of the four physiologic determinants of alertness are worsened by the extended shifts worked by firefighters. Rescuers regularly work during the biological night when alertness is the lowest. They also work long hours so they experience acute sleep deprivation regularly. Firefighters are also regularly exposed to chronic partial sleep deprivation because they may repeatedly fail to gain adequate recovery sleep after extended shifts. Also, firefighters who do manage to sleep when on an overnight shift are often asked to perform emergent actions immediately upon awakening, when sleep inertia is maximal. This impairment in performance is normal even in individuals who wake up at their normal circadian phase after sufficient amount of sleep. The effect can take 2 to 4 hours to fully dissipate. The two leading causes of death in firefighters—heart disease and motor vehicle accidents —are closely associated with sleep disorders and fatigue. (Barger et al. 2009.).

In conclusion, both safety and productivity are reduced at night. There may be many underlying factors, including impaired health, a disturbed social life, shortened and disturbed sleep, and disrupted circadian rhythms. (Folkard & Tucker 2003.).

2.2 Autonomic nervous system

As the name suggests, the autonomic nervous system is largely autonomous; it is almost fully independent of our will. It maintains the homeostasis of the body by controlling HR, BP, body temperature, respiratory airflow, papillary diameter, digestion, energy metabolism, defecation, and urination in response to daily challenges, such as exercise or postural changes. There is a complex interaction between the two portions of ANS to maintain a dynamic adaptive state in response to internal and external demands: sympathetic and parasympathetic (also known as vagal) divisions. The two divisions differ in anatomy and function but they often innervate the same target organs and may work together or against each other in their function. Both of these divisions are concurrently active but according to the needs of the body the balance between the sympathetic and parasympathetic tone changes. (Martinmäki 2009; Saladin 2008, 469.).

The sympathetic division of ANS is responsible for preparing the body for physical activity. Its action is commonly known as the “fight or flight”-response but normally the effects are more subtle. The sympathetic influence increases alertness, HR, BP, pulmonary airflow, blood glucose concentration, and blood flow to cardiac and skeletal muscle. It also reduces blood flow to the skin and digestive tract. (Saladin 2008, 469.).

The parasympathetic division has an opposite, calming effect in the body. Reduced energy expenditure, waste elimination, and digestion are associated with parasympathetic activity. (Martinmäki 2009; Saladin 2008, 469.).

The origin for both divisions is in the central nervous system (brainstem and spinal cord). From these nuclei in the central nervous system (CNS), preganglionic efferent fibers exit and terminate in motor ganglia. The sympathetic preganglionic fibers leave CNS through the thoracic and lumbar spinal nerves. The parasympathetic preganglionic fibers leave CNS through the cranial nerves and the third and fourth sacral spinal roots (see figure 5). Most of the sympathetic preganglionic fibers lead to the nearby paravertebral ganglia (longitudinal series of ganglia that lie adjacent to the vertebral column). The remaining sympathetic preganglionic fibers terminate in prevertebral ganglia, which lie in front of the vertebrae. From the ganglia, postganglionic sympathetic fibers run to the target cells. Some preganglionic parasympathetic fibers terminate in parasympathetic ganglia located outside the target organs. The majority of parasympathetic preganglionic fibers terminate on ganglion cells distributed diffusely or in networks in the walls of the innervated organs. (Saladin 2008, 470-475.).

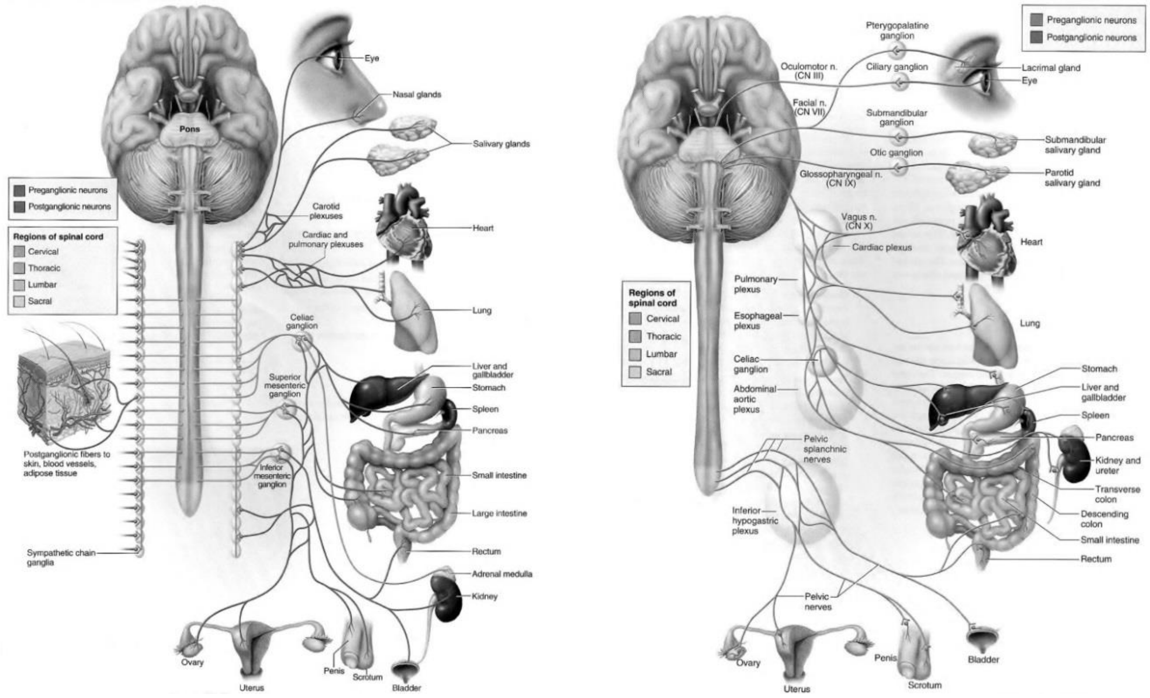


FIGURE 5. Anatomy of the sympathetic (left) and parasympathetic (right) nervous system. (Saladin 2008, 472-475).

The opposing actions of the two divisions of ANS can be explained by the neurotransmitters their neurons secrete and by the differing neurotransmitter receptors. The most important transmitters in ANS are acetylcholine and norepinephrine. The peripheral nervous system fibers that release acetylcholine are called cholinergic fibers. Almost all efferent fibers leaving CNS and most parasympathetic postganglionic and a few sympathetic postganglionic fibers (innervating sweat glands and some blood vessels) are cholinergic. Most sympathetic post ganglionic fibers release norepinephrine, and these fibers are called noradrenergic. Most autonomic nerves also release several transmitter substances (cotransmitters) in addition to the primary transmitter. (Saladin 2008, 477-478).

The cardiovascular system is mostly controlled by ANS. Without extrinsic control of the heart, there are pacemaker tissues in the heart that maintain the heart rhythm at 90-120 beats per minute (bpm). Extrinsic control including reflexes and hormones, however, allow a heart rhythm of 28-220 bpm, showing that heart rate and rhythm are fundamentally controlled by ANS. Like stated before, the parasympathetic influence on heart rate is mediated via release of acetylcholine. The sympathetic influence on heart rate is mediated by release of epinephrine and norepinephrine. Vagal tone dominates under resting conditions, and vagal modulation is largely responsible for variations in heart period. Many studies have shown that the functioning of ANS plays a substantial role in cardiovascular health and disease. (Martinmäki 2009; Task Force 1996.).

2.3 Measurement of stress

2.3.1 Heart rate variability

Heart rate variability (HRV) is the temporal beat-to-beat variation in successive RR intervals on an electrocardiographic (ECG) recording, and it reflects the regulation of the heart rate (Nicolini et al. 2012, see also figure 6 below). Although heart rate is relatively stable, there can be considerable differences in the time between two heart beats (Routledge et al. 2010). HRV is generally accepted as an estimate of the autonomic, especially parasympathetic, control of the heart (Carter et al. 2003; Hynynen et al. 2011; Martinmäki 2009; Nicolini et al. 2012). This non-invasive method has increasingly been used to provide additional insight into physiological and pathological conditions and to enhance risk stratification after myocardial infarction (Acharya et al. 2006; Task Force 1996), to survey diabetic patients (Acharya et al. 2006), to examine training load, disturbance of body's homeostasis, and recovery state after training (Myllymäki et al. 2012). HRV is an effective tool in detecting stress in working population and in athletes. It has classically been used to measure resting autonomic control (Sandercock & Brodie 2006). The human heart and ANS respond to environmental stimulation, and HRV is affected by both psychological and physiological stimuli.

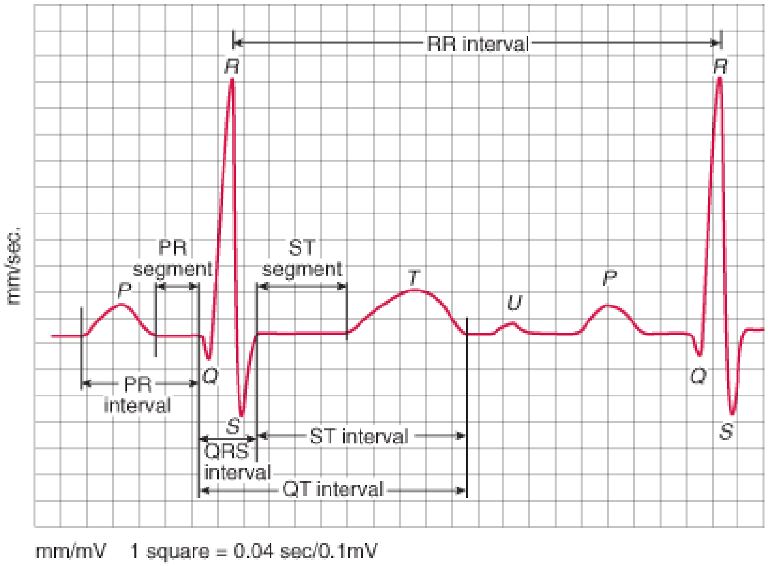


FIGURE 6. ECG waves. (The Merck Manual for Health Care Professionals, 2011).

Chronic emotional stress seems to have an impact on vagal modulation of the heart regardless of age, gender, respiration rate or cardiorespiratory fitness. HRV is normally high during rest, especially during the night when you are sleeping. The night sleep seems to be the most important period for health because this is when both physiological and psychological recovery happen. (Hynynen et al. 2011.). In healthy individuals HRV increases during nighttime. This increase in HRV during night is blunted by acute stress (Thayer et al. 2010).

In the 1960’s, Hon and Lee showed clinical relevance to HRV when they demonstrated that HRV was a global index of fetal distress (Task Force 1996). They found that fetal distress was preceded by changes in interbeat intervals before one could see a change in heart rate. As is reported in Task Force (1996), in 1977, Wolf and coworkers were the first researchers to illustrate that reduced HRV is associated with a higher risk of post-infarction mortality, which was confirmed by multiple research groups the next decade. Today, the clinical use of HRV focuses on evaluating autonomic modulation of sinus node in normal subjects and in patients with cardiac and non-cardiac diseases and most of all, on identifying patients at risk for an increased cardiac mortality (Lombardi 2002).

HRV normally decreases with age because of a decrease in autonomic modulation and a decrease in aerobic capacity (Hynynen 2011). This reduction begins in childhood. Infants have high sympathetic activity that quickly decreases between 5 and 10 years of age. (Acharya et al. 2006.). There are also heritable factors that affect variations in HR and HRV. Gender differences have been found but they could potentially have to do with other factors related to gender. (Hynynen 2011.).

2.3.2 Measurement and analysis of HRV

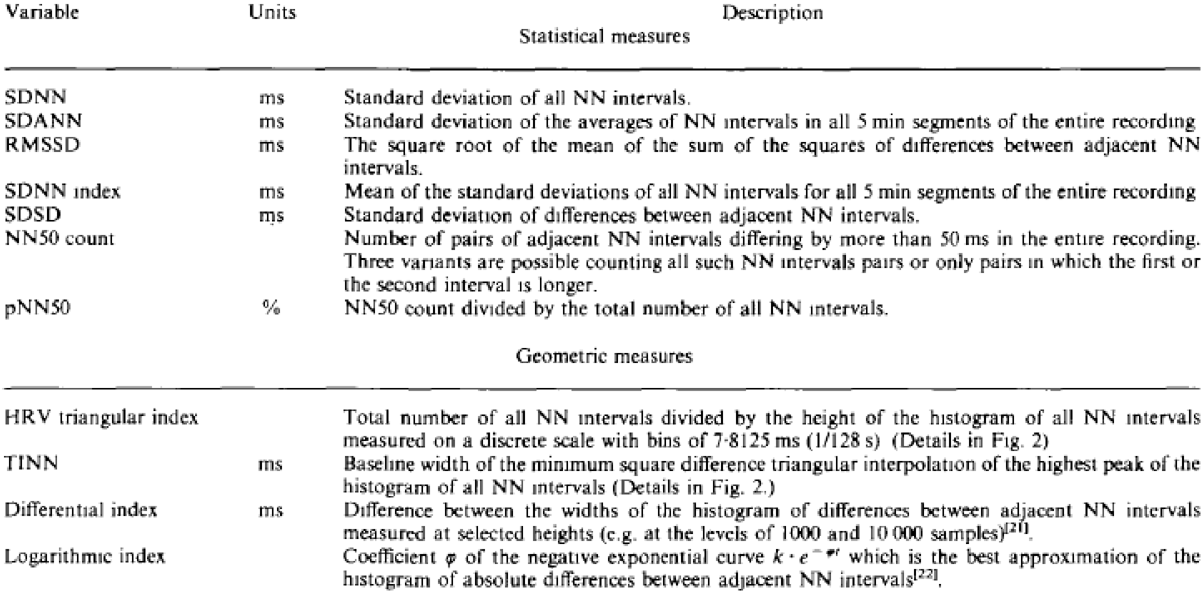
Measurement of HRV usually requires a high-quality ECG with a sampling rate over 250 Hz and an accurate algorithm to detect QRS complexes. Ambulatory HRV recorders, called Holter monitors, have been developed to enable recording outside of laboratories. Firstbeat Technologies Ltd. has developed a portable HRV recorder called Firstbeat BODYGUARD (Firstbeat Technologies Ltd., Jyväskylä, Finland) that detects RR interval data (Figure 7). There are also wireless heart rate monitors that have an elastic electrode belt that detects RR intervals (Gamelin et al. 2006) and those are commonly used during exercise. HRV may be analyzed by a number of methods, but the most commonly used and highly validated methods are time-domain and frequency-domain (also known as power spectral density) methods (Hynynen 2011; Martinmäki 2009).

FIGURE 7. Firstbeat BODYGUARD RR interval recorder. (BODYGUARD 2013).

Time domain methods. Time domain methods are probably the simplest way to measure HRV. HR at any point in time or the intervals between successive normal complexes are determined. From a continuous electrocardiographic record (ECG) each QRS complex is detected and the normal-to-normal (NN) intervals are determined (Task Force, 1996). A list of selected time domain measures can be seen in Table 1.

The most commonly used index derived from the differences of the NN intervals is the square root of mean squared differences of successive NN intervals. This is called the RMSSD, and it estimates high frequency variation in HR and is considered to be mainly vagally mediated (Hynynen 2011).

TABLE 1. Time domain measures of HRV. (Task Force 1996).



Variable	Units	Description
		Statistical measures
SDNN	ms	Standard deviation of all NN intervals.
SDANN	ms	Standard deviation of the averages of NN intervals in all 5 min segments of the entire recording
RMSSD	ms	The square root of the mean of the sum of the squares of differences between adjacent NN intervals.
SDNN index	ms	Mean of the standard deviations of all NN intervals for all 5 min segments of the entire recording
SDSD	ms	Standard deviation of differences between adjacent NN intervals.
NN50 count		Number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording. Three variants are possible counting all such NN intervals pairs or only pairs in which the first or the second interval is longer.
pNN50	%	NN50 count divided by the total number of all NN intervals.
		Geometric measures
HRV triangular index		Total number of all NN intervals divided by the height of the histogram of all NN intervals measured on a discrete scale with bins of 7·8125 ms (1/128 s) (Details in Fig. 2)
TINN	ms	Baseline width of the minimum square difference triangular interpolation of the highest peak of the histogram of all NN intervals (Details in Fig. 2.)
Differential index	ms	Difference between the widths of the histogram of differences between adjacent NN intervals measured at selected heights (e.g. at the levels of 1000 and 10 000 samples)[21].
Logarithmic index		Coefficient φ of the negative exponential curve $k \cdot e^{-\varphi t}$ which is the best approximation of the histogram of absolute differences between adjacent NN intervals[22].

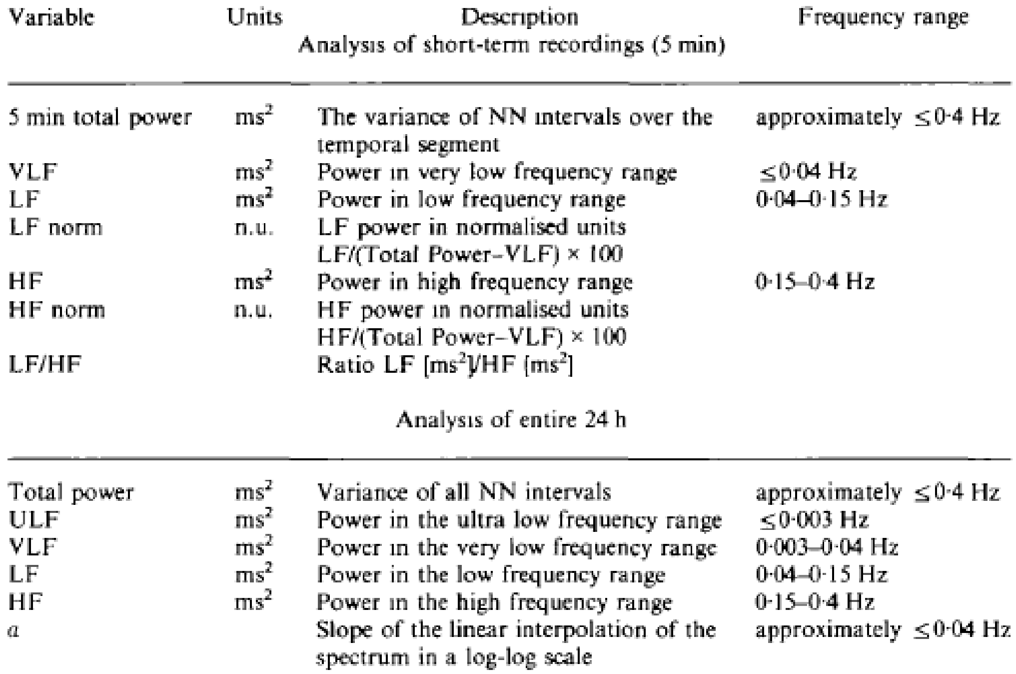
Frequency domain methods. Frequency domain analysis, also called power spectral density (PSD) analysis, decomposes the NN interval data into its frequency components and quantifies them in their relative intensity, termed power. It provides information how overall HRV is distributed as a function of frequency (Carter et al. 2003; Hynynen 2011; Martinmäki 2009). Methods for the calculation of PSD may be generally classified as non-parametric and parametric (Task Force 1996). The most commonly used methods are nonparametric Fast Fourier Transformation and parametric autoregressive modeling (Hynynen 2011; Martinmäki 2009).

Four frequency bands can be identified in a recording: high frequency (HF), low frequency (LF), very low frequency (VLF), and ultra-low frequency (ULF) power (Bigger et al. 1992). The HF power (0.15-0.40 Hz) reflects vagal modulation primarily by breathing. The LF power (0.04-0.15 Hz) reflects modulation of sympathetic or parasympathetic tone by baroreflex activity (Bigger et al. 1992; Carter et al. 2003). VLF power (<0.04 Hz) shows a relative increase in patients with congestive heart failure and is the lowest-frequency band that can be estimated by the 5-minute method. The physiological mechanisms for VLF and ULF (<0.0033 Hz) power have not been identified (Bigger et al. 1992), yet they account for more than 90% of the total power in a 24-hour heart period power spectrum. Hypotheses about the processes modulating ULF and VLF powers of the heart period power spectrum include temperature regulation and fluctuations in activity of the renin-angiotensin system. Together, HF and LF powers account for only about 6% of the total power in a 24-hour heart period power spectrum (Bigger et al. 1992).

The LF/HF ratio has generally been accepted as an indicator of sympatho-vagal balance (Bigger et al. 1992; Lombardi 2002). High values for the ratio suggest predominance of sympathetic nervous activity (Bigger et al. 1992). Increased mental stress increases the ratio (Huovinen et al. 2009).

Long-term recordings. Spectral analysis may also be used to analyze the sequence of NN intervals in the entire 24-hour period. The result then includes ULF, in addition to VLF, LF and HF components. If mechanisms responsible for heart period modulations of a certain frequency remain unchanged during the whole period of recording, the corresponding frequency component of HRV may be used as a measure of these modulations. If the modulations are not stable, interpretation of the results of frequency analysis is less well defined. In particular, physiological mechanisms of heart period modulations responsible for LF and HF power components cannot be considered stationary during the 24-hour period. Thus, spectral analysis performed in the entire 24-hour period as well as spectral results obtained from shorter segments averaged over the entire 24-hour period provide averages of the modulations attributable to the LF and HF components. Such averages obscure detailed information about autonomic modulation of RR intervals available in shorter recordings. The spectral analyses of short- and long-term electrocardiograms should always be strictly distinguished when interpreting HRV measures. (Task Force 1996.).

TABLE 2. Frequency domain measures of HRV. (Task Force 1996).



Variable	Units	Description	Frequency range
		Analysis of short-term recordings (5 min)	
5 min total power	ms^2	The variance of NN intervals over the temporal segment	approximately ≤0·4 Hz
VLF	ms^2	Power in very low frequency range	≤0·04 Hz
LF	ms^2	Power in low frequency range	0·04–0·15 Hz
LF norm	n.u.	LF power in normalised units LF/(Total Power–VLF) × 100	
HF	ms^2	Power in high frequency range	0·15–0·4 Hz
HF norm	n.u.	HF power in normalised units HF/(Total Power–VLF) × 100	
LF/HF		Ratio LF [ms^2]/HF [ms^2]	
		Analysis of entire 24 h	
Total power	ms^2	Variance of all NN intervals	approximately ≤0·4 Hz
ULF	ms^2	Power in the ultra low frequency range	≤0·003 Hz
VLF	ms^2	Power in the very low frequency range	0·003–0·04 Hz
LF	ms^2	Power in the low frequency range	0·04–0·15 Hz
HF	ms^2	Power in the high frequency range	0·15–0·4 Hz
a		Slope of the linear interpolation of the spectrum in a log-log scale	approximately ≤0·04 Hz

Spectral analysis of 24-hour recordings shows that in normal subjects LF and HF expressed in normalized units exhibit a pattern and reciprocal fluctuations, with higher values of LF in the daytime and of HF at night. These patterns become undetectable when a single spectrum of the entire 24-hour period is used or when spectra of subsequent shorter segments are averaged. LF and HF can increase under different conditions. An increased LF (expressed in normalized units) is observed during 90° tilt, standing, mental stress and moderate exercise in healthy subjects, and during moderate hypotension, physical activity and occlusion of a coronary artery or common carotid arteries in conscious dogs. Conversely, an increase in HF is induced by controlled respiration, cold stimulation of the face and rotational stimuli. Previous studies have shown that HR is lower during the night than during daytime and HRV during daytime indicates relative sympathetic dominance, while the night is characterized by parasympathetic, or vagal dominance. (Rusko et al. 2006.).

It is important to note that HRV measures fluctuations in autonomic inputs to the heart rather than the mean level of autonomic inputs. Thus, both autonomic withdrawal and a high level of sympathetic input lead to diminished HRV (Task Force 1996).

2.3.3 Cortisol as a measure of stress

The golden standard for evaluating work stress has been urinary and blood cortisol. Cortisol can also be measured from saliva. Salivary cortisol has been shown to be an excellent indicator of unbound concentrations of cortisol in serum (Hansen et al. 2008). The benefit of salivary cortisol samples is that they are easy to sample and non-invasive. Cortisol levels have been shown to be a reliable biological marker for adrenocortical activity, and acute and chronic stress. (Lundberg 2005; Rusko et al. 2006.).

The hypothalamic pituitary adrenocortical (HPA) system is activated due to psychological or physical stress. It is responsible for the secretion of cortisol. Adrenocorticotropic hormone (ACTH) is released from the pituitary gland and regulates the secretion of cortisol from the adrenal cortex. Secretion of cortisol reaches a peak in blood about 30 minutes after an acute stress exposure. Cortisol influences metabolism in cells, fat distribution and immune system. (Lundberg 2005; McEwen 1998; Wust et al. 2000.).

Regular working conditions do not normally increase cortisol levels in the body but heavy workloads and emotionally challenging situations can increase the secretion of cortisol. Environmental conditions can change cortisol levels dramatically. There are complex immunological and endocrine responses to strenuous firefighting drills that vary based on the measurement timing. (Michaelides 2008, 22; Lundberg 2005.). Smith and coworkers (2005) found that the responses to live fire-fighting drills were similar to intense exercise: firefighting stress activated the HPA axis, and plasma levels of ACTH and cortisol were significantly elevated post firefighting and remained elevated following 90 minutes of recovery.

Cortisol levels can also be reduced under certain conditions. In a study of white-collar workers, it was found that individuals high in psychological well-being had significantly lower cortisol levels at work compared with individuals lower in well-being. However, very low cortisol levels are also associated with burnout and post-traumatic stress disorders. Overactivity or disturbance of the HPA axis has been associated with cardiovascular disease, Type 2 diabetes, reduced immune function and cognitive impairment. These health problems occur due to high cortisol levels. Chronically high levels of cortisol increase the risk of infections due to the anti-inflammatory effects. Attenuated cortisol responses combined with elevated baseline levels have been found in individuals exposed to chronic psychosocial stress. (Lundberg 2005.).

Secretion of cortisol expresses circadian rhythms. Morning awakening has been associated with an increase in cortisol secretion, which is called the cortisol awakening response (CAR) (Lundberg 2005; Looser et al. 2010; Clow et al. 2004). This increase is most significant during the first 30-45 minutes after awakening and can be even 50-160% in the first 30 minutes after awakening in salivary cortisol (average increase 9nmol/l) (Clow et al. 2004; Hansen et al. 2008). In most individuals cortisol levels decline throughout the day after peaking in the morning. (Lundberg 2005; Looser et al. 2010.). CAR is mostly driven by awakening-induced activation of the HPA axis, and it is fine-tuned by direct sympathetic input to the adrenal gland. There is also awakening-induced activation of the CV system which is associated with a shift towards dominance of the sympathetic branch of the autonomic nervous system. Both the HPA axis and ANS show marked circadian rhythms. There is large interindividual variation in the circadian pattern of cortisol secretion (Looser et al. 2010; Wust et al. 2000). Also, about 18% of people have inverted CAR and are referred to as “non-responders” (Hansen et al. 2008). Age, gender, and smoking can all affect the differences in this pattern (Looser et al. 2010). Exercise has been shown to acutely increase cortisol levels but Hansen et al. (2008) observed no carry-over effect to CAR the following morning.

2.4 Physical fitness and recovery

2.4.1 Exercise-induced changes in the function of ANS

It is generally agreed that heart rate increases due to both a parasympathetic withdrawal and an increased sympathetic activity during dynamic exercise (Aubert et al. 2003; Carter et al. 2003). It has been proposed that long-term endurance training affects the autonomic nervous system by increasing parasympathetic activity and decreasing sympathetic activity in the human heart at rest (Carter et al. 2003, Malfatto et al. 1998). A group of researchers found that following an 8-week endurance training program SDNN was increased by 25%, RMSSD was increased by 69%, and LF/HF ratio was decreased by 30% (Malfatto et al. 1996). The measurement was done under resting conditions and the recording period was 15 minutes. The mechanisms causing the beneficial effect of aerobic training remain unknown, but some researchers hypothesize that exercise training suppresses angiotensin II expression (Buch et al. 2002), and suppression of this hormone enhances cardiac vagal tone (Okano et al. 2009). Another hypothesis is that nitric oxide mediates the relationship between exercise and vagal tone of the heart (Routledge et al. 2010). Greater HRV has been associated with better aerobic fitness, overall health, and enhanced ANS function reflected by increased parasympathetic modulation of the heart. Many studies have focused on the acute effects of exercise on HRV, and the results show that HRV decreases during exercise, and acute recovery of HRV seems to be associated with type, intensity, and duration of exercise as well as training background. It has also been found that full recovery of autonomic activity after exercise may take several hours or even days (Myllymäki et al. 2012), although after low- to moderate-intensity exercise HRV can recover in a matter of minutes (Hynynen 2011).

Not many studies were found on strength training and its effects on cardiac autonomic control. Figueroa et al. (2008) studied the effects of resistance training on patients with fibromyalgia, a chronic disorder where patients experience musculoskeletal pain, fatigue, reduced muscle strength, and orthostatic intolerance. These patients have autonomic dysfunction with a decrease in parasympathetic drive at rest. Interestingly, they found that a 16-week resistance training program improved HRV (total power and RMSSD) and muscle strength. Also HFP was increased, but the increase was non-significant (ns). In another study, no increase in parasympathetic cardiac control after 8 weeks of resistance training was found (Cooke & Carter 2005). Because of the limited amount of research in this area and the inconclusive results, it is interesting to look at the effects of different fitness parameters on ANS.

The interplay between sympathetic and parasympathetic regulation of heart rate is usually organized in a reciprocal fashion, which means that increased activity in one system is accompanied by decreased activity in the other. These reciprocal changes in sympathetic and parasympathetic activity occur during common autonomic challenges, such as dynamic exercise. During exercise there is simultaneous sympathetic and parasympathetic outflow resulting in rapid changes in beat-to-beat RR interval dynamics. The risk of sudden cardiac death is increased in the 30 minutes immediately after intense exercise. Delayed heart rate recovery 1–2 minutes after exercise has been shown to predict cardiovascular events in the general population and in various patient groups and animal studies. (Tulppo et al. 2011.).

During rhythmic exercise, global HRV decreases as a function of exercise intensity (Carter et al. 2003; Sandercock & Brodie 2006). Measures reflecting sympathovagal interactions at rest do not behave as expected during exercise. This makes interpretation of HRV measures difficult, especially at higher exercise intensities. This problem is further confounded by the occurrence of non-neural oscillations in the high frequency band due to increased respiratory effort. Standard spectral HRV analysis should not be applied to exercise conditions. The use of non-linear analyses shows much promise in this area. Until further validation of these measures is carried out and clarification of the physiological meaning of such measures occurs, HRV data regarding altered autonomic control during exercise should be treated with caution (Sandercock & Brodie 2006). When expressed in either the frequency domain or in the time domain, HRV is greatly reduced during exercise. Also, the decrease in HRV may reach the limit of resolution of some analysis systems. Time- and frequency domain measures of HRV can be difficult to interpret, especially at higher exercise intensities. When expressed in absolute units (ms^2), both LF and HF decrease exponentially as a function of exercise intensity. (Sandercock & Brodie 2006.).

Because of these issues, researchers have looked at other methodological approaches to understand the changes in autonomic control during exercise. The following data treatments have been used: the expression of LF and HF as percentages of total spectral power (LF%, HF%), normalized units, and the LF/HF ratio. Oscillations in the LF band are only neurally mediated but there are non-neural mechanisms that contribute to HF. During moderate intensity exercise these mechanisms become significant. This leads to specific problems associated with the use spectral analysis of RR interval as an autonomic marker during exercise. (Sandercock & Brodie 2006.).

2.4.2 Rescuers' recovery from shift work

As can be understood from this review, rescuers' recovery from their shifts is of great importance. They have a highly demanding and dangerous occupation, where they have to be able to stay alert and work efficiently. Many researchers have studied the demands of simulated and real-life firefighting and rescue tasks and some have even looked at the recovery from these tasks. However, there have not been studies done on the recovery that happens after the whole 24-hour shift until the beginning of the next shift. This type of research is important in helping us to understand what the overall stress and recovery is during the shift work cycle (24 hours work - 72 hours rest). Wikström & Lusa (2009) mention in their literature review that there have not been much published data on the physical demands of rescuers that takes into account the whole 24-hour shift. They suggest that research be done on the physical demands and recovery from the 24-hour shift as a whole.

Lusa et al. (2009) studied work stress and recovery in Finnish rescue workers during a 24-hour shift. They found that the physical strain of work did not exceed the individual capacity in well-trained men. In the whole group, ANS function and recovery were sufficient. There were some peaks in physical loading during fire suppression activities (78% of VO_{2max}) which led to delayed recovery. (Lusa et al. 2009.). This study is one of the few to study recovery during a whole 24-hour shift by means of ANS changes.

Lindholm (2008) looked at stress and recovery of rescuers not only during the 24-hour shift but also during the first day off after the shift. In his Master’s thesis project he compared two groups of rescuers; under 35 and over 40 years of age. He found that older rescuers were less strained physically and mentally than younger rescuers during the shift but younger rescuers recovered more effectively during the day off.

3 PURPOSE OF THE STUDY

It is well established that good physical fitness helps rescuers perform their work more safely and effectively. When the physiological strain is reduced, then presumably recovery will also be faster. Good aerobic fitness increases parasympathetic influence on the heart and parasympathetic nervous system activity reflects recovery when measuring HRV. The association between the fitness levels and recovery of rescuers has yet to be studied.

The previously mentioned Finnish studies on rescuers have provided important information on the physical demands and recovery of rescuers, but more information is needed on the recovery process. Thus, the purpose of this thesis is to further study the stress and recovery of rescuers from a 24-hour shift and to see if there is an association between physical fitness and recovery.

Answers to the following research questions are studied in this thesis:

1. What kind of changes in HRV can be seen between a 24-hour work shift and three resting days in rescuers?
2. Does physical fitness have an association with recovery in rescuers?

Hypotheses:

1. Overall HRV, parasympathetic influence on autonomic nervous system, and relaxation will increase after the work shift.
2. Better physical fitness enhances recovery processes in rescuers by increasing parasympathetic and decreasing sympathetic influence on the heart.

4 METHODS

4.1 Subjects

Fourteen male rescuers and two paramedics volunteered to participate in the study (Table 3). Since only two paramedics participated in the measurements and they had very different working schedules than the rescuers, they were excluded from the data analysis. All subjects included in further analysis were healthy rescuers from the Central Finland Fire Department. All rescuers did similar type of work, including 12 hours of firefighting and 12 hours of paramedic work during one shift.

The research study was introduced to all of the shifts on separate days. After an explanation of the study and the protocols and after giving a chance to ask questions regarding the research study, the rescuers who wanted to participate filled out a written consent form. The study was approved by the Ethical Committee of the University of Jyväskylä.

TABLE 3. Subject characteristics.

	Mean±SD	Maximum	Minimum
Age (years)	34±9	51	24
Height (cm)	178±7	190	168
Body mass (kg)	80,8±11,4	110,5	70,2
BMI	16,5±5,2	30,7	11,6
$VO_{2}max$ (ml/kg/min)	51±9	78	38

4.2 Procedure

Prior to measurements subjects filled out a health questionnaire to establish any contraindications to submaximal exercise testing. None of the subjects were taking medications that affect the autonomic nervous system. All measurements were done between June and August 2012, except for one subject, who did the physical fitness assessment in October due to a lower leg injury. After the initial measurements (height, weight, body composition, physical fitness assessment), HRV recordings were started in the morning of a 24-hour work shift. HRV recordings were finished at the end of the 3rd resting day (recovery). Cortisol samples were collected on all 3 recovery days (Figure 8).

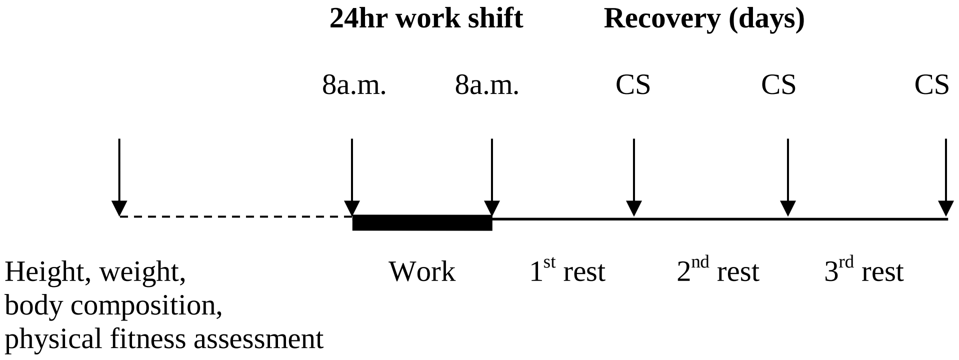


FIGURE 8. Measurement design. CS=cortisol sample

4.3 Description of the work shift

The subjects included in this study did shift work, working 24 hours at a time and then resting for 72 hours. The work shift began at 8a.m. and ended at 8a.m. the next day. This work shift cycle is typical for Finnish rescuers. The work shift is split into two 12-hour sections, 12 hours of firefighting work and 12 hours of paramedic work. In general, the 12 hours of paramedic work was busier than 12 hours of firefighting. Not all subjects reported the number of alarms during the shift, but from the more detailed reports of work shift activities, it can be seen that in the 12-hour paramedic work shift subjects had alarms more frequently than in the 12-hour firefighting shift. One of the subjects had no firefighting activities during his shift, while most of them had 1-2 firefighting-related activities during the 12 hours. Most of the subjects were able to take naps during their shift and 10 subjects were also able to sleep longer periods (>2.5 hours) at night. Eight subjects were able to sleep >4 hours during their shift.

Most of the subjects exercised during their shift (11 out of 14). Riding a stationary bike and doing resistance training were the most popular modes of exercise. Usually, subjects exercised during their 12-hour firefighting shift, because that is when they had more breaks from work, as mentioned earlier. On the off-days they were physically very active, all subjects exercised at least on one, if not all resting days. Many of them did multiple hours of physical activity on most days. Many of them also did other physical work, such as hunting, renovating, and painting in addition to exercise.

4.4 Measurements

4.4.1 Anthropometrics

Measurements were started with the collection of anthropometrical data. The data were collected in the morning after at least 12 hours of fasting. Subject height was measured first without shoes and socks. Subjects were instructed to keep heels, buttocks, shoulders, and back of head against the wall and stand straight. Height was rounded to the nearest cm. Body composition was measured using bioelectrical impedance analysis (InBody 3.0, Biospace Co, Seoul, Korea). It is a multifrequency bioelectrical impedance method that differentiates body weight into 3 components - total body water, dry mass, and body fat.

The measurement was performed in laboratory conditions according to the user manual instructions. Subjects were given feedback on their body composition immediately after the measurement.

4.4.2 Physical fitness assessment

Bicycle ergometer test. A maximal exercise test with gas analysis is the golden standard for measuring VO_{2max}. For the purpose of this study it seemed sufficient to have a submaximal test that estimates maximal oxygen uptake from workloads and respective heart rates. Submaximal exercise tests have been shown to be reliable in estimating VO_{2max}, time-efficient, and safe to perform. (Keskinen et al. 2004, 78.).

For testing aerobic power, a WHO submaximal bicycle ergometer test (adjusted for Finland) was used. In tests recommended by WHO, the difference in VO_{2max} is between -2.4% and 7.7% between estimated and measured $VO_{2max.}$ In this test maximal oxygen uptake is derived from the linear relationship between heart rate and oxygen uptake during submaximal exercise. The goal is to obtain three or four 4-minute loads (40-80% of VO_{2max}) and estimate VO_{2max} from the heart rates and loads. (Keskinen et al. 2004, 86-88.).

Subjects were told to avoid exhaustive exercise and use of alcohol prior to testing. For subjects >40 years, a medical doctor was present during the submaximal bicycle ergometer test. Before starting the graded exercise test, the Borg scale was introduced and the procedure was explained. Heart rate was recorded with an elastic HR belt (Polar Electro Ltd., Kempele, Finland), and only the researcher was able to see the HR readings. Subjects were reminded that they could stop the test at any time they wanted. The test was done on a Monark bicycle (Monark Exercise AB, Vansbro, Sweden). After filling in subject information (gender, age, height, weight, physical activity level (0-7)), the computer software gives a non-exercise estimate of the subject's VO_{2max} and based on the information suggests loads for each stage of the test. The suggested loads were predominantly used or possibly changed during the test if it looked like the load was too light or heavy. Subjects were asked to keep pedaling at 60rpm throughout the test so that the load and power could easily be determined. The test consisted of a warm-up period (2 minutes), three 4-minute stages of increasing load, and a cool-down. Test was ended when HR was back to <120bpm during the cool-down period. Heart rate and rating of perceived exertion (RPE) were recorded during the last 30 seconds of each stage.

Strength tests. The second part of the physical fitness assessment included upper- and lower body strength tests. Upper body strength was measured with an isometric bench press. Back had to lay flat on the bench when doing the test and upper arms were parallel to the bench, elbows at a 90 degree angle (Santtila et al. 2008). Lower body strength was measured with an isometric leg press, where the subject presses their feet against a force plate. Knee angle was measured with a goniometer and it was set at 107 degrees when performing the test (Häkkinen et al. 1998). These isometric maximal strength tests are easy to perform and safe and do not require specific skills from the subject (Keskinen et al. 2004, 139). For both tests subjects were told to do a few warm-ups before testing. For the actual measurements subjects were instructed to push as fast and as hard as possible and to hold it for 3-4 seconds. Strong verbal encouragement was given during testing. There was a 2-minute break between each repetition. For both tests, the subjects had 3 trials unless there were still clear changes in maximal force (>5%) between repetitions. In that case more repetitions were done until maximal force had been reached. Bench press results were read from a monitor and recorded on the results sheet. Signal 2.16 software was used to analyze leg press results.

4.4.3 Heart rate variability recordings

Heart rate variability recordings were obtained on 4 consecutive days (total 96 hours), starting in the morning of the work shift (8:00 a.m.) and ending at the beginning of the next shift (8:00 a.m.). A Firstbeat BODYGUARD recorder (Firstbeat Technologies Ltd., Jyväskylä, Finland) with a sampling rate of 1000Hz was used to collect the HRV data. This should provide very accurate and reliable analysis of HRV since a sampling rate of 250-

500Hz or higher is recommended for the collection of reliable data (Task Force, 1996). A researcher from the Institute of Occupational Health in Jyväskylä was at the fire department to attach the electrodes and the recorder on the subjects the first morning and instructed the subjects how to get the recorder off and back on. Subjects were told to take the recorder off when showering and going to the sauna. Electrodes used were Kendall / Tyco ARBO H92 Disposable Surface EMG/ECG/EKG Electrodes (57 mm x 34 mm).

The daily habits (e.g. physical activity, alcohol consumption, food intake) of the subjects were not limited in any way during the HRV measurement period. The idea was to get a picture of a regular shift and a normal resting period between shifts for these individuals.

Diaries. While wearing the HRV recorder, subjects kept a diary on their daily activities and alcohol consumption. Work shifts, naps, sleeping periods, and physical activity periods were written down with exact times. Also, an estimation of how long it took the subject to fall asleep at bedtime, was recorded.

HRV data analysis. Firstly, HRV data were split into 24-hour sections. Also, a 2.5-hour night recording was used in analysis that was started 30 minutes after going to bed. HRV data were first analyzed with Firstbeat HEALTH software version 3.1. The software calculates HRV indices second-by-second using short-time Fourier Transform method (STFT), and HR- and HRV-derived variables that describe respiration rate and oxygen consumption using neural network modeling of data (Kinnunen et al. 2006). After this modeling of data the software identifies exercise, stress, and recovery states. The software automatically detects and replaces artifacts. After analysis with the Firstbeat HEALTH software, data were transferred to Microsoft Excel and remaining artifacts were removed by visual inspection. Data were used for further analysis if ≥80% of the data were left after removal of the artifacts. The following HRV parameters were analyzed from the data: standard deviation of normal-to-normal intervals (SDNN), root mean square of successive differences (RMSSD), and autoregressive calculations of very low frequency power (VLF; 0.003-0.04Hz), low frequency power (LFP; 0.04-0.15Hz), high frequency power (HFP;

0.15-0.40Hz), low to high frequency ratio (LF/HF), and total power (TP). The automatic analysis in HEALTH software provided also stress and relaxation percentages for the recording period, that were used in later analysis.

4.4.4 Cortisol awakening response (CAR)

Cortisol awakening response was measured from salivary cortisol samples. The samples were collected on 3 consecutive resting days, on the same rest days as HRV was recorded. Subjects obtained saliva samples 0, 15, and 30 minutes after awakening. Subjects were given instructions on how to collect the saliva samples with a cotton pad. They were told to gently chew and roll the cotton tampon around in the mouth for 1 minute and then to put it in the Salivette tube (Sarstedt Ltd., Rommelsdorf, Germany). Subjects stored the samples in refrigerators until all the samples were collected. Salivary cortisol samples can be stored at 5°C for 3 months (Hansen et al. 2008). When all the samples were collected they were brought to the research facilities and were frozen at -20°C. After melting the samples they were centrifuged at 3500 rpm for 10 minutes. IMMULITE 1000 chemiluminescent immunoassay method was used for the analysis of cortisol. Reagents were from IMMULITE 1000 (Cortisol, Siemens, Llanberis, UK). Intra- and inter-assay variability of the assay was 11,5% and 15,4%, respectively.

4.5 Statistical analysis

Statistical analyses were done with IBM SPSS Statistics for Windows 20.0 (IBM Corp. Armonk, NY, USA) and Microsoft Excel 2010. Values are expressed as means and standard errors (SE) or 95% confidence intervals (CI). Probability level of ≤ 0.05 was set for statistically significant results.

Generalized estimating equations (GEE) were used for analysis of means (HR, HRV, cortisol) and the association between physical fitness and HRV variables. Both 24-hour and

2.5-hour night recordings were used in HRV analysis. GEE procedure extends the generalized linear model to allow for analysis of repeated measurements or other correlated observations (Liang & Zeger 1986).

In the analysis of the association between physical fitness and HRV, the following HRV variables (outcomes) were used: RMSSD, SDNN, HF, LF, LF/HF ratio, stress percentage, and relaxation percentage. Statistical analysis was done to reveal any association with the HRV variables and the three measured physical fitness parameters: VO_{2max} (ml/kg/min), bench press (kg), and leg dynamometer (Newtons). Also, the effect of time was analyzed, as well as the combined effect of the fitness parameter and time. Values from each of the three resting days (or nights) were compared to the working day (or night) value.

4.6 Graphs

Graphs were drawn to depict the changes during the 4 days and nights. Resting day/night values were compared to the working day/night values. Values are expressed as means, 95% confidence intervals (CI) are included in the graph. Statistically significant changes are noted with *, **, and *** ($p<0.05$, $p<0.01$, $p<0.001$, respectively). Results showing the association between physical fitness parameters and HRV were represented in tables.

5 RESULTS

5.1 Changes in HR and HRV over 4 days

Figure 9 shows that RMSSD on resting nights was lower than on the night of the work shift, however, only night 4 was significantly lower (p<0.01).

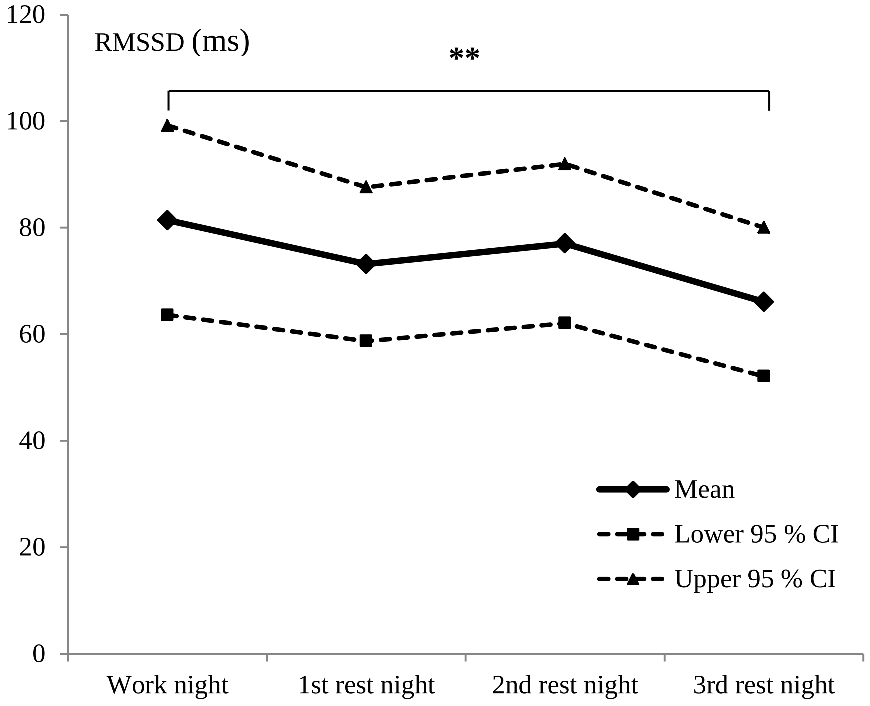


FIGURE 9. Mean (±95% CI) RMSSD during nights.

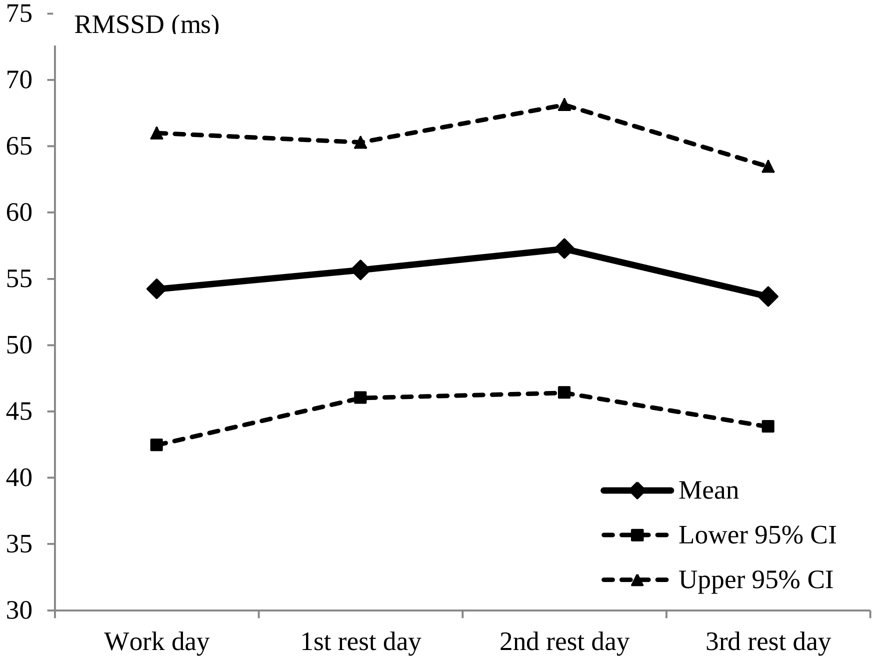


FIGURE 10. Mean (±95% CI) RMSSD during the 24hr recordings.

No significant changes were observed in day recordings for RMSSD (Figure 10). Neither SDNN measured at night showed any statistically significant changes, although there seems to be a decreased trend in SDNN on the 2nd and 3rd rest nights (Figure 11).

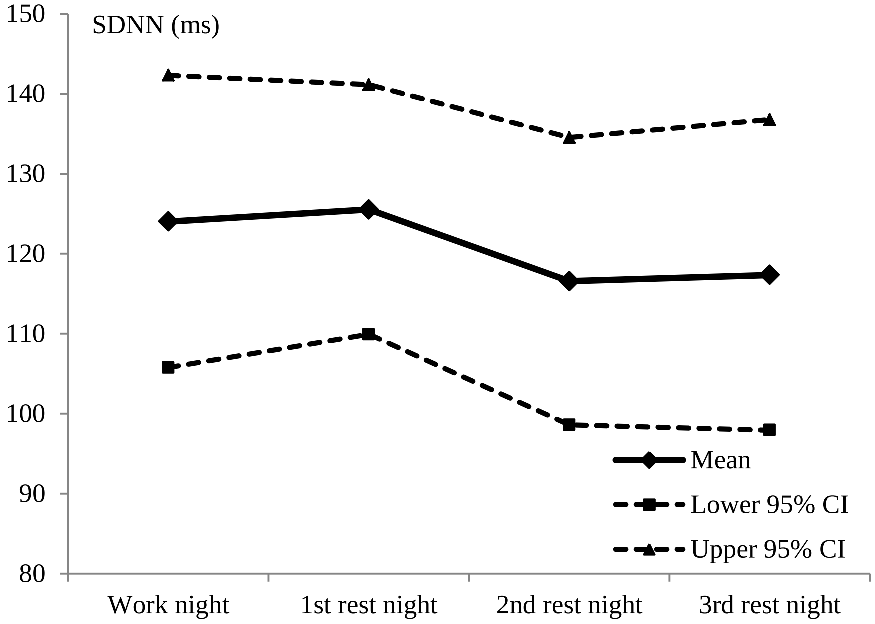


FIGURE 11. Mean (±95% CI) SDNN during nights.

SDNN increased gradually since the working day (214ms), and this increase was statistically significant on days 3 (241ms) and 4 (251ms) ($p<0.05$, $p<0.001$, respectively). (Figure 12).

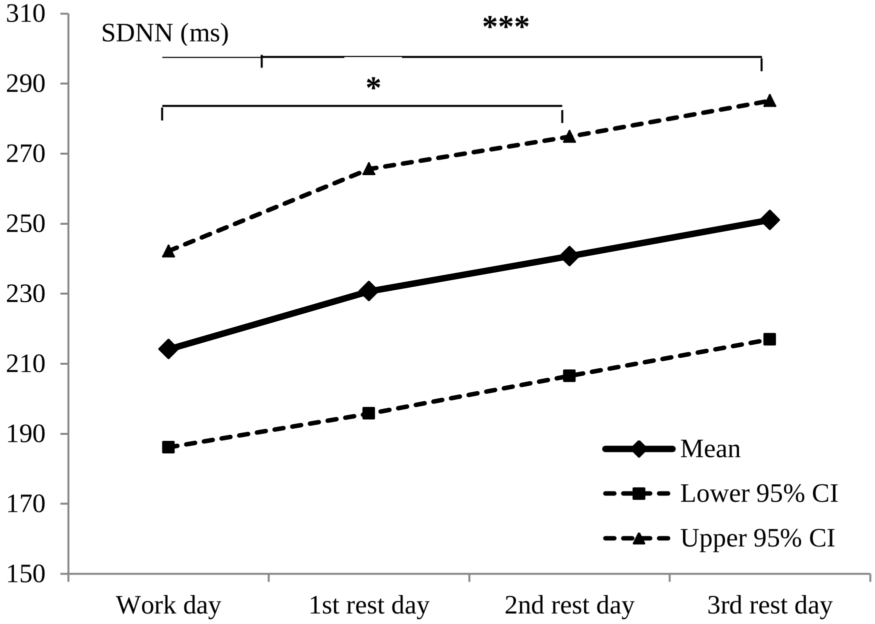


FIGURE 12. Mean (±95% CI) SDNN during 24hr recordings.

No statistically significant changes were observed in HF power in the 24-hour or the night recordings (Figures 13-14). However, a non-significant trend can be seen where HFP decreased during the night after work shift and started increasing thereafter. HF power in the 24-hour recording was at its lowest level on the work day. It increased (ns) on days 2 and 3 but decreased (ns) again on day 4, almost to the working day levels. No statistically significant changes were observed in mean HR and LF power in the 24-hour or the night recordings.

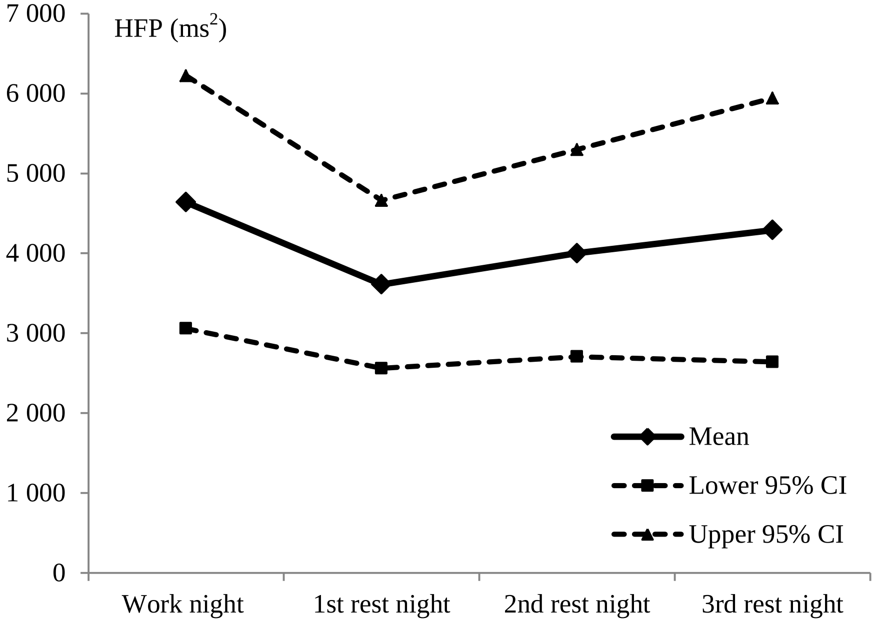


FIGURE 13. Mean (±95% CI) HFP during nights.

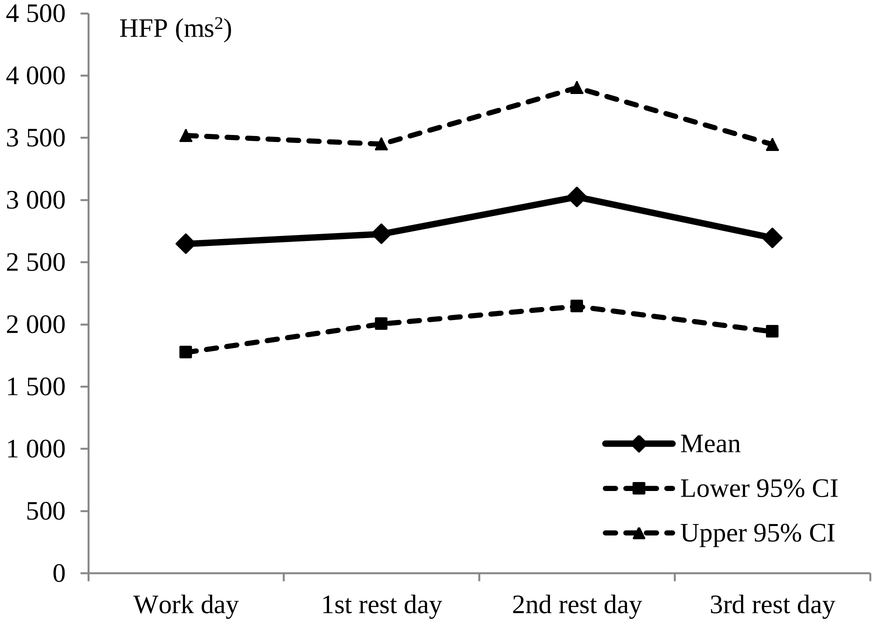


FIGURE 14. Mean (±95% CI) HFP during 24hr recordings.

Some significant changes were seen in total power (TP) calculations in night-time recordings (Figure 15). Total power decreased from the highest value on the night of the work shift (9492 ms²) to the lowest value on the night of the 3rd resting day (8383 ms²), $p<0.05$. No significant changes were observed in the 24-hour calculations of total power.

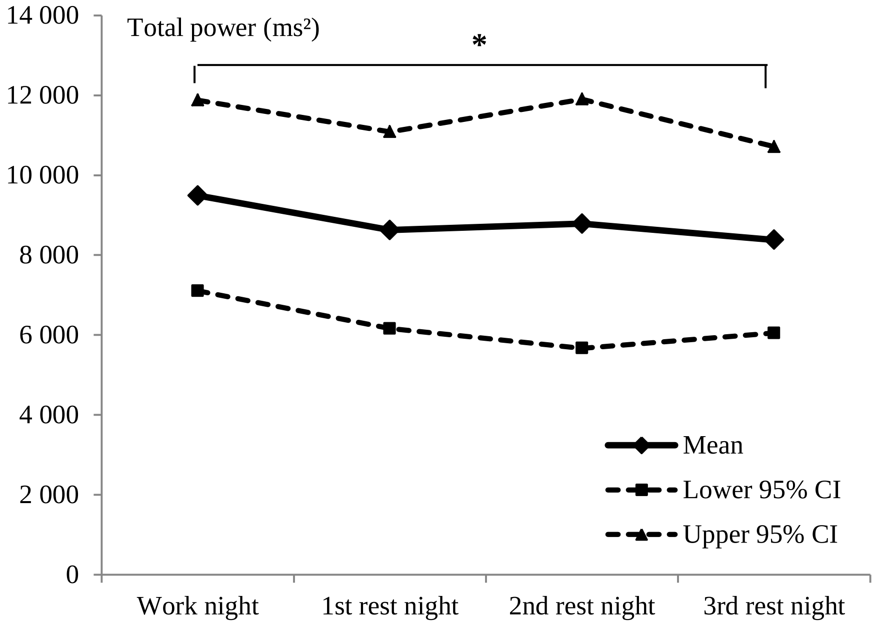


FIGURE 15. Mean (±95% CI) total power during nights.

LF/HF ratio calculated over the 24-hour period decreased after the highest value on the working day (2.11, Figure 16). Days 3 and 4 showed a significant decrease in comparison to the working day (1.75 and 1.73, respectively, $p<0.05$). No significant changes were observed in night-time recordings of LF/HF ratio.

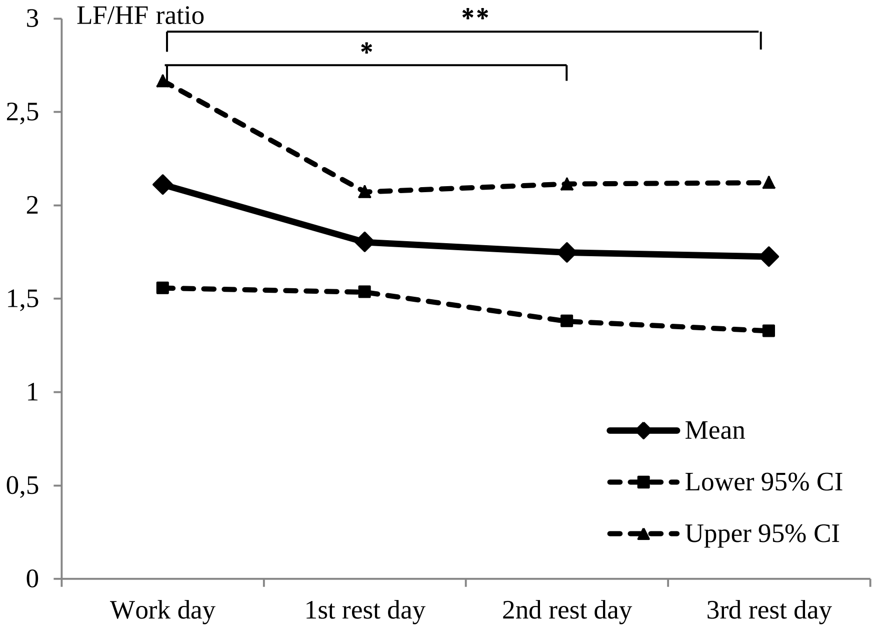


FIGURE 16. Mean (±95% CI) LF/HF ratio during 24hr recordings.

Stress percentage (Figure 17) decreased from the initial value of 47,1% on the working day until day 3, where it was significantly lower than on day 1 (35,2%, $p<0.05$). Then it increased on day 4 to 42.1%.

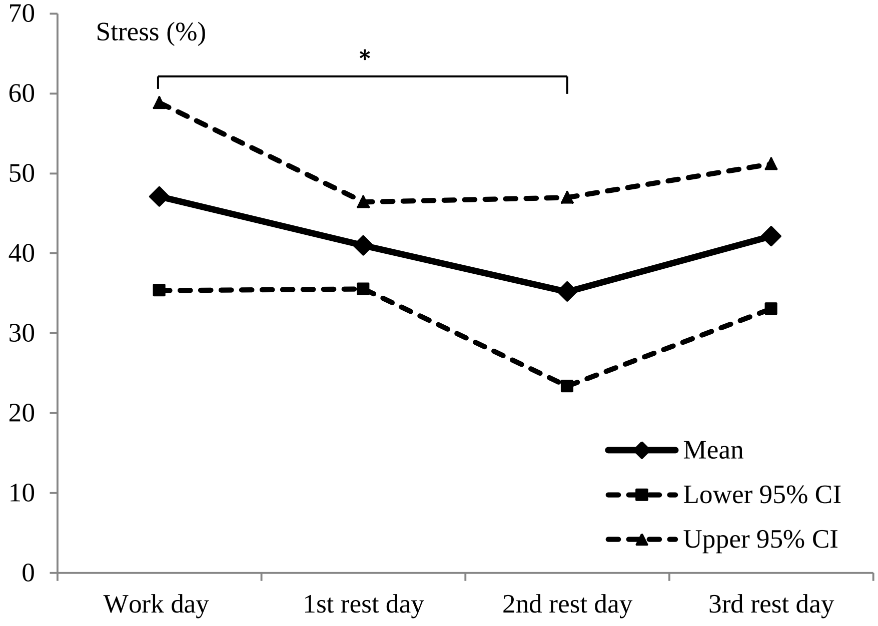


FIGURE 17. Mean (±95% CI) stress percentage during 24hr recordings.

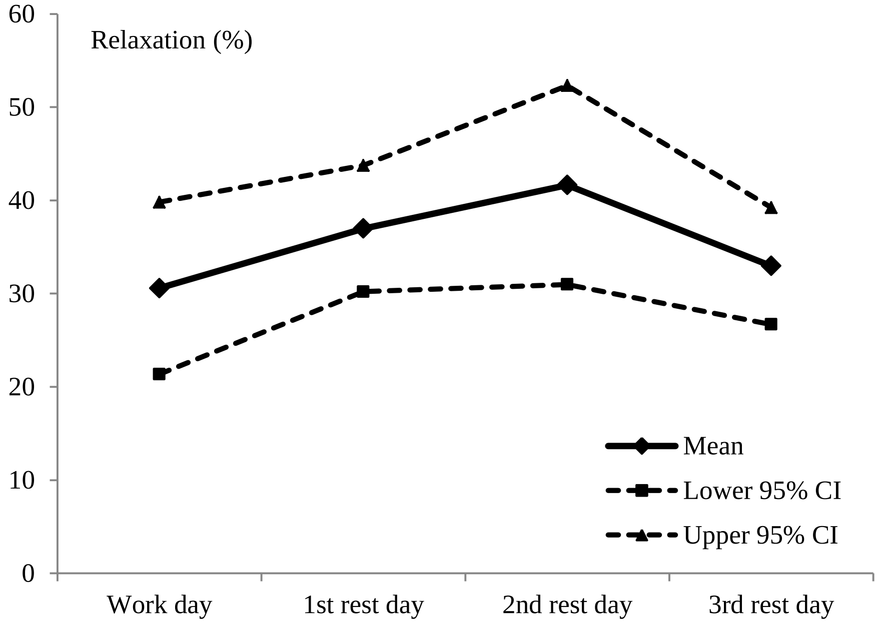


FIGURE 18. Mean (±95% CI) relaxation percentage during the 24hr recordings.

Relaxation percentage moved in the opposite direction than stress percentage and increased until day 3, where it started decreasing again. These changes, however, were not statistically significant (Figure 18).

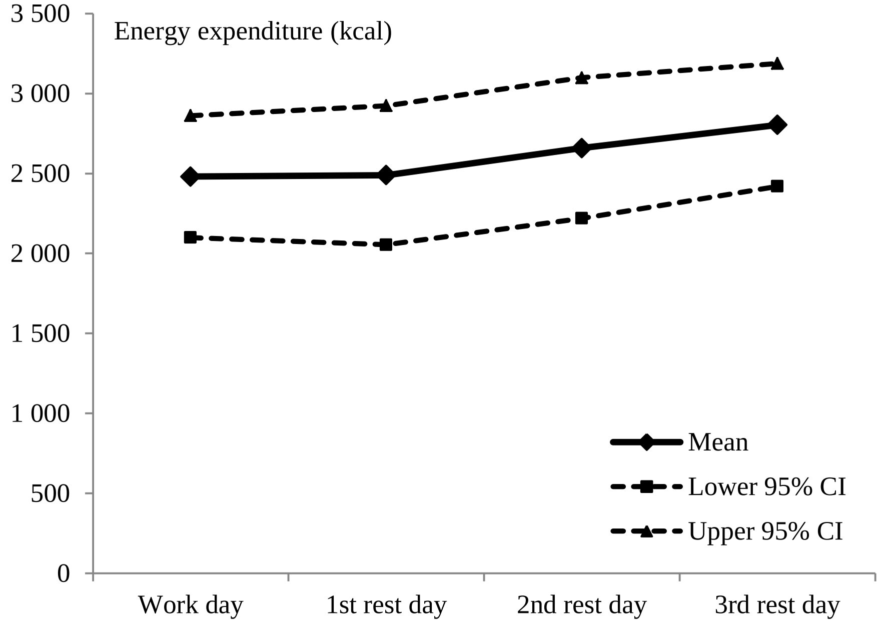


Figure 19. Mean (±95% CI) energy expenditure during the 24hr recordings.

Energy expenditure increased gradually from the day of the work shift (2481 kcal) to the 3rd resting day (2803 kcal). This increase was statistically non-significant (Figure 19).

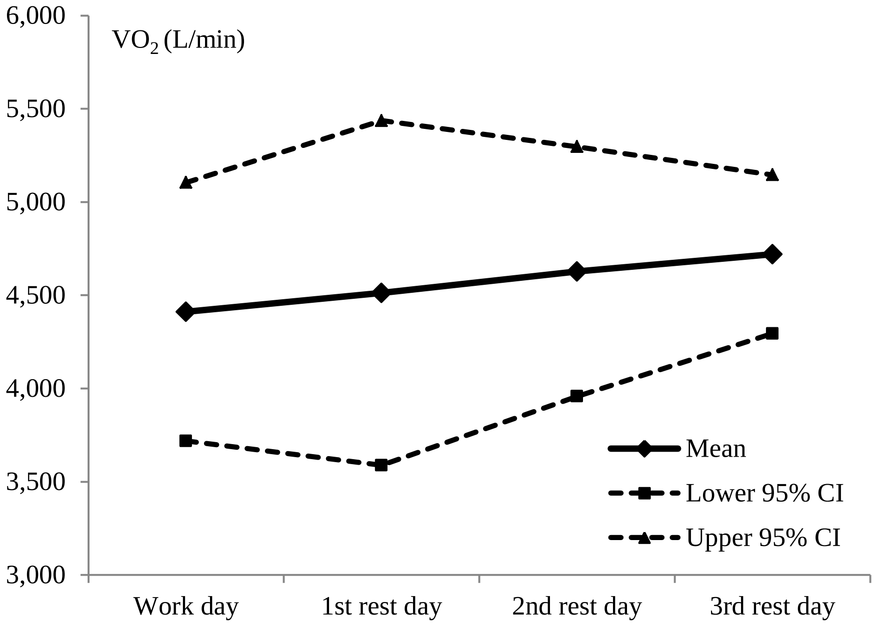


Figure 20. Mean (±95% CI) VO_2 during the 24hr recordings.

Absolute VO_2 (L/min) increased gradually after the work shift but this increase was statistically non-significant (Figure 20).

5.2 Association of physical fitness to HRV

The association between physical fitness parameters (VO_{2max}, bench press, leg press) and different HRV variables, as well as relaxation and stress percentages, are depicted in Tables 4-9.

The model parameter VO_{2max} describes the effect produced by a unit increase in VO_{2max} in the outcome (RMSSD, SDNN, etc.). The same applies to the other two physical fitness variables, bench press and leg press. The Time effect describes the difference between the baseline measurement (working 24hrs/night) and the successive time points (resting 24hrs/nights). The parameter Time x VO$_{2max}$ describes the additional variation over time that is related to variability in VO$_{2max}$. Same applies to bench press and leg press.

TABLE 4. Effect estimates, standard errors and p-values for generalized estimation equations models for RMSSD (Night) and RMSSD (24hr).

	RMSSD (Night)			**RMSSD (24hr)**		
Effect	**Estimate**	**Std.Error**	**p-value^a**	**Estimate**	**Std.Error**	**p-value^a**
VO$_{2max}$	0.71	0.89	0.428	1.09	0.68	0.112
Time			<0.001			<0.001
baseline vs. 1st rest	-14.65	11.96	0.221	43.11	12.36	<0.001
baseline vs. 2nd rest	37.22	8.81	<0.001	0.73	15.09	0.961
baseline vs. 3rd rest	-17.19	24.16	0.477	34.59	17.23	0.045
Time× VO$_{2max}$			<0.001			<0.001
baseline vs. 1st rest	0.14	0.20	0.493	-0.85	0.21	<0.001
baseline vs. 2nd rest	-0.82	0.13	<0.001	0.12	0.29	0.682
baseline vs. 3rd rest	0.25	0.44	0.568	-0.69	0.30	0.021
BenchPress	-0.19	0.21	0.350	-0.17	0.21	0.421
Time			0.004			0.151
baseline vs. 1st rest	-0.20	7.25	0.978	-10.52	12.81	0.411
baseline vs. 2nd rest	-18.10	17.45	0.300	-9.97	11.44	0.384
baseline vs. 3rd rest	-20.65	13.54	0.127	-12.91	9.18	0.160
Time×BenchPress			0.031			0.553
baseline vs. 1st rest	-0.06	0.08	0.442	0.10	0.12	0.395
baseline vs. 2nd rest	0.13	0.13	0.292	0.11	0.10	0.255
baseline vs. 3rd rest	0.10	0.12	0.404	0.11	0.08	0.188
LegPress	-0.00	0.01	0.766	0.00	0.01	0.750
Time			<0.001			0.378
baseline vs. 1st rest	6.53	9.91	0.510	6.53	14.25	0.647
baseline vs. 2nd rest	-21.72	19.64	0.269	-5.31	9.34	0.570
baseline vs. 3rd rest	-33.27	10.54	0.002	-1.11	11.98	0.028
Time×LegPress			0.001			0.129
baseline vs. 1st rest	-0.004	0.00	0.306	-0.00	0.00	0.684
baseline vs. 2nd rest	<0.01	0.00	0.321	0.00	0.00	0.388
baseline vs. 3rd rest	<0.01	0.00	0.020	0.00	0.00	0.960

Note. a) Total effect of Time and Time× VO$_{2max}$ is the type III effect.

VO_{2max}. Table 4 shows that a unit increase in VO_{2max} increased RMSSD (Night) by 0.71 units. This effect was not statistically significant. We also observed a significant main effect of Time ($p<0.001$). The difference between baseline (work night) and second follow-up measurement (2nd rest night) indicated increase in the level of RMSSD ($p<0.001$). For all other time points the Time effect was negative, but non-significant. The change over time attributable to VO_{2max} (i.e. the interaction effect with time) was significant when comparing the work night and second rest night ($p<0.001$). The negative effect indicated that increase in VO_{2max} was related to lower levels of RMSSD at the second time point.

As an example, a unit increase in VO_{2max} increased RMSSD (Night) by 0.71 units. When moving to the second follow-up time point, the mean increases by 37.22 units. The combined effect shows that a unit increase in VO_{2max} decreases the main effect by 0.82 units at the 2nd time point. So for a theoretical subject, whose VO_{2max} equals the VO_{2max} mean, RMSSD increases 37.22 units. For a theoretical subject, whose VO_{2max} is 1 unit larger than the mean VO_{2max}, RMSSD will increase $0.71+37.22-0.82=37.11$ units at the second time point. For a theoretical subject, whose VO_{2max} is 10 units above the VO_{2max} mean, RMSSD will increase $10x0.71-37.11+10x(-0.82)=36.01$ units. These calculations demonstrate that VO_{2max} is related to an increase in RMSSD, but higher levels of VO_{2max} level off the increase.

A unit increase in VO_{2max} increased RMSSD (24hr) by 1.09 units (Table 4). This effect was not statistically significant. Again, we observed a significant main effect of Time ($p<0.001$). An increase in the level of RMSSD was observed in the difference between the work day and the first and third rest days ($p<0.001$ and $p<0.05$, respectively). On the 2nd rest day the Time effect was also positive, but non-significant. The change over time attributable to VO_{2max} was significant when comparing the work day and the first and third rest days ($p<0.001$, $p<0.05$, respectively). The negative effect indicated that increase in VO_{2max} was related to lower levels of RMSSD on the first and third rest days.

Bench press. A unit increase in bench press decreased RMSSD (Night) by 0.19 units and RMSSD (24hr) by 0.17 units, but both were non-significant. A main effect of Time was observed ($p<0.01$) for RMSSD (Night). A non-significant decrease in the level of RMSSD (both night and 24hr) was observed in the difference between work day and rest days and work night and rest nights. The interaction effects of Time and bench press were non-significant.

Leg press. A main effect of Time ($p<0.001$) was observed in leg press measurements (RMSSD Night). With a unit increase in leg press, average RMSSD levels decreased from work shift values on the 3rd resting night and 3rd resting day ($p<0.01$, $p<0.05$, respectively). Additionally, a small but significant positive effect was observed in the change over time attributable to leg press when comparing the work night and the 3rd resting night (<0.05).

Table 5. Effect estimates, standard errors and p-values for generalized estimation equations models for SDNN (Night) and SDNN (24hr).

	SDNN (Night)			**SDNN (24hr)**		
Effect	**Estimate**	**Std.Error**	**p-value**[a]	**Estimate**	**Std.Error**	**p-value**[a]
VO$_{2max}$	-0.58	1.23	0.635	1.95	1.45	0.180
Time			0.712			0.006
baseline vs. 1st rest	-30.29	29.38	0.303	31.11	37.73	0.410
baseline vs. 2nd rest	-15.05	26.18	0.565	138.07	86.29	0.110
baseline vs. 3rd rest	-80.08	84.05	0.341	79.69	24.47	0.001
Time× VO$_{2max}$			0.388			0.053
baseline vs. 1st rest	0.62	0.52	0.237	-0.41	0.63	0.518
baseline vs. 2nd rest	0.18	0.49	0.714	-2.26	1.82	0.213
baseline vs. 3rd rest	1.46	1.56	0.351	-.080	0.37	0.030
LegPress	0.00	0.01	0.991	0.01	0.01	0.359
Time			<0.001			<0.001
baseline vs. 1st rest	20.27	21.03	0.335	90.12	32.64	0.006
baseline vs. 2nd rest	-52.30	12.18	<0.001	8.43	31.45	0.789
baseline vs. 3rd rest	4.77	32.94	0.885	22.55	27.26	0.408
Time×LegPress			<0.001			<0.001
baseline vs. 1st rest	-0.01	0.01	0.408	-0.02	0.01	0.026
baseline vs. 2nd rest	0.01	0.004	0.002	0.01	0.01	0.547
baseline vs. 3rd rest	-0.004	0.01	0.687	0.004	0.01	0.566

Note. a) Total effect of Time and Time× VO$_{2max}$ is the type III effect.

VO_{2max}. Table 5 shows that a unit increase in VO_{2max} decreased SDNN (Night) by 0.58 units. This effect was not statistically significant. A unit increase in VO_{2max} increased SDNN (24hr) by 1.95 units, but this was also non-significant. We observed a significant ($p<0.01$) main effect of Time in SDNN (24hr). No significant main effect of Time was observed in SDNN (Night). The difference between the baseline (work day) and the rest days indicated an increase in the level of SDNN (24hr), third rest day having a significant effect ($p<0.001$). Night recordings show a non-significant decrease in the average level of SDNN on rest nights. The interaction effect of VO_{2max} and Time was significant when comparing the work day and 3rd rest day ($p<0.05$). The negative effect indicated that increase in VO_{2max} was related to lower levels of SDNN at the 3rd time point (other time points also negative, but non-significant).

Bench press. No significant changes in SDNN recordings were observed.

Leg press. A significant main effect of time was observed in both night and 24hr recordings of SDNN ($p<0.001$). The difference between the work night and 2nd rest night indicated a decrease in the level of SDNN ($p<0.001$). Other time points had positive values but were non-significant. The difference between work day and the 1st rest day indicated an increase ($p<0.01$) in the level of SDNN (24hr). Also other time points had positive values, but they were non-significant. The combined effect of time and leg press shows a small but significant positive effect on SDNN on 2nd rest night and a small negative effect on 1st rest day.

Table 6. Effect estimates, standard errors and p-values for generalized estimation equations models for LF/HF ratio (Night) and LF/HF ratio (24hr).

	LF/HF ratio (Night)			**LF/HF ratio (24hr)**		
Effect	**Estimate**	**Std.Error**	**p-value**[a]	**Estimate**	**Std.Error**	**p-value**[a]
VO_{2max}	-0.02	0.01	0.201	-0.17	0.18	0.340
Time			0.009			0.021
baseline vs. 1st rest	-0.39	0.40	0.324	-1.04	0.65	0.108
baseline vs. 2nd rest	-0.87	0.31	0.005	-0.21	0.78	0.787
baseline vs. 3rd rest	-0.70	0.58	0.231	-1.12	0.47	0.018
Time× VO_{2max}			0.004			0.038
baseline vs. 1st rest	0.01	0.01	0.351	0.18	0.12	0.142
baseline vs. 2nd rest	0.02	0.01	0.008	-0.06	0.18	0.731
baseline vs. 3rd rest	0.01	0.01	0.304	0.21	0.10	0.049
BenchPress	0.01	<0.01	0.226	0.01	<0.01	0.076
Time			<0.001			<0.001
baseline vs. 1st rest	0.03	0.16	0.860	0.27	0.16	0.104
baseline vs. 2nd rest	0.43	0.26	0.098	0.24	0.29	0.399
baseline vs. 3rd rest	0.28	0.11	0.009	0.49	0.11	<0.001
Time×BenchPress			0.001			<0.001
baseline vs. 1st rest	-<0.01	<0.01	0.474	-0.01	<0.01	0.050
baseline vs. 2nd rest	-<0.01	<0.01	0.012	-0.01	<0.01	0.041
baseline vs. 3rd rest	-<0.01	<0.01	0.003	-0.01	<0.01	<0.001
LegPress	<0.01	<0.01	0.773	<0.01	<0.01	0.714
Time			<0.001			0.206
baseline vs. 1st rest	-0.33	0.34	0.338	-0.32	0.42	0.445
baseline vs. 2nd rest	0.28	0.25	0.276	-0.16	0.35	0.643
baseline vs. 3rd rest	0.40	0.22	0.075	-0.05	0.33	0.881
Time×LegPress			0.001			0.049
baseline vs. 1st rest	<0.01	<0.01	0.616	<0.01	<0.01	0.988
baseline vs. 2nd rest	0.00	<0.01	0.178	<0.01	<0.01	0.414
baseline vs. 3rd rest	0.00	<0.01	0.012	<0.01	<0.01	0.445

Note. a) Total effect of Time and Time× VO_{2max} is the type III effect.

VO_{2max}. A significant main effect of time was observed in Table 6 in both night and 24hr recordings ($p<0.01$ and $p<0.05$, respectively) of LF/HF ratio. There was a non-significant decrease in LF/HF ratio (both night and 24hr recordings) with a unit increase in VO_{2max}. The difference between baseline and the rest nights indicated a decrease in LF/HF ratio, 2nd rest night being significantly lower ($p<0.01$). Also, the difference between working 24hrs

and resting 24hrs indicated a decrease in LF/HF ratio, 3rd resting day being significantly lower (<0.05). The combined effect of Time and VO_{2max} shows a significant positive effect on 2nd rest night and 3rd rest day ($p<0.01$ and $p<0.05$, respectively).

Bench Press. A significant main effect of Time was seen for both night and 24hr recordings of LF/HF ratio ($p < 0.001$). A unit increase in bench press increased LF/HF ratio, but this increase was non-significant. Average levels of LF/HF ratio increased from work shift values on rest nights and days, 3rd rest night and day having statistically significant increases. The combined effect of time and bench press shows a negative effect, 2nd and 3rd rest night and day showing significant changes.

Leg Press. A significant main effect of time was seen in night recordings of LF/HF ratio ($p<0.001$). No statistically significant changes were seen in the average LF/HF ratio but the 24hr recordings suggest a decrease in the ratio on rest days. The combined effect of time and leg press shows a positive effect on 3rd rest night ($p<0.05$).

Table 7. Effect estimates, standard errors and p-values for generalized estimation equations models for HF power (Night) and HF power (24hr).

	HF power (Night)			**HF power (24hr)**		
Effect	**Estimate**	**Std.Error**	**p-value[a]**	**Estimate**	**Std.Error**	**p-value[a]**
VO_{2max}	478.41	604.35	0.429	69.57	51.33	0.175
Time			<0.001			0.001
baseline vs. 1st rest	-3913.99	2318.32	0.091	2509.39	857.46	0.003
baseline vs. 2nd rest	1539.09	1679.88	0.360	-114.46	1155.49	0.921
baseline vs. 3rd rest	591.49	895.26	0.509	2119.17	1220.13	0.082
Time× VO_{2max}			<0.001			<0.001
baseline vs. 1st rest	698.85	434.21	0.108	-50.96	14.72	0.001
baseline vs. 2nd rest	-562.17	288.21	0.051	11.96	24.23	0.622
baseline vs. 3rd rest	-249.95	153.55	0.104	-41.21	21.05	0.050
BenchPress	-8.28	19.96	0.678	-10.23	15.28	0.503
Time			<0.001			0.373
baseline vs. 1st rest	356.28	819.60	0.664	-286.42	944.22	0.762
baseline vs. 2nd rest	-1739.57	1105.38	0.116	-246.43	802.60	0.759
baseline vs. 3rd rest	-1599.64	478.14	0.001	-448.74	730.20	0.539
Time×BenchPress			<0.001			0.807
baseline vs. 1st rest	-11.69	10.69	0.274	2.24	8.61	0.795
baseline vs. 2nd rest	10.64	9.49	0.262	5.04	6.73	0.454
baseline vs. 3rd rest	10.88	4.86	0.025	4.31	6.56	0.511
LegPress	0.13	0.65	0.843	0.24	0.42	0.567
Time			<0.001			0.291
baseline vs. 1st rest	787.39	1183.92	0.506	643.86	900.35	0.475
baseline vs. 2nd rest	-878.85	1585.90	0.579	-181.45	608.89	0.766
baseline vs. 3rd rest	-2140.41	492.11	<0.001	231.36	823.08	0.779
Time×LegPress			<0.001			0.048
baseline vs. 1st rest	-0.46	0.43	0.278	-0.18	0.26	0.494
baseline vs. 2nd rest	0.07	0.41	0.862	0.14	0.17	0.428
baseline vs. 3rd rest	0.47	0.14	0.001	-0.06	0.21	0.788

Note. a) Total effect of Time and Time× VO_{2max} is the type III effect.

VO_{2max}. Table 7 shows that a unit increase in VO_{2max} increased HF power (Night) by 478.41 units. This effect was not statistically significant. We also observed a significant main effect of Time (p<0.001). No statistically significant changes were revealed between the working

and resting nights for HF power at specific time points. The changes over time attributable to VO_{2max} were also non-significant.

A unit increase in VO_{2max} increased HF (24hr) by 69.57 units (Table 7). This effect was not statistically significant. Again, we observed a significant main effect of Time (p=0.001). A statistically significant increase in the level of HF power was observed on the first resting 24 hours in comparison to the working 24 hours (p=0.003). The change over time attributable to VO_{2max} (interaction) was significant when comparing the working 24 hours and the first resting 24 hours (p=0.001, indicating a decrease of 50.96 units in the main effect of 2509 at the 2nd time point per unit increase in VO_{2max}). Also the difference between working 24 hours and the 3rd resting 24 hours produced a p-value of 0.05. The negative interaction effect indicates that increase in the main effect of VO_{2max} was reduced on the first and third rest 24-hour periods.

Bench press. A unit increase in bench press decreased HF power (Night) by 8.28 units, but this was not statistically significant. A main effect of Time was observed (p<0.01) for HF (Night). A significant decrease in the level of HF power was observed in the difference between working night and the 3rd resting night (p=0.001). The change over time attributable to bench press was significant when comparing the working night and the 3rd resting night (p<0.005). No statistically significant associations were observed in HF power (24hr) recordings. The non-significant values, however, suggest a negative effect of bench press on HFP.

Leg press. A positive main effect of Time (p<0.001) was observed in HF power (Night). A decrease in the level of HF (Night) was observed on the 3rd rest night (p<0.001) in comparison to the work night. Additionally, a significant positive effect was observed in the change over time attributable to leg press when comparing the work day and the 3rd resting day (p=0.001). In 24hr recordings of HFP the only statistically significant effect was a main effect of the combined effect of time and leg press (p<0.05).

Table 8. Effect estimates, standard errors and p-values for generalized estimation equations models for stress percentage (24hr).

Stress % (24hr)			
Effect	**Estimate**	**Std.Error**	**p-value**[a]
VO_{2max}	-0.45	0.48	0.340
Time			<0.001
baseline vs. 1st rest	-38.11	18.01	0.034
baseline vs. 2nd rest	70.03	20.49	0.001
baseline vs. 3rd rest	-27.10	20.68	0.190
Time× VO_{2max}			<0.001
baseline vs. 1st rest	0.64	0.31	0.037
baseline vs. 2nd rest	-1.71	0.40	<0.001
baseline vs. 3rd rest	0.483	0.37	0.190
LegPress	-0.01	0.01	0.071
Time			0.004
baseline vs. 1st rest	-35.49	13.90	0.011
baseline vs. 2nd rest	-15.69	10.17	0.123
baseline vs. 3rd rest	-13.07	12.90	0.311
Time×LegPress			0.062
baseline vs. 1st rest	0.01	0.004	0.047
baseline vs. 2nd rest	0.001	0.003	0.664
baseline vs. 3rd rest	0.002	0.004	0.553

Note. a) Total effect of Time and Time× VO_{2max} is the type III effect.

VO_{2max}. Table 8 shows that a unit increase in VO_{2max} decreased stress percentage by 0.45 units. This effect was not statistically significant. We also observed a significant main effect of Time ($p<0.001$). The difference between the baseline and the 1st rest day indicated decrease in the level of stress percentage ($p<0.05$). For the second follow-up measurement there was an increase in the level of stress percentage ($p=0.001$). The third rest day showed a decrease from the baseline measurement but this was statistically non-significant. The interaction effect of VO_{2max} and time was significant when comparing the work day and the first and second rest day ($p<0.05$ and $p<0.001$, respectively). The effect was positive at the first time point and negative at the 2nd time point.

Bench press. We observed a significant effect of Time ($p<0.001$). No other statistically significant associations were observed between bench press and stress percentage.

Leg press. A unit increase in leg press decreased stress percentage by 0.01 units. This was statistically non-significant. A main effect of Time ($p<0.01$) was observed. Increase in leg press values was related to a decrease in stress percentage and this effect was significant on the 1st rest day ($p<0.05$). This effect was reversed for those with increasing values of leg press, 1st rest day value being significant again.

No statistically significant associations were observed between night recordings of stress percentage and the physical fitness variables.

Table 9. Effect estimates, standard errors and p-values for generalized estimation equations models for relaxation percentage (Night) and relaxation percentage (24hr).

	Relaxation % (Night)			**Relaxation % (24hr)**		
Effect	**Estimate**	**Std.Error**	**p-value[a]**	**Estimate**	**Std.Error**	**p-value[a]**
VO_{2max}	0.41	0.33	0.215	0.64	0.29	0.026
Time			0.679			<0.001
baseline vs. 1st rest	8.22	13.45	0.541	60.18	18.42	0.001
baseline vs. 2nd rest	17.24	20.26	0.395	-46.54	25.79	0.071
baseline vs. 3rd rest	-13.07	13.92	0.348	30.17	15.57	0.053
Time× VO_{2max}			0.242			<0.001
baseline vs. 1st rest	-0.25	0.23	0.268	-1.05	0.32	0.001
baseline vs. 2nd rest	-0.52	0.28	0.063	1.24	0.57	0.029
baseline vs. 3rd rest	0.16	0.21	0.438	-0.48	0.28	0.090
LegPress	0.01	0.01	0.044	0.01	0.004	0.273
Time			0.014			0.116
baseline vs. 1st rest	45.03	21.43	0.036	25.89	19.32	0.180
baseline vs. 2nd rest	-49.77	37.31	0.182	0.93	9.50	0.922
baseline vs. 3rd rest	-20.63	10.69	0.054	2.53	10.90	0.817
Time×LegPress			0.033			0.196
baseline vs. 1st rest	-0.01	0.01	0.040	-0.01	0.01	0.359
baseline vs. 2nd rest	0.01	0.01	0.232	<0.01	<0.01	0.328
baseline vs. 3rd rest	<0.01	<0.01	0.142	<0.01	<0.01	0.828

Note. a) Total effect of Time and Time× VO_{2max} is the type III effect.

Relaxation % & VO_{2max}. Table 9 shows that a unit increase in VO_{2max} increased relaxation percentage (night) by 0.41 units, but this was not statistically significant. No other significant effects were observed for night recordings of stress percentage. 24hr recordings of relaxation percentage show that a unit increase in VO_{2max} increased relaxation percentage by 0.64 units ($p<0.05$). Also, we observed a significant main effect of time ($p<0.001$). Increase in VO_{2max} was related to an increase in relaxation percentage on the 1st rest day ($p=0.001$). The interaction effect at that time point was negative, meaning that with increasing values of VO_{2max} the effect is reduced.

Relaxation % & Bench Press. A significant main effect of time was observed in 24hr recordings of relaxation percentage. No other significant effects were observed.

Relaxation % & Leg Press. In night recordings, a unit increase in leg press increased relaxation percentage by 0.01 units ($p<0.05$). Also, we observed a significant main effect of time ($p<0.05$). On first rest night the time-effect was positive ($p<0.05$), on other resting nights it was negative but non-significant. On 1st rest night the interaction effect of time and leg press was negative ($p<0.05$). On 2nd and 3rd rest nights it was positive but non-significant.

No significant effects were observed in 24hr recordings of relaxation percentage. However, the main effects of leg press and time were positive.

5.3 Cortisol awakening response

Cortisol values were at their lowest at the first measurement (0min) and increased gradually thereafter on all days (Figure 21). Mean values of cortisol (all 3 days combined) at 0, 15, and 30min were 15,5, 21,0, and 24,3 nmol/l, respectively. Both 15min and 30min values of cortisol were significantly higher than mean cortisol at 0min ($p<0.001$, $p<0.01$, respectively). Cortisol levels on day 2 at 0min was significantly higher than at 0min on day 3 ($p<0.05$). On day 3 cortisol levels rose significantly from 0 to 30min ($p<0.05$).

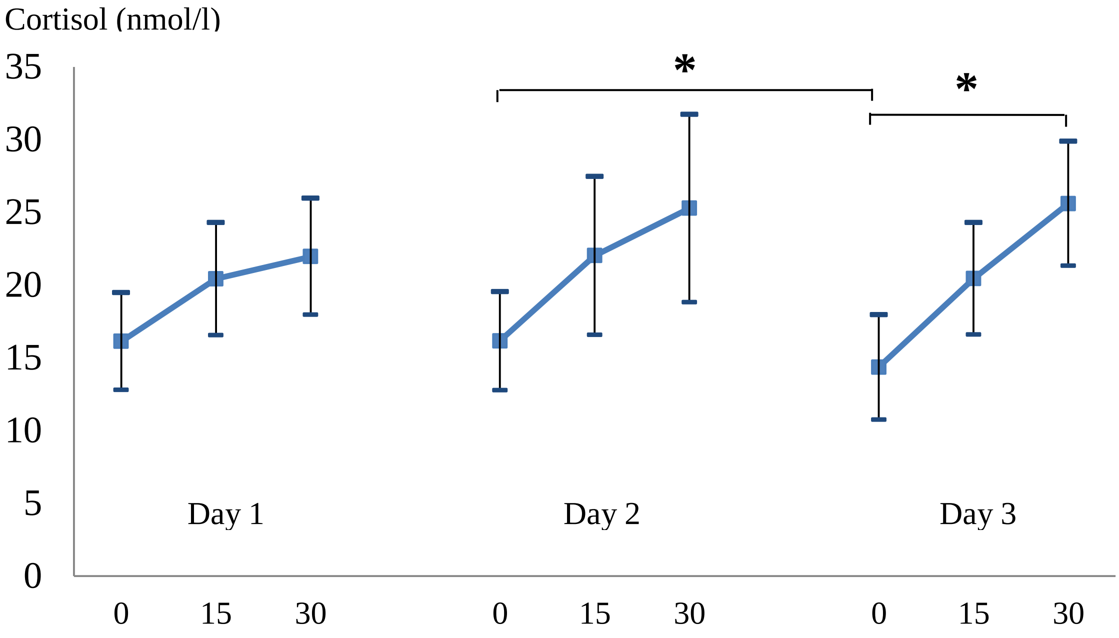


FIGURE 21. Cortisol awakening response (CAR) over 3 days measured immediately (0), 15 and 30 minutes after awakening. Statistically significant changes are noted with * ($p<0.05$). Day 1= rest day 1, day 2=rest day 2, day 3=rest day 3.

6 DISCUSSION

It was hypothesized that parasympathetic influence on the heart would increase with increasing recovery time and that better physical fitness would have a positive association with recovery. Some of the HRV indices showed anticipated results. The results from 24-hour recordings of SDNN and LF/HF ratio support the first hypothesis. Based on relaxation and stress percentage values, stress decreased and relaxation increased after the work shift. It also seems that increased aerobic fitness levels are associated with increased recovery. It was interesting to see that high levels of VO_{2max} did not increase recovery measures in a linear fashion, but the effect leveled off with increased values of $VO_{2max.}$ This raises an interesting question: what is the optimal level of aerobic fitness in terms of enhanced recovery from this type of physical work? High levels of fitness are undoubtedly beneficial, but is there a level after which the added benefits are negligent? Very high levels of aerobic fitness require intense endurance training and high amounts of rigorous exercise could compromise recovery time.

There were some discrepancies in the HRV results. The significant decreases in night-recordings of RMSSD and total power are very surprising and hard to understand. When looking at the association of recovery with physical fitness, night recordings were more inconsistent than 24hr recordings.

Presumably, the fact that the leisure time of rescuers was not controlled caused some of the discrepancies in the results. The methodology in the study was good, but it seems that during the HRV measurement the actions of the rescuers should have been controlled more closely to get comparable results for analysis.

Cortisol awakening response was attenuated right after the work shift. After a “normal” night sleep (after rest nights) the response was larger. There are contradictory results in previous literature regarding the effect of stress on CAR. Some authors have found a larger and some a smaller cortisol response with stress. In this study, it was hypothesized that stress would decrease with increasing recovery time. If this was the conclusion, then the present results suggest an attenuated response with increased stress levels.

6.2 Recovery state after the work shift

It was anticipated that measures reflecting overall HRV and parasympathetic influence on the heart would increase with increasing recovery time. SDNN reflects the overall variability of HR and high variability reflects a well recovered state of the autonomic nervous system. So it was no surprise to see an increase in the 24-hour recordings of SDNN after the work shift. This measure was the lowest during the work shift and increased thereafter, with significant increases on the 2nd and 3rd resting days. These results support the hypothesis of increasing recovery with increasing time for rest. RMSSD reflects parasympathetic influence on the heart and an anticipated, but non-significant increase was seen in the 24-hour recordings of RMSSD after the work shift, but this effect did not last until the 3rd resting day.

LF/HF ratio decreased significantly on days 3 and 4 from the working day value. This was expected, since an increase in the ratio would suggest an increase in stress levels. A decrease in LF/HF ratio means that there is either an increase in HF (parasympathetic drive), a decrease in LF (which is considered to reflect sympathetic activity or both sympathetic and parasympathetic activity), or both. No matter what the source of the change, the decrease in LF/HF ratio supports the hypothesis of increasing recovery over the resting days. LF/HF power is generally interpreted with LFP and HFP values, but now it cannot be estimated which one, or if both, are causing the change in the ratio. No significant changes were observed in either LFP or HFP.

Stress percentage also decreased significantly after the working day. This effect supports the 1st hypothesis. However, the decrease did not extend to the last resting day. Relaxation percentage increased after the working day but this was statistically non-significant. The curve on the relaxation percentage figure also showed a decrease in relaxation on the 3rd rest day, similarly to how the stress percentage figure showed an increase on the 3rd rest day. Could it be possible that the subjects were starting to get emotionally stressed out because of the upcoming work shift? Or could this increase in stress be explained by the high levels of physical activity? It is hard to speculate the reasons for this change in the curve because of the low number of subjects and the fact that this analysis does not reveal if stress is of physical or emotional origin.

Night recordings of HRV showed unexpected results. There was a statistically significant decrease in RMSSD on the resting nights in comparison to night of the work shift. RMSSD is considered mainly vagally mediated, so it was surprising to see a decrease in RMSSD with increasing number of rest days. Although statistically non-significant, it was surprising to see a similar trend in night recordings of SDNN. Total power decreased from the work night to the 3rd rest night. This was unexpected since according to Hynynen (2009), total power decreases with chronic stress.

It would have been interesting to see significant changes in HF power. HFP reflects parasympathetic influence on autonomic nervous system and is an important variable when looking at stress and recovery. There were some large changes, especially, in the night-time recordings but probably due to the low number of subjects these did not turn out to be statistically significant. HFP decreased from the work night to the 1st rest night and started increasing thereafter, never reaching baseline values of the first night. This initial drop could be explained by increased stress during and right after the work shift.

To sum up, some statistically significant changes were seen in the HRV variables, but not all of them supported the original hypotheses. The 24-hour recordings of SDNN showed anticipated and significant results. Also LF/HF ratio results supported the first hypothesis, although the ratio does not reveal changes in overall HRV. Stress and relaxation percentages support the first hypothesis. Stress reactions decreased and relaxation increased after the work shift, but this effect did not last until the last resting day.

When looking at the leisure time activities of these rescuers it is clear that most of the subjects were physically very active on their off-days. It has been shown in literature that physical exertion decreases HRV (Hynynen 2011; Martinmäki 2009). As stated before, HRV measures the fluctuations of the inputs to the heart, with both autonomic withdrawal and a high level of sympathetic input leading to diminished HRV. It seems reasonable to suggest that the large amount of physical exertion during off-days might have affected the results. For example, HF decreases exponentially as a function of exercise intensity (Sandercock & Brodie 2006). This exercise effect, paired with a low number of subjects, might have blunted some of the recovery effects so that some statistically significant results were not found. Also, energy expenditure and oxygen uptake values show that there was an increase in physical activity after the work shift (ns) and the values in both variables were highest on the 3rd resting day. It is good to see that the rescuers are physically active on their recovery days but looking at the stress and relaxation percentages, it seems reasonable to suggest that rescuers should pay attention to sufficient recovery before the next work shift. Maybe hard physical exertion could be avoided before the work shift so that recovery before the upcoming shift would be optimized. It would be interesting to study the effects of different exercise intensities and alternative approaches to optimizing recovery on the rest days in this type of a population in the future, since rescuers need to stay physically fit but also assure sufficient recovery between work shifts.

The night-time recordings seem to conflict with the 24-hour recordings. Many of the rescuers consumed alcohol on their resting days before going to bed, which affects recovery processes negatively and possibly had an effect on the night recordings of HRV. This is something worth considering since acute ingestion of alcohol decreases HRV and only 2.5-hour night recordings were used for analysis. It is hard to speculate other reasons for this discrepancy between the 24-hour and night recordings of HRV.

6.3 Physical fitness and recovery

As Lindholm (2008) reports, physical strain of work is affected by the cardiorespiratory fitness level, muscular strength, and muscular endurance of the individual. The higher the fitness level, the easier it is to perform work-related tasks and the less strain the individual will experience. Less strain, in turn, means that recovery from a given task, or a work shift, will take less time and effort from the body. Since endurance exercise improves autonomic HR control at rest and autonomic HR response to endurance exercise (Martinmäki 2009), it was hypothesized that good fitness levels would improve HRV and thus, enhance recovery processes in rescuers. Positive effects of physical fitness were expected especially on measures such as RMSSD and SDNN, since they reflect parasympathetic influence on the heart and overall variability of the HR.

The results showed that VO_{2max} was positively associated with RMSSD (both 24-hour and night-recordings), supporting the 2nd hypothesis. When interpreting the results it has to be noted that although the significant main effect of Time was related to an increase in RMSSD, this increase was reduced for those with increasing values of VO_{2max}. So the increase in RMSSD leveled off with increasing levels of VO_{2max}. This effect was also seen in other measures of HRV, such as SDNN (24hr), which also had a positive association with VO_{2max}. Based on these results good cardiovascular fitness helps in the recovery process, since increased RMSSD and SDNN are measures reflecting enhanced parasympathetic functioning of ANS and increased overall HRV. But very high levels of VO_{2max} reduce this positive effect.

A positive effect was also found between SDNN (24hr) and leg press, and 1st rest day was statistically significant. Large standard errors probably caused the absence of statistically significant results at other time points. The increase in SDNN was reduced for those with increasing values of leg press. Good lower body strength was associated with increased SDNN, but high values in leg press reduced the positive effect. Also, VO_{2max} had an expected positive effect on relaxation percentage. Again, the increase was reduced for those with increasing values of VO_{2max}. The effects of leg press values on relaxation percentage showed anticipated results. Increase in leg press values was related to increased relaxation, and this effect was significant in the night recordings. Increased lower body strength helps the rescuers to perform activities with less effort and strain, thus allowing enhanced recovery. Although an increase in leg press was related to increased relaxation percentage, this effect was reduced with increasing levels of leg press.

Fitness variables were not always expected to have a positive association with HRV. Statistically significant negative effects were observed in two HRV variables. VO_{2max} had an expected and statistically significant negative effect on LF/HF ratio (both Night and 24hr), with 2nd rest night and 3rd rest day being significantly lower. The effect was reduced with increasing values of VO_{2max}. As stated earlier, high values for the ratio suggest predominance of sympathetic nervous activity. As hypothesized, these results show that increase in VO_{2max} was associated with decreased LF/HF ratio. Increasing levels of aerobic fitness lead to a decreased LF/HF ratio, reflecting enhanced parasympathetic activity. VO_{2max} also had a negative main effect on stress percentage, with 1st rest day having a statistically significant value. The effect was reduced with increasing levels of aerobic fitness. Also leg press had an anticipated negative effect on stress percentage (24hr). Although only the 1st follow-up time point showed a significant negative effect, the other time points also support this direction of the effect. These results support the 2nd hypothesis. With increased lower body strength, work tasks are easier to perform and recovery is faster.

Some unexpected results were also observed. Statistically significant negative associations were observed between leg press and RMSSD (one time point in Night and 24hr recordings). Bench press had a negative effect on HF power, but this effect was only significant at one time-point. Also, although the point estimates for these effects appear large, the associated standard errors are also large. Leg press also had a negative effect on HF power, but only one time-point had a significant value. The results regarding HF power have to be interpreted with caution, because of the large inter-individual variation. Bench press had a non-significant negative effect on RMSSD, and VO_{2max} had a non-significant negative effect on SDNN (Night), but these will not be further discussed, because the effects were not statistically significant.

Also some of the positive associations were unexpected. Bench press had a positive effect on LF/HF ratio, and VO_{2max} had a positive effect on stress percentage at the 2nd follow-up time-point (2nd rest day statistically significant). Some inconsistent results were also found. The effects of leg press on LF/HF ratio did not show any significant values. Because of the low number of subjects and large inter-individual variation it is hard to draw conclusions from these results.

The association between HF power and fitness levels has to be interpreted with caution, because the standard errors were large. When looking at the effect of VO_{2max} on HF power (Night), a significant main effect of Time was observed and this was most likely due to the differences between the 2nd and 3rd, and between the 2nd and 4th time points. The absence of significant effects in the interaction effect of VO_{2max} and Time are also probably due to the large standard errors. The main effect of VO_{2max} suggests a positive effect on HFP (24hr) but it was statistically non-significant. The other results do not reveal a specific trend and only one time point had a significant value so conclusions are hard to draw from these results. However, the significant and positive association on the 1st rest day supports the hypothesis of increasing recovery and parasympathetic influence on the heart with increasing values of VO_{2max}. Again, this effect leveled off with increasing values of $VO_{2max.}$ Bench press had inconsistent effects on relaxation percentage. The only significant effect was the main effect of Time in 24hr recordings of relaxation percentage. Because of the large standard errors, no significant effects were observed at specific time points.

Interestingly, bench press had a significant association with only 3 measures of HRV (RMSSD, LF/HF ratio, HFP) and in all cases the effect was opposite from the expected. Especially since rescuers have to carry and lift heavy objects regularly in their work, it was anticipated that upper body strength would enhance recovery. In this study HRV is used as a measure of recovery, but HRV does not reflect recovery in such a simple manner. Different measures of HRV tell us different things about the function of ANS and with some of the indices it is still hard to predict how they will react to different stimuli. It has been shown in literature that exercise training improves HRV but usually the training program consists of aerobic exercise training, with increased aerobic capacity as a primary goal. Although bench press had opposite effects on HRV than expected, it is important to realize that it does not mean that increased upper body strength does not enhance recovery. It means that in this study, increased upper body strength did not improve HRV indices that reflect parasympathetic influence on the heart. Bench press values had large standard errors, so these results have to be treated with caution. Also, previous literature remains inconclusive about the effects of strength training on HRV.

As stated earlier, it has been generally agreed that exercise modulates cardiac autonomic control by decreasing sympathetic influence and increasing parasympathetic tone of the heart. In this study, results from the effects of VO_{2max} on HRV support previous literature. Since earlier studies have not been consistent on the effects of muscular strength on autonomic control of the heart, the results from this study are hard to compare to results from other authors.

Although this current study did not look at intervention effects of an exercise training program, previous literature shows that exercise training improves HRV and autonomic control of the heart. Improved autonomic control of the heart, in turn, enhances recovery processes. Buch et al. (2002) report that increased parasympathetic influence on the heart decreases the amount of work and oxygen consumption by the heart because of a reduction in resting heart rate (RHR) and myocardial contractility.

6.4 Cortisol awakening response

An expected increase in cortisol shortly after awakening (CAR) was clear on all 3 days of measurement. There was an increase in mean cortisol from immediately after awakening to

30 minutes after awakening, and this increase was statistically significant. In literature, an increase of 50-160% in cortisol has been reported during the first 30 minutes after awakening. Cortisol measured immediately after awakening was significantly higher on resting day 2 than on resting day 3.

There seems to be an attenuated response in CAR on the first resting morning, which is the morning after the work shift. Many studies have been conducted on the changes in CAR in response to different stressors (work stress, PTSD, acute stressors) but the results have been inconsistent. Some studies show an augmented CAR response (Karlson et al. 2011; Schulz et al. 1998), while others report an attenuated response (Lauc et al. 2004; Mutsuura et al. 2009; Sjögren et al. 2006; Wahbeh & Oken 2013) in relation to stress. Chida and Steptoe (2009) report in their meta-analysis of 147 studies that CAR was positively associated with stressors like work and general life stress and that it was negatively associated with fatigue, burnout, and exhaustion. Clow et al. (2004) studied the methodological issues with CAR measurement and analysis and reported that “it remains unclear whether positive affect and good health are consistently associated with larger or smaller awakening responses”. Because of the discrepancy in the literature, it is hard to draw definite conclusions from the results of the CAR measurement in this study. Also, since the results from HRV measurements are inconsistent, it is difficult to relate the CAR findings to the autonomic nervous system recovery state measured with HRV.

6.5 Limitations of the present methodology

It has to be noted that the subject population is somewhat selective. It is possible that the rescuers, who volunteered to participate in the study, are physically more active than the average rescuer. This, of course, is only speculation. All the subjects were volunteers so it may be that rescuers who have a more active lifestyle are more likely to participate in studies like this. So the subjects participating in the study may not be a perfect representative sample of all rescuers in Finland. Rescuers in Jyväskylä have recently undergone a lot of exercise testing due to research studies and testing for work-related fitness standards. Some of the rescuers at the fire department mentioned being tired of all the testing so they were not eager to participate in the study. However, this study provided the participants some new information on their health and fitness status so regardless of the large amount of testing some were still interested to participate. It would have been interesting to compare groups of older and younger rescuers but unfortunately there were not enough subjects to do so.

Another issue in regards to limitations of the study is that there was no control group. However, it is difficult to compare this specific occupational group to any other profession because of the many factors that affect the stress levels of rescuers (shift work, long shifts, psychological and physical stress, and dangerous work environment). Some comparisons about stress and recovery could be done but then it needs to be taken into consideration that there are many factors that could explain the differences. Because of the difficulty in comparing the work of rescuers to other occupations, it was decided that no control group would be used in this study.

VO_{2max} was estimated with a submaximal exercise tests, which is not the golden standard for measuring aerobic capacity. However, as mentioned earlier, submaximal exercise tests have been shown to be reliable in estimating VO_{2max} (Keskinen et al. 2004, 78.).

Some of the participants were physically very active during the recording period. This was not unusual for them but physical activity has an effect on HR and HRV. It was the purpose of the study to look at stress and recovery markers during normal life so this is why physical activity levels were not controlled.

One limitation in using HRV analysis for the purpose of studying stress and recovery is that HRV does not reveal if stress is of physical or emotional origin. This has to be taken into account when interpreting the results.

Subjects were instructed to keep record on alcohol consumption. However, not all of the subjects reported the use of alcohol very accurately (doses/day), so this data could not be used to assess the effect of alcohol on recovery. Since acute ingestion of alcohol decreases HRV (Acharya et al. 2006), it would have been interesting to look deeper into this data and see if there was an association between alcohol consumption and recovery as measured with HRV.

Statistical analysis would have been more reliable if more subjects had participated in the study. Some of the results might have been affected by outliers due to the small sample size.

6.6 Future studies

In future studies with rescuers the HRV data could be split into segments based on different tasks that were performed during the work shift. It would be ideal to get the HRV recording from many rescuers performing the same task so comparisons could be made between individuals. Looking back, a subjective assessment of the loading (physical and psychological) of the work shift, would be a useful addition to the data. This could be done with a simple questionnaire. In future studies using HRV as a measure of stress and recovery in a natural setting, it should be stressed that accurate records of the timing and amount of alcohol consumed are important for the analysis of HRV data. Since there are so many variables affecting the stress and recovery state of rescuers doing shift work, it is important to carry out studies with a larger subject population to diminish the effect of statistical outliers. Also it could be useful to compare older and younger rescuers since the physical and psychological stressors seem to affect these 2 groups in different ways. Autonomic cardiovascular control also becomes impaired with age and autonomic balance shifts towards sympathetic dominance (Martinmäki 2009).

The aim of this study was to investigate the recovery from stress during and after a work shift so long-term effects of stress were not included in the study. If also long-term effects of work stress in rescuers were to be investigated, an orthostatic stress test conducted in the morning could be included in the methodology. Hynynen (2009) mentions in his doctoral dissertation that this type of testing is appropriate for studying the effects of chronic physical and/or emotional stress. Parasympathetic influence was decreased in the morning during an orthostatic stress test in subjects in the high stress group, leading to decreased HRV, while no change in autonomic control was observed during the night. Because changes in autonomic control were somewhat inconclusive in this study, it could be useful to add an orthostatic stress test in the methodology in similar research studies.

Interestingly, Esco et al. (2011) found that body composition measured with skinfolds of the chest, abdomen, and thigh regions had a stronger independent relationship with HRV than other body composition measures (BMI, waist circumference) and $VO_{2max.}$ This is an interesting finding that could be further studied, since the effects of body composition on autonomic cardiac control have not been extensively studied. A later study by Esco and Williford (2013) revealed that greater skinfold thickness was also related to a delayed recovery of HRV after maximal exercise.

7 CONCLUSIONS

Rescuers have a physically and emotionally demanding job with many different stressors. Long work shifts, heavy equipment, time-constraint in rescue operations, and dangerous work environment are some of the things adding to the overall stress of the job. Physical demands of this type of work have been evaluated in many studies, but the overall stress and recovery of rescuers has not been thoroughly investigated. As mentioned in previous literature, physical and psychological challenges of rescuers during the whole work shift need to be studied. The purpose of this project was to further investigate how rescuers recover during and three days after a work shift. It was useful to have a 96-hour HRV recording, since in previous studies only shorter segments have been used.

Although some of the results in this study were inconsistent, some of them support the two original hypotheses. Based on the 24-hour recordings of SDNN and LF/HF, autonomic control on the heart was enhanced after the work shift. Stress decreased and relaxation increased with increasing recovery time. For some reason, the enhanced effect in autonomic control did not extend to the last resting day in all of the variables studied. Night recordings of HRV were more inconsistent than 24-hour recordings of HRV. It is possible that the discrepancies were due to lack of control in leisure time activities of rescuers. It also seems that increased aerobic fitness levels are associated with increased recovery. The effects of lower- and upper-body strength on recovery were less consistent, although increased lower body strength was in many cases associated with enhanced recovery. Cortisol awakening response was attenuated right after the work shift. The CAR response was larger after rest nights.

Firstbeat BODYGUARD was a good tool for measuring autonomic nervous system changes non-invasively. Firstbeat HEALTH software was also a useful tool to examine stress and recovery. The software offers many useful tools, such as different reports and many more variables than were used in data analysis of this study. The automatic analysis done by the software includes some artifacts despite of automatic removal by the software. This is why the data in the reports were not used for further analysis. The reports, however, show quickly and clearly changes in recovery state and summarize the data from the whole recording period so they are useful for giving feedback to the subjects after the recording period. Some of the variables offered by the automatic analysis, such as stress and relaxation percentage, were included in the statistical analysis regardless of having some artifacts because they offered an interesting addition to the traditional HRV variables when looking at stress and recovery.

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APPENDIX 1. Written consent form.

TUTKITTAVAN SUOSTUMUS

Olen lupautunut osallistumaan yllämainittuun tieteelliseen tutkimukseen, jonka tarkoituksena on tutkia palautumisen ja fyysisen kunnon yhteyksiä. Olen saanut riittävän selvityksen tutkimuksen tarkoituksesta ja sen toteutuksesta sekä tutkimuksen hyödyistä ja riskeistä. Olen saanut selvityksen tutkimuksen yhteydessä suoritettavasta tietojen keräämisestä, käsittelystä ja luovuttamisesta.

Minulla on riittävät tiedot oikeuksistani, Ymmärrän, että osallistumiseni on vapaaehtoista. Tiedän, että tietojani käsitellään luottamuksellisesti eikä niitä luovuteta sivullisille. Tutkimuksen tulokset esitetään ryhmämuotoisina, yksilöt eivät henkilöidy.

Minulla on ollut mahdollisuus esittää kysymyksiä ja olen saanut riittävän vastauksen kaikkiin tutkimusta koskeviin kysymyksiini. Tiedot ovat antaneet tutkimushankkeen edustajina Katariina Lyytikäinen ja Leena Toivonen.

Allekirjoituksellani vahvistan osallistumiseni tutkimushenkilönä tähän tutkimukseen ja suostumukseni siihen, että tässä tutkimuksessa minusta kerättyjä tietoja saa käyttää tutkimustyöhön Jyväskylän yliopiston yllä mainitussa hankkeessa ja tietoni ovat käytettävissä Työterveys Aallossa.

Tutkittavan nimi Tutkittavan henkilötunnus Tutkittavan osoite

Päivämäärä Allekirjoitus

Suostumus vastaanotettu

Tutkijan nimi Päivämäärä Allekirjoitus
(Suostumuksen vastaanottaja)

Alkuperäinen allekirjoitettu tutkittavan suostumus sekä kopio tutkimustiedotteesta jäävät tutkijan arkistoon. Tutkimustiedote ja kopio allekirjoitetusta suostumuksesta annetaan tutkittavalle.

APPENDIX 2. Health questionnaire.

Terveyskysely

Nimi ____ **Ikä** ____

1. **Onko sinulla lääkärin toteamaa hengitys-, sydän- tai verenkiertoelimistön sairautta?**
   Vastausrivi 1. kyllä (A) ei (B)
   Mikä____

2. **Sairastatko verenpainetautia tai onko lääkäri todennut, että verenpaineesi on kohonnut?**
   Vastausrivi 2. kyllä (A) ei (B)

3. **Pyörryttääkö sinua usein tai kärsitkö huimauksesta?**
   Vastausrivi 3. kyllä (A) ei (B)

4. **Onko sinulla lääkärin toteama tulehduksellinen nivelsairaus?**
   Vastausrivi 4. kyllä (A) ei (B)

5. **Onko sinulla selkävaivoja tai tuki- ja liikuntaelinten pitkäaikaisia tai usein toistuvia vaivoja?**
   Vastausrivi 5. kyllä (A) ei (B)
   Mikä____

6. **Onko sinulla jokin muu omaan terveyteesi liittyvä syy (jota ei edellä ole vielä mainittu), jonka takia sinun ei tulisi osallistua liikuntaan, vaikka itse haluaisitkin?**
   Vastausrivi 7. kyllä (A) ei (B)
   Mikä____

7. **Käytätkö tällä hetkellä lääkkeitä?**
   Vastausrivi 8. kyllä (A) ei (B)
   Mikä____

8. **Oletko viimeisen kahden viikon aikana sairastanut jotain tulehdustautia (flunssa, kuumetauti)?**
   Vastausrivi 9. kyllä (A) ei (B)
   Mikä____

9. **Oletko viimeksi kuluneen vuorokauden aikana nauttinut runsaasti alkoholia (enemmän kuin 2 ravintola-annosta)?**
   Vastausrivi 10. kyllä (A) ei (B)

10. **Esiintyykö sinulla rintakipuja tai hengenahdistusta? YMPYRÖI VAIHTOEHTO!**
    Vastausrivi: **Levossa** kyllä ei
    Vastausrivi: **Rasituksessa** kyllä ei

Vakuutan antamani tiedot oikeiksi. Ymmärrän testausmenetelmät ja osallistun tutkimukseen omalla vastuullani.

Paikka ja aika ____

Allekirjoitus ____