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Physiological and perceived sleep recovery comparison of 19 to 24-year-old elite hockey players

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Abstract

Sleep is an essential part of recovery and hence also of high importance for athletic performance and health. While most athletes and coaches are aware of this fact, studies have shown that athletes often have difficulties achieving adequate sleep length and/or -quality. Possible reasons for sleep issues include, among others, neurological stimulants (e.g. stadium light, caffeine, blue light), travel, pre-game anxiety or the unfamiliar environment of hotel rooms.

This study aimed to compare the physiological and perceived sleep recovery of eight 19-24-year-old elite hockey players from the team Pori Ässät. Physiological findings were obtained using the Firstbeat Bodyguard 2 devices and perceived recovery was enquired through daily personal phone interviews. Measurements took place during a 5-day road trip, including 2 away game nights, and covered five nights in total.

For technical reasons, physiological measurements only provided sufficient data for six out of eight players. The six players were, in contrast to previous studies, able to achieve the minimum recommended amount of seven hours total sleep time (TST) per night. TST was slightly lower on game nights than on non-game nights. Firstbeat data demonstrated that all players achieved good sleep recovery, despite the fact that interviews showed that none of them followed any particular sleep routine and most consumed caffeine up until the evening. Interviews further showed that players’ perceived sleep quality and recovery were in line with the physiological findings, although the perceived recovery was slightly lower than the Firstbeat data would suggest.

In summary, all six examined players recovered well during the night. Coaches can use the data of this study to further develop training intensities and plan for rest and recovery days. They can also use the results to further educate players on the importance of good sleep hygiene.

Key words
Recovery, sleep, hockey, firstbeat, elite athlete, perceived recovery, heart rate variability

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1 INTRODUCTION

Physical activity is known to provide many health benefits including increased adaptations of the musculoskeletal, metabolic, and cardiovascular systems. Regular physical activity can have a positive impact on sleep quality and quantity. (Nedelec, Aloulou, Duforez, Meyer & Dupont 2018, 1) However, the elite level presents many different conditions unfamiliar to amateur athletes such as high training (physical) loads (Dumortier *et al.* 2018), high psychological/psychosocial pressure on an individual (“need to succeed situations”), and limitations on personal life (Schaal *et al.* 2011, 5-6). An elite athlete as defined by Segen’s Medical Dictionary (2011) is “a person who is currently or has competed as a varsity player (individual or team), a professional player or a national or international level player”. Due to the high loads, elite athletes are continuously at a high risk of injury (Segen's Medical Dictionary 2011).

Elite athletes, coaches and trainers have gained an interest in sleep recovery and its influence on training, recovery, and optimal performance (Samuels & James 2014). Currently, there is not much scientific evidence to support this belief. Research has shown that training (load and time), competition, travel, hypoxia, sleep environment, light exposure, and sleep disorders are the factors which can affect sleep. (Roberts, Teo & Warmington 2019, 8-11) As society (e.g., fans) and sport performance itself (e.g., trade value) highly influence professional athletes, it can be difficult to distinguish between the effects of sport and society on an athlete’s sleep (Nedelec *et al.* 2018, 2). Therefore, this thesis aims to compare the physiological recovery findings with the perceived recovery of individual elite hockey players. Furthermore, the findings may help coaches to make possible adjustments in training loads or seek professional assistance for individual players to improve sleep recovery quality.

In this thesis, a study including 8 players from the Finnish Elite Hockey League team Pori Ässät will be presented. The criteria for participating players were age, gender, date of birth, health, active roster position, and active contract. The participants were 19-24 years of age and would not be turning 25 years old during the course of the study. This criterion was selected based on research stating that brain maturation (rewiring continued after puberty) is not completed until the age of 24, particularly in the prefrontal cortex. Prefrontal cortex helps accomplish executive brain functions. Its development is very important for complex behavioral performance, cognitive analysis, and the control of correct behavior in any difficult or social situations. Individual sleep patterns is one of the many factors that can impact brain maturation during adolescence. (Arain *et al.* 2013, 450-456.)

2 AIM AND OBJECTIVES

The aim of this thesis is to compare the physiological sleep recovery to perceived sleep recovery in elite hockey players 19-24 years old. The results of this thesis can be used to help the coaching staff manage rest and recovery periods of individual players. Furthermore, this thesis can help coaches to better educate players concerning sleep hygiene in order to improve the individual player sleep recovery. The objectives of this thesis are to measure 8 players’ sleep recovery using the Firstbeat Bodyguard 2 and to compare each player’s perceived recovery to the physiological findings. The perceived recovery findings will be obtained through daily personal interviews, which include among other questions, the perceived recovery status (PRS) scale. Interviews will be held via phone upon awakening each morning for the space of five days.

3 THE GAME OF HOCKEY – A BRIEF OVERVIEW

Ice hockey was founded in the early 1800s in Canada (Montgomery 1988). The sport is played in intermittent high intensity shifts that are combined with passive rest periods. Regulation time is made up of 60 minutes in an ice hockey game. The game consists of three periods, each period lasting 20-minutes. A player is on the ice in 30-90 second shifts before going to the bench for a rest period (Website of Mid Sweden University 2020). More precisely, the average shift, including 39.7 seconds of nonstop play and 27.1 seconds of stoppages, continues for 84.5 seconds on the ice (Green, Bishop, Houston, McKillop, Norman & Stothart 1976) before the player returns to the bench to recover for an average of four to five minutes (Montgomery 1988). The cycle is repeated throughout the period between 6-10 shifts and a player can play a total of 10-28 minutes in a single period (Website of Mid Sweden University 2020). However, several factors must be considered with these times such as position (defender or forward), tactics of play or special events (e.g. power play or pulled goaltender) (Twist & Rhodes 1993a). Defensemen for example, are on the ice approximately 50% of the time while forwards occupy about 35% of the game on the ice (Twist & Rhodes 1993b, 44).

The various physical demands of the sport are demonstrated in a player’s physiological ability, a combination of high VO2max, explosiveness, high maximal anaerobic power, and work ability (Website of Mid Sweden University 2020). To succeed at the elite level of ice hockey, players must develop an all-around fitness, namely anaerobic sprint ability, high aerobic endurance, superior muscle strength, power, and endurance (Montgomery 1988). In addition to physiological abilities, Sigmund, Kohn & Sigmundová (2016) classified average body height (184.3 ± 5.79 cm) and weight (88.1 ± 7.37 kg) values of top world class players in accordance to International Ice Hockey Federation (IIHF) ranking.

4 PHYSICAL AND MENTAL DEMANDS OF ELITE HOCKEY DURING THE REGULAR SEASON

Elite hockey players must excel in all physical capacities to perform at the top level (Peterson *et al.* 2015, 1195). Ice hockey is a physically and metabolically unique sport. Highly trained aerobic and anaerobic energy systems are required to succeed at the top level. Hockey requires a high demand of glycolytic activity, aerobic power and endurance (Cox, Miles, Verde & Rhodes 1995; Montgomery 1988). Green, Pivarnik, Carrier & Womack (2006) claim that 69% of energy necessary during high intensity periods comes from glycolytic adenosine triphosphate (ATP). Furthermore, the sport demands a large, lean body mass and extraordinary muscular strength (Orvanová 1987). Thus, it can be concluded that total body fitness is required for the sport of ice hockey. Additionally, necessary protocol of proper training and maintenance of fitness levels demanded by the sport can assist in injury prevention and delay premature exhaustion to sustain performance (Cox, Miles, Verde & Rhodes 1995). A representation of approximate energy system percentages used in hockey can be seen in table 1.

Table 1. Commonly used approximation percentages of energy system utilization in ice hockey (Reproduced from The Canadian Hockey Association 1989)

Energy system	**5-seconds burst**	**10 sec. of hard skating**	**30 sec. of continuous activity**	**1-min shift of intermittent sprints, coasting and stops**	**Recovery between shifts/periods**
Alactic Anaerobic	85%	60%	15%	10%	5%
Lactic Anaerobic	10%	30%	70%	60%	5%
Aerobic	5%	10%	15%	30%	90%

While a normal shift consists of 39% of ice time using the energy sparing ‘two-foot glide’ (Bracko, Fellingham, Hall, Fisher & Cryer 1998, 261), a hockey player will play at 85-90% of their heart rate max (Montgomery 1988, 107). Noonan (2010) found that blood lactate levels vary between 4.4m.mol/l and 13.7m.mol.l and have an average value of 8.15mm.mol/l in division 1 hockey players.

4.1 Speed

Ice hockey, like many other sports, demands high production of speed, power, and acceleration (Cox, Miles, Verde & Rhodes 1995; Peyer, Pivarnik, Eisenmann & Vorkapich 2011). On and off ice tests have provided a moderate relationship in sprint speed to one another. Dry ground sprints have shorter contact and stride rates in comparison to the longer contact and slower stride rates in ice skating. (Nagahara, Matsubayashi, Matsuo & Zushi 2014; Neeld 2018)

4.2 Strength and power

To meet the forceful demands of hockey, a player must be able to produce the two most important physical requirements; namely, upper and lower body strength and power (Bompa & Chambers 2003, 22; Montgomery 1988, 116). The high production of force needed in ice hockey (e.g. shooting, hitting, checking, and skating) will require a player to develop a higher degree of power (Bompa & Chambers 1991, 22; Twist & Rhodes 1993a, 69). However, prior to proper development of power, a player must meet a specific level of conditioning in aerobic, anaerobic and strength components. The goals of strength training are an increase in muscle mass, improve “absolute strength”, and develop a power training foundation. In addition, absolute strength is required to develop a tolerance for contact in the sport. Along with added muscle mass, absolute strength can reduce the probability of injury. (Twist & Rhodes 1993a, 69)

4.3 Flexibility

Powerful and explosive movements require flexibility. An increased flexibility of the hip, groin, quadriceps, and hamstrings muscles will improve speed and effectiveness of moving. This is made possible by allowing the hip to extend sufficiently while skating and the correct utilization of the muscles required for powerful strides. (Twist & Rhodes 1993a, 69.)

Flexibility in the mid torso and lumbar region are necessary since ice hockey players are in a flexed lumbar position throughout the game. The production of powerful trunk rotations, turns, and giving/taking hits occur constantly while on the ice. Incorporation of an effective flexibility plan will 1) increase elasticity of muscles and connective tissues and 2) minimize risk and degree of injury. (Twist & Rhodes 1993a, 70.)

4.4 Endurance

Because ice hockey is played in high intensity intermittent shifts, there is a demand for sporadic, explosive bursts of maximal effort. Thus, there is a necessity for anaerobic power and endurance. Obtaining a high aerobic capacity will have a positive effect in fatigue reduction and player performance. Hence, the importance of an all-around physiological development. (Montgomery 1988, 111-112.)

Muscular endurance is attained through high repetitive contractions (20+) and movements using weights or body weight. Developing strength is beneficial to muscular endurance. Muscular endurance can be improved through regular strength training. (Bompa & Chambers 2003, 1.)

Stanula et al. (2014) conducted a study to evaluate the effect of aerobic capacity using a VO2 max test on the ability to skate multiple short distances (6 timed 89m sprints) while exerting maximal intensity. The results were consistent with previous studies, indicating that high intensity exercise recovery is dependent on the aerobic processes and its effect on the recovery of energy substrates. Most specifically, the effects of repeated shifts of anaerobic power (lactic acid accumulation) can be decreased through lactate utilization in slow twitch muscle fibres by consequence of having high aerobic power (Tomlin & Wenger 2001, 9). In relation, Green et al. (2006) concluded that VO2max is also connected to overall scoring probability during a hockey season.

4.5 Agility

Although the definition of agility has undergone frequent changes and is commonly recognized as “the ability to change direction and start and stop quickly”, (Little & Williams 2005, 76) the most current definition is “the ability to change speed and direction of movement rapidly and accurately, usually in response to a highly specific stimulus”. In addition, agility efficiency is a likely result of cognitive factors (e.g. decision-making ability, pattern recollection and predictability) and physical characteristics (e.g. braking, speeding up, reaction strength) (Shepard, Dawes, Jeffreys, Spiteri & Nimphius 2014, 22). Ice hockey players must be able to perform cuts, make quick turns, weave, breakaway, hit and accelerate in any situation (Novák, Lipinska, Roczniok, Spieszny & Stastny 2019, 680).

4.6 Coordination and executive function

Good coordination requires an athlete to highly develop smooth and efficient fine motor skills (e.g. holding a hockey stick, wrist movements) and gross motor skills (e.g. ice skating, shooting). A player must combine multiple movements into one smooth movement to achieve a specific task such as a wrist shot. In ice hockey, hand-eye coordination and foot-eye coordination are essential. A player's hands and feet react in relation to the eyes following another player or the puck. (Website of pdhpe.net 2020.)

Building strength is insufficient for the complexity of continual coordinated muscular patterns that are required in the effective application of force in learned movements (e.g. passing a puck, slap shot, deke). The brain, spinal cord, and periphery are much like an advanced network system, synchronizing millions of internal and external stimuli data signals almost instantaneously. (McArdle, Katch & Katch 2015, 384.) Table 2 provides the three cores of executive function.

Table 2. Executive function consists of three cores (Diamond 2013)

Inhibition	Inhibitory control - self-control (behavioral inhibition) - interference control (selective attention and cognitive inhibition)
Working memory	- Verbal and nonverbal - Reasoning, learning, comprehension, manipulation of mental information
Cognitive flexibility	Also known as: set shifting, mental flexibility, or mental shifting - relatively linked with creativity

Executive function in ice hockey requires players to simultaneously process very fast paced game situations and distribute that information based on each individual unfolding play. Thus, highly trained split vision (acute peripheral vision), cognitive flexibility, inhibitory control, adaptable attention, making choices, and creativity separates elite players from the rest. (Lundgren *et al.* 2016, 325.) Center forwards, for example, have been shown to outperform other positions on the design fluency test. A possible reason for such performance is center forwards play between defense and offense where there is a continual need to make quick decisions based on the present situation (e.g. position, risks, and opportunities). Furthermore, the center forward position, in relation to other positions (wings and defense), is also more likely to require greater split vision, cognitive flexibility, and decision making. (Lundgren *et al.* 2016, 333.)

4.7 Game schedule during the regular season

A total of 450 matches are played in the regular season, 60 games per team. A total of 62% of all regular season matches are played on Fridays and Saturdays. There is a traditional break in the League games during the Finnish Euro Hockey Tournament mid-November. The final round of the regular season is played in mid-March. (Website of Liiga 2020.)

5 AUTONOMIC NERVOUS SYSTEM

The human nervous system is divided into two divisions: the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS consists of the brain and the spinal cord and it basically coordinates all body functions through information it receives. (Rea 2015, 1.) The PNS lies outside of the CNS and consists generally of the somatic nervous system and the autonomic nervous system (ANS) (Rea 2015, 14-15).

The somatic nervous system sends input and output signals that are usually, with very few exceptions, consciously perceived or stimulated. In contrast, the input to the ANS is normally not consciously perceived. It comes from autonomic sensory neurons which are located in muscles, visceral organs, blood vessels, and the nervous system which monitor the internal environment of the body. The output of the ANS happens through autonomic motor neurons that excite or inhibit activities in the effected tissue, for example by increasing or decreasing the heart rate, thereby regulating visceral activities. (Tortora & Derrickson 2014, 524.)

The ANS consists of three divisions, the sympathetic division, the parasympathetic division, and the enteric division. The sympathetic division is also known as the “fight or flight division” because its activities prepare the body for an emergency situation. For instance, the dilation of blood vessels to skeletal muscles or increasing the breathing rate. The parasympathetic division on the other hand is often called the “rest and digest division” and as the name suggests, its main purpose is to conserve and restore energy and to replenish nutrient stores. (Tortora & Derrickson 2014, 524-526.) The enteric division manages the functions of the gastrointestinal tract. It acts independently but may also be influenced by sympathetic and parasympathetic activity. (Svorc 2018, 3.)

5.1 Anatomy and physiology

Unlike the somatic nervous system, which uses one single myelinated neuron to reach the skeletal muscle, the autonomic nervous system requires two neurons which meet in autonomic ganglia. The first neuron is called preganglionic neuron, has its cell body in the CNS, and its myelinated axon extends to a ganglion. The second neuron has its cell body in the ganglion, is called postganglionic neuron, and its unmyelinated axon extends directly to the effector. (Tortora & Derrickson 2014, 526.)

The ganglia of the sympathetic division are called sympathetic trunk ganglia and prevertebral ganglia. The sympathetic trunk ganglia are located on both sides of the vertebral column in a vertical row and extend from the base of the skull to the coccyx. The prevertebral ganglia can be found anteriorly to the vertebral column and close to the large abdominal arteries. Most ganglia are hence located close to the spinal cord, which means that the preganglionic axons are usually very short. While the postganglionic axons from the sympathetic trunk ganglia mainly innervate the organs above the diaphragm, for example heart, shoulders, neck, and head, the postganglionic axons from the prevertebral ganglia innervate the organs below the diaphragm. (Tortora & Derrickson 2014, 526-529.)

In the parasympathetic division, the cell bodies of the preganglionic neurons are based in the nuclei of four cranial nerves in the brain stem (III, VII, IX, and X) and in the lateral gray matter of the second through fourth sacral segments of the spinal cord. The ganglia of the parasympathetic system are called terminal ganglia and, as the name suggests, they are close to or even within the wall of an organ. Consequently, the parasympathetic preganglionic axons are often very long. (Tortora & Derrickson 2014, 526-529.)

Autonomic neurons can be classified as either cholinergic or adrenergic. All sympathetic and parasympathetic preganglionic neurons, all parasympathetic postganglionic neurons, and the majority of the sympathetic postganglionic neurons are cholinergic. They release the neurotransmitter acetylcholine and bind to cholinergic receptors, which can be either nicotinic or muscarinic. Activation of nicotinic receptors always leads to excitation of the postsynaptic cell, whereas activation of muscarinic receptors can lead to either excitation or inhibition, depending on where they are located. (Tortora & Derrickson 2014, 535-536.)

The majority of the sympathetic postganglionic neurons are adrenergic, and they release noradrenaline (norepinephrine). Most of the time, adrenergic neurons cause longer lasting effects than cholinergic neurons, because acetylcholine gets inactivated quickly by acetylcholinesterase. As mentioned, most postganglionic neurons of the sympathetic division are adrenergic, whereas the postganglionic neurons in the parasympathetic division are cholinergic. Consequently, the effects of sympathetic stimulation are longer lasting than the effects of parasympathetic input. (Tortora & Derrickson 2014, 536 – 538.)

5.2 Autonomic responses

In situations of physical or emotional stress, that is, physical exertion or emotions (e.g. fear, anger, embarrassment) the sympathetic division is dominant. As previously mentioned, the sympathetic division prepares the body for “fight or flight” situations and therefore increases body functions that support quick production of ATP and strenuous physical activity: Heart rate and contractility become increased, bronchial muscles relaxed, and the pupils dilated. At the same time, blood supply to areas not needed for physical activity, such as the kidneys or the gastrointestinal tract, gets restricted, to be able to redirect blood to other areas like the skeletal or cardiac muscles. (Rea 2015, 20; Tortora & Derrickson 2014, 537-538.)

When the body is not stressed, the parasympathetic division dominates over the sympathetic division and supports functions responsible for conserving and restoring energy. The effects are essentially the opposite to those which are brought about by the sympathetic division: The heart rate slows down, bronchial muscles contract, the pupils constrict, and the gastrointestinal tract and the digestive glands get stimulated. (Rea 2015, 20-21; Tortora & Derrickson 2014, 538-539.) A more detailed overview of the sympathetic and parasympathetic responses can be found in table 3.

Table 3. Comparison and contrast of the wide effects of the sympathetic and parasympathetic nervous system at key areas throughout the body (Modified from: Rea 2015, 20)

	Sympathetic	**Parasympathetic**
Heart	Rising of heart rate	Reduction of heart rate
	Increase of contractility of the atria and ventricles	Reduction of contractility of the atria and ventricles
	Increased conduction	Reduced conduction
Lungs	Relaxation of bronchial muscles	Contraction of bronchial muscles
	Reduction in secretions (via α 1 receptors)	Stimulation of secretions (via α 1 receptors)
Stomach and intestines	Reduction in tone and motility	Increase in tone and motility
	Contraction of sphincters	Relaxation of sphincters

	Inhibition of secretions	Stimulation of secretions
Pancreas	Inhibition of exocrine secretion	Stimulation of exocrine secretion
	Inhibition of insulin secretion	Stimulation of insulin secretion
Eyes	Contraction of radial muscle (dilation of the pupil)	Contraction of the sphincter muscle (constriction of the pupil)
	Relaxation of the ciliary muscle (for far vision)	Contraction of the ciliary muscle (for near vision)
Nasal, lacrimal and salivary glands	No significant effect	Stimulation of mucous and serous secretions from the secretory cells
Skin	Contraction of the arrector pili muscles (hair to stand on end)	N/A
	Localized secretion of the sweat glands	Generalized secretion of the sweat glands
Urinary bladder	Relaxation of the bladder wall	Contraction of the bladder wall
	Contraction of the sphincter	Relaxation of the sphincter
Genital organs	May stimulate vasoconstriction but it is uncertain and variable	May stimulate glands and smooth muscle; vascular dilation
Adrenal gland	Stimulation of secretory cells to produce epinephrine	No effect
Arterioles	Variable	Dilation of coronary and salivary gland arterioles (via α 1,2 receptors)

The balance between sympathetic and parasympathetic activity is called autonomic tone and it is regulated by the central nervous system, most importantly the hypothalamus in the brain, and the autonomic reflex arc. The hypothalamus receives information from the somatic and autonomic sensory neurons (e.g. level of substances in the blood, changes in temperature, or visceral functions) as well as information about emotions from the limbic system. Based on this, the hypothalamus can increase or decrease sympathetic / parasympathetic activity as it is connected to both divisions. When sympathetic activity is increased, parasympathetic activity is usually decreased at the same time and vice versa. (Tortora & Derrickson 2014, 536 – 541.)

5.3 Heart rate variability

Heart rate variability (HRV) is a noninvasive method which provides a quantitative assessment of cardiovascular neural control (Zhuang, Gao & Gao 2005, 316). More precisely, it is the fluctuations of intervals between successive heartbeats and the fluctuations between successive heart rates. HRV has therefore become the prevalent term in describing instantaneous HR and R-R intervals. Furthermore, HRV is quick method used to represent and analyze ANS activity on the heart. It provides perspective of sympathetic and parasympathetic stimulus through HR recordings. (Electrophysiology Task Force of the European Society of Cardiology the North American Society of Pacing 1996, 354-355.) HRV is a common tool used to moderate training in athletes (Bellenger *et al.* 2016).

Short-term (beat-to-beat) changes in HRV measurements are produced by the interactions of autonomical neural activity, blood pressure, and breathing control systems, namely the sympathetic (SNS) and parasympathetic nervous systems (PSNS) (Hirsch & Bishop 1981; Hirsch, Bishop & York 1996; Bradley *et al.* 2009). Thus, HRV has been used to measure and record heart-brain interactions and autonomic nervous system (McCraty *et al.* 2009, 6). The variations in R-R intervals reflect the balance or imbalance in sympathetic and parasympathetic input to the myocardium. A widespread difference in R-R intervals (milliseconds) suggests a “healthy” balance between the two systems. Though, a short difference could possibly reflect an unbalanced autonomic input (McArdle, Katch & Katch 2015, 330).

Several studies have stated that reduced HRV is linked with morbidity and life expectancy, quality of life and mental well-being (Sajadieh *et al.* 2004; Stein *et al.* 2005; Geisler *et al.* 2010). Furthermore, acute stress can result in decreased HRV during the day and disturbed sleep at night (Dishman *et al.* 2000; Hall *et al.* 2004). Additionally, it has been concluded that higher levels of HRV are related to better physical fitness and age of an person (De Meersman 1993, McArdle, Katch & Katch 2015, 330).

The root mean square of successive differences (RMSSD) is the HRV index most used to monitor aerobic training (Plews *et al.* 2013, 780). The value of RMSSD is reached by the calculation of consecutive time difference of each heartbeat (in ms). After which, each value is squared, and the total is averaged. RMSSD is then obtained by taking square root of the total (Shaffer, McCraty & Zerr 2014, 13). Parasympathetic activity can be measured by using the RMSSD of HRV (Yilmaz, Kayancicek & Cekici 2018). HRV is linked with high frequency (HF) power (McCraty & Shaffer 2015, 52). HF is believed to be controlled by the parasympathetic nervous system and is one of the key factor of respiratory sinus arrhythmia (Yilmaz, Kayancicek & Cekici 2018).

5.4 Disturbances of the autonomic nervous system

There are several possible diseases and disorders of the autonomic nervous system and describing each of them in detail would go beyond the scope of this thesis. Generally, however, it can be said that they can either happen alone, or by virtue of another disease, for example diabetes, Parkinson’s disease, or alcoholism (Website of MedlinePlus 2020). Disorders of the hypothalamus can lead to problems such as sleep disturbances, eating disorders, growth disturbances, premature maturation or complications with thermoregulation, the menstrual cycle, or hormone production (Svorc 2018, 10-11).

If the sympathetic division is excessively activated, for example by emotions, painful stimuli, or stress, this can lead to conditions such as gastric ulceration or type 2 diabetes mellitus (Svorc 2018, 10-11). Sympathetic overactivity is also strongly associated with a variety of cardiovascular diseases (Malpas 2010, 514). On the other hand, parasympathetic overactivity can promote bronchoconstriction or weaken blood circulation (Website of the American Psychological Association 2020). Other symptoms of autonomic disorders may include erectile disfunction in men, loss of bowel and bladder control, and orthostatic intolerance, which is an excessive decrease in blood pressure when standing, leading to light headedness or dizziness (Low 2020).

6 SLEEP AND RECOVERY

As mentioned in the introduction, elite athletes and coaches have determined sleep as a vital part of the post exercise recovery process and described it as essential for excellent performance (Samuels 2008, 169). Sleep is a natural, reoccurring state which is characterized by a time of unconsciousness, reduced sensory function, and inactivity of the skeletal musculature. It differs from wakefulness through a reduced ability to react to external stimuli and from a coma through the immediate reversibility of this state. (Ahrberg 2014, 1.)

Several important metabolic and immune processes happen during particular sleep stages, highlighting the fact that the athlete's capacity to perform at full capacity is largely dependent on the recovery the athlete gets during sleep (Samuels 2008, 171). One of those processes is the secretion of growth hormone. Growth hormone is essential for muscle growth and repair after competition or strenuous training and therefore plays a vital part in the physical recovery process. The biggest part, 95% of the daily production, is released during NREM sleep stage three from the pituitary gland in the endocrine system. (O'Donnell, Beaven & Driller 2018, 245.) Furthermore, Xie *et al.* (2013) point out that during wakefulness, several waste products accrue in the central nervous system, which are then removed during sleep, highlighting the importance for metabolic homeostasis.

The main aspects influencing the recovery outcome of sleep are its duration, its circadian timing, and its quality (disturbance or fragmentation). When the quantity of the sleep is sufficient, but the quality is poor, the term "nonrestorative sleep" is often used. (Samuels 2008, 170-171.) It is recommended for young adults aged 18-25 to sleep 7-9 hours per night (Website of Sleep Foundation, 2020) and attain at least 85% sleep efficiency (actual time sleeping expressed as a percentage of time in bed) on a nightly basis to maintain a healthy lifestyle (Ohayon *et al.* 2017, 10). However, the exact amount needed may vary from person to person and their individual circumstances (e.g. activity level and general health) (Website of Sleep Foundation 2020).

Knufinke-Meyfroyt *et al.* (2017) found that of the 98 elite athletes competing at the national and international level the average sleep duration was almost eight hours. Although, sleep restlessness was an issue seen in the escalation of wake after sleep onset (WASO) values. Previous reports indicate a sleep efficiency (SE) below 85% on 22% of test nights even though the mean sleep efficiency was 88%. Thus, sleep fragmentation is an issue.

Two of the most important internal instruments affecting sleep onset (SO), duration, and quality are the circadian rhythm and the sleep-wake homeostasis. The latter can be seen as a sleep drive. The longer the body is awake, the stronger it gets and will therefore remind the body to sleep. (Website of the National Institute of Neurological Disorders and Stroke 2019.)

The circadian rhythm is also known as the body's natural clock (Vitale, Owens, Hopkins & Malhotra 2019a, 5) and plays a part in regulating several functions in the human body, for example in the metabolism or the release of hormones. Furthermore, it is important for the timing of sleep. It determines when the body feels sleepy at night and when it tends to wake up in the morning without an alarm. External cues, most importantly light, have an impact on the circadian rhythm. (Website of the National Institute of Neurological Disorders and Stroke 2019.) Table 4 provides terms and their definitions used throughout this thesis.

Table 4. Sleep-related terms

Term	**Definition**
Bedtime	The time at which an individual goes to bed with the attempt to sleep
Time in bed (TIB)	The time elapsed from lying down with the intension of going to sleep, to the final getting up out of bed
Sleep onset (SO)	The actual time at which sleep begins after lying down in bed
Total sleep time (TST)	The total time spent asleep in bed before awakening
Wake after sleep onset (WASO)	The total amount of time spent awake after the first onset of sleep and the final awakening

Sleep efficiency (SE)	TST expressed as a percentage TIB: ie, TST/TIB x 100. SE is a sensitive measurement of sleep quality. A SE >85% is considered healthy (Gupta, Morgan & Gilchrist 2017, 1320)
Sleep onset latency (SOL)	The time elapsed between getting in bed and SO
REM	Rapid eye movement
NREM	Non rapid eye movement

6.1 Sleep stages

There are two basic types of sleep: rapid eye movement (REM) and non-REM (NREM) sleep, the latter being divided into stages 1, 2, 3, and 4. However, since stage 3 and 4 are difficult to differentiate, they are nowadays usually summarized into one stage, which is sometimes also referred to as slow-wave sleep (SWS). (Irwin 2015.) In this thesis, this stage will be referred to as NREM stage 3, as this seems to be the most commonly chosen term (Nedelec *et al.* 2018; O'Donnell, Beaven & Driller 2018, 245).

People usually go through all four stages several times per night, but in the beginning of the night, the NREM stages dominate, while towards the end REM sleep takes more time. Stage three NREM sleep is considered to be the deepest sleep phase and therefore essential for recovery. (Website of the National Institute of Neurological Disorders and Stroke 2019.) A brief description of every sleep stage can be found in table 5.

Table 5. Sleep stages and their characteristics (Website of the National Institute of Neurological Disorders and Stroke 2019)

STAGE	**CHARACTERISTICS**
NREM STAGE 1	- Transition from wakefulness to sleep - Muscles start to relax (occasional twitches) - Heartbeat and breathing start slowing down
NREM STAGE 2	- Further slowing of heartbeat and breathing - Further relaxation of muscles

	- Brain activity and body temperature drop
NREM STAGE 3	- Deepest sleep phase - Lowest heartbeat and breathing - Lowest brain activity
REM	- Eyes moving quickly from side to side behind closed eyelids - Higher brain activity and heartbeat, but paralyzed body - Most dreaming occurs in this stage

6.2 Factors affecting sleep recovery

Sleep can often times be overlooked by coaches and staff in regard to individual athletic performance. Although diet and fitness may be up to par, the results of low-quality sleep can have a negative effect on diet and performance. Demanding game day and travel schedules, and intense training/conditioning may interfere with an athlete's ability to get good quality sleep. Even with sleep as a priority, some individual may find falling asleep or even staying asleep challenging. (Vitale, Owens, Hopkins & Malhotra 2019, 2-7.) Although some factors such as early morning trainings (at or before 07:00), hypoxia, jet lag, and type of sport have been shown to have an effect in sleep recovery, they will not be covered in this thesis.

6.2.1 Game/competition night

Total sleep time (TST) and SE have been found to be less likely achieved on game night when compared to the night before competition. Some studies have linked the reduction of TST to the delayed bedtimes due to night-time competition. (Eagles & Lovell 2016; Sargent & Roach 2016; Shearer, Jones, Kilduff & Cook 2015.) Some factors that may decrease TST and SE post competition are hyperactivity of the sympathetic nervous system, an escalation in circulating cortisol, raised core body temperature, and pain (e.g. acute traumatic injury, overuse injuries, subacute recurring injuries and chronic degenerative conditions) (Hainline *et al.* 2017; Kivlighan & Granger 2006; O'Donnell, Bird, Jacobson & Driller 2018; Veale & Pearce 2009).

6.2.2 Neurological stimulants

The use of caffeine prior to practice or game time is quite common among athletes due to its availability (e.g. energy drinks, sodas, pre-workouts and other thermogenic supplements) and powerful stimulating effects (Mielgo-Ayuso et al. 2019, 2). Although small doses of caffeine consumption pre-exercise have been reported to improve football (soccer) skills (e.g. vertical jump, repeated sprint capability, running distance and passing precision) during soccer matches (Mielgo-Ayuso et al. 2019, 12), post-game saliva caffeine levels were higher compared to pre-game levels in rugby players after a super rugby game. Consequently, there was a 3.5-hour delay in SO and a total of 1.5 hours sleep loss on game night (Dunican *et al.* 2018).

Zeitzer *et al.* (2000) found that stadium lights may have an effect on the circadian pacemaker (found in the hypothalamus). Melatonin levels are found to be affected even after 6.5h in dim lighting around 100 lux (e.g. hallways, elevators, and stairways). It was concluded that the circadian pacemaker is much more sensitive than previously thought, thus the amplified amount of stadium light can result in its dysregulation.

Moreover, it has been calculated that ninety percent of people in the United States, including children, are using electronic devices as a wind down tool one hour prior to going to sleep (Website of the Sleep Foundation 2020). It is believed that blue light exposure before bedtime can be the culprit of sleep disturbances (Kimberly & R 2009). The use of any blue light emitting electronic device (e.g. TV, tablet, smart phone, laptop) has a negative impact on the body's circadian rhythm, suppressing melatonin release, therefore making it harder to sleep. Consequently, these devices can delay both onset and total amount of REM sleep which over a period can lead to chronic sleep deficiency. (Website of the Sleep Foundation 2020.) However, meta-analysis, by Roberts, Teo & Warmington (2019), did not find any evidence supporting evening use of electronic devices prior to sleep to have any result in athletes' sleep. To back this claim, netball players that read a book or used a tablet two hours before bed had no major changes in sleep quantity, quality, or next-day performance (Jones *et al.* 2018).

6.2.3 Pre-competition night

According to subjective research (use of sleep journals and questionnaires), sleep disturbance is not uncommon among athletes of various sports on the night before competition (Ehrlenspiel, Erlacher & Ziegler 2016; Erlacher *et al.* 2011; Juliff, Halson & Peiffer 2014). Similar to college students states of hyperarousal during exam periods (e.g. pre-sleep cognition, stress or worry) before bedtime (Ahrberg *et al.*2012; Lund *et al.* 2010), the common issue athletes have reported is trouble falling asleep. Athletes expressed the poor sleep is due to thoughts about the upcoming competition and nervousness (Ehrlenspiel, Erlacher & Ziegler 2016; Erlacher, Ehrlenspiel, Adegbesan & El-Din 2011; Juliff, Halson & Peiffer 2014).

Juliff, Halson & Peiffer (2014) discovered that over fifty percent of team sport athletes have no knowledge (e.g. use of relaxation, meditation, or reading) of how to overcome the issue of difficulty falling asleep. Nevertheless, Lastella *et al.* (2015) found that team sports athletes have a higher TST and SE during normal training days, when compared to individual sport athletes. Yet, athletes overall sleep (6.5h individual sport vs 7.0h team sport) was below the recommended amount of sleep of 8 hours.

6.2.4 Training load

Training plans and loads are carefully created with the intent of improving performance in preparation for upcoming seasons and competitions. This is achieved by intensifying training loads that place sufficient stress to stimulate the needed physiological adaptations to improve performance. (Schaal *et al.* 2014, 1416.) This may occur in phases during a competitive season and can therefore have a negative effect on adaptation and performance (e.g. overreaching, overtraining) (Meeusen *et al.* 2013, 1-2).

Research shows that an increase >25% training intensity, during intensified training periods, can result in reduction of good sleep quality and quantity parameters (e.g. later bedtime, delayed SL, SE, and WASO) (Hausswirth *et al.* 2014*;* Schaal *et al.* 2014*)*. Former studies indicate a prolonged activation of sympathetic activity (e.g. increased epinephrine and norepinephrine levels) and delayed hypothalamic-pituitary-adrenal activation (melatonin production) after strenuous exercise (Mastorakos *et al.* 2005; Netzer *et al.* 2001).

6.2.5 Nutrition and sleep recovery

Sleep and nutrition have an effect on one another. Sleep deprivation, in any form, may cause changes in neuroendocrine function and glucose consumption which can cause alterations in carbohydrate usage, hunger/cravings, food absorption and protein synthesis. The results of such alterations may have a negative effect on an athletes athletic performance due to altered nutritional, metabolic and endocrine state. (Halson 2014, S21.)

Because protein synthesis rates are quite low during sleep following evening exercise (even after consuming 20g of protein post workout), high protein consumption (at least 40g) consumed before bedtime has been shown to produce strong stimulation of muscle protein synthesis rates overnight. Consumption of 40g of protein before bedtime results in added muscle mass and strength gains during extended resistance training. (Trommelen & van Loon 2016.)

Research on the effect of nutrition and sleep is still minimal and questionable. Apart from the focus on good sleep hygiene, Halson (2014) has made several recommendations about the effects of food consumption on sleep. Table 6 presents foods that can affect sleep.

Table 6. Recommendations of possible effects of food on sleep (Halson 2014, S21)

Food type	**Effect on sleep**
High glycemic index foods	May promote sleep when eaten >1h before bedtime
High carbohydrate diets	Possible shorter sleep latencies
High protein diets	Possible improved sleep quality
High fat diets	Negative effect on TST
Caloric deficits	Possible sleep quality disturbance
Small doses of tryptophan (1g) (e.g. 300g of turkey or ~200g of pumpkin seeds)	May improve sleep latency and sleep quality
Melatonin rich foods (e.g. tart cherries)	Possible decrease in SO
Ingestion of the herb valerian	May improve subjective sleep quality. *Athletes must be mindful of possible contaminants and unintentional risk of a positive drug test.

Alcohol, on the other hand reduces the time to fall asleep for non-alcoholics, but leads to sleep disruptions, especially in the second half of the night (Thakkar, Sharma & Sahota 2015).

6.2.6 Unfamiliar environment

It is common for athletes to spend one night to several nights in an unfamiliar hotel environment throughout the pre-season, regular season, and post-seasons (Nedelec *et al.* 2018, 7). The well-known phenomenon known as the “first-night effect” is a likely factor of sleep impairment in such situations. The negative effects on sleep are believed to come from the individual’s unfamiliarity of the environment (typically sleep laboratory and polysomnography equipment). Consequently, TST, REM sleep are shortened, sleep efficiency index is lower, and REM sleep latency is extended. (Suetsugi, Mizuki, Yamamoto, Uchida & Watanabe 2007, 839.) As an example, during a 2-week high-intensity training camp, TST, TIB, and SE were all reduced in professional rugby players (-85 min, -53 min, 8% respectively) when compared with home (Thornton *et al.* 2017).

6.2.7 Overreaching and overtraining

It is believed that an athlete’s total sleep requirement and continued sleep debt are important factors in determining post-exercise recovery, performance and vulnerability to overtraining syndrome. Chronic training fatigue is mainly thought to be due to immunologic, neuroendocrinological, and musculoskeletal factors. (Samuels 2008, 171.) McArdle, Katch & Katch (2015) defined two clinical forms of overtraining seen in table 7.

Table 7. Types and symptoms of overtraining (McArdle, Katch & Katch 2015)

Less common:	Sympathetic form (Hyperthyroidism)	Rise in sympathetic activity at rest. Hyperexcitability, decrease in exercise performance and restlessness. - May be a result of an increase of psychological/emotional stress brought on by training, competition, and everyday responsibilities.
More common:	Parasympathetic form (adrenal exhaustion)	Early stage: Overreaching occurs within as few as 10 days. Symptoms are similar to the severe form of parasympathetic overtraining syndrome but in a briefer period. Short-term rest period ranging from a couple days to weeks normally allows for full restoration. Parasympathetic overtraining syndrome includes chronic fatigue throughout exercise and training workouts and recovery periods.

		Symptoms: - Poor performance - Altered sleep patterns and appetite - Changes in immune and reproductive functions - Acute and chronic changes in systemic inflammatory responses - Mood swings (e.g. anger, anxiety) - General dissatisfaction and loss of interest in top-level training.

6.3 Sleep deprivation

There appears to be a high prevalence of sleep disturbances in elite sports. Symptoms of sleep disturbance include difficulties falling asleep, trouble staying asleep, nonrestorative sleep and excessive daytime fatigue. Athletes in individual sports appear to be more often affected by these issues than team sport athletes. (Gupta, Morgan & Gilchrist 2017, 1330.)

6.3.1 Insomnia

Insomnia is a disorder characterized by a difficulty falling asleep, maintaining sleep, or nonrestorative sleep, despite appropriate opportunity for sleep (Roth 2007). When awake, people with insomnia experience symptoms such as fatigue or irritability (Buysse 2013). The prevalence of insomnia is high, with about 30% of the general population affected by it (Roth 2007). More specific to sport, a study of 107 professional ice hockey players found that one out of every four players has major trouble sleeping during the regular season (Tuomilehto *et al.* 2017, 708).

6.3.2 General effects of sleep deprivation / disturbances

The importance of sleep becomes especially clear when considering the effects of partial or total sleep deprivation. Sleep deprivation and -disturbances negatively affect the immune system. The reasons for that are believed to be increased sympathetic activity and decreased growth hormone secretion during NREM stage 3. (Irwin 2015). Furthermore, sleep disturbances are linked to weight gain (Patel *et al.* 2006), increased inflammation, cardiovascular diseases, cancer (Irwin 2015), diabetes, accidents, and depression (Watson *et al.* 2015).

Pro-inflammatory cytokines are increased as a consequence of sleep deprivation. This can for example lead to impaired muscle recovery and autonomic nervous system imbalance with symptoms similar to overtraining. (Haack *et al.* 2009; Haack, Sanchez & Mullington 2007; Vitale *et al.* 2019.) Cortisol is a hormone that is usually released by the body as a response to stress. Acute sleep deprivation leads to an increase of blood cortisol and stress markers. (Wright *et al.* 2015.)

Insufficient sleep can also lead to impaired brain function. This presents mainly as reduced response speed and lower levels of attention and alertness. Also creativity, innovation, as well as decision making may be affected, all of which can be of high importance in sports. (Killgore 2010; Vitale *et al.* 2019.)

Moreover, Haack & Mullington (2005) showed that restricted sleep may play a part in the onset or amplification of pain. In their study participants were randomized to either four or eight hours of sleep for 12 nights in a row. The authors also noticed that the optimistic outlook of the participants with four hours of sleep declined compared to those who got eight hours of sleep.

6.3.3 Sleep deprivation and its effects on performance

Several studies have observed the effect of total sleep restriction on athletic performance. A sleep restriction of 24 hours does not seem to have a significant impact on anerobic performance (Blumert *et al.* 2007; Souissi *et al.* 2003). On the other hand, endurance and perceived effort appear to be negatively affected after one night of sleep restriction (Azboy & Kaygisiz 2009; Oliver *et al.* 2009). Partial sleep restriction can also have an effect on performance. Mejri *et al.* (2016), for example, asked Taekwondo athletes to perform an intermittent running recovery test (Yo-Yo) after being restricted to four hours of sleep and saw notable declines in their running performance.

Also, psychomotor functions may be affected by sleep loss. One study (Reyner & Horne 2013) restricted tennis players to five hours of sleep and noticed that their serving accuracy was significantly decreased. Furthermore, in another study (Taheri & Arabameri 2012) college students had significantly impaired reaction times after 24 hours of sleep deprivation.

7 FIRSTBEAT

The Firstbeat Bodyguard 2 (BG2) heart rate monitor (Firstbeat Technologies Ltd, Jyväskylä, Finland) is a device that measures beat-to-beat heart rate signals. The device functions by way of an exclusive sleep algorithm that produces a real-time sleep analysis. This algorithm uses HRV data, respiration rate based off of HRV, and wrist/body movement and time of day data. The device is able to tell when a person is in/out of bed and awake. The HRV data is used to detect ANS function while sleeping, which in turn allows for the assessment of stress and recovery during sleep. (Firstbeat technologies Oy 2019.)

The Firstbeat device is meant for long term heart rate variability and physical activity. Additionally, the device measures R-R intervals (RRI) by way of disposable electrodes being placed on the subject in the two channel Holter measurement position as stated in the instructions. RRI are attained on a 1ms resolution by combining the BG2 device with an offline beat correction algorithm. (Parak & Korhonen 2013.) The BG2 detects and calculates physiological phenomena along with HRV (e.g. oxygen consumption

(VO_2), respiration rate, excess post-exercise oxygen consumption (EPOC) based on RRI (Firstbeat Technologies Ltd. 2014).

7.1 Method of Firstbeat Bodyguard 2 setup

The Firstbeat BG2 devices are set up individually prior to testing in the Firstbeat Lifestyle Assessment software. This requires the creation of a personal profile per individual including the input of date of birth, gender, height, weight, and fitness level. The software then calculates individual BMI and maximum HR.

Each individual is sent a weblink containing a personal online assessment journal where daily activities are recorded. The most important information for this study is bedtime at night and wake up time each morning. Based on this information the software can show periods of work and periods of sleep in chart form (see figure 1).

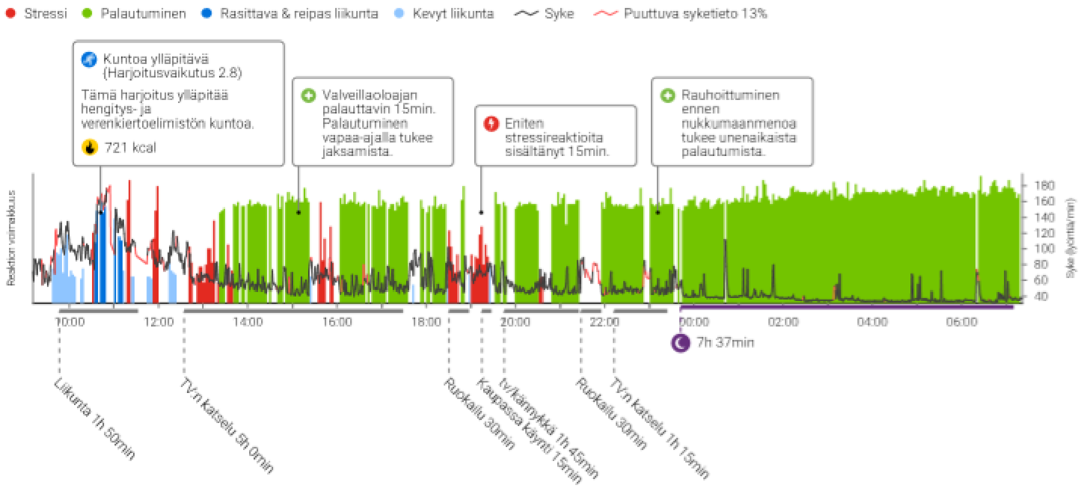


Figure 1. Description of the first day and nighttime periods of stress (red), exercise (blue and light blue), and recovery (green). Also, the graph shows, according to journal entry description, stress and recovery levels during activity and relaxation periods. Most importantly, it shows the time the player went to bed and the states of stress and recovery during sleep periods

8 METHODOLOGY AND THESIS PROCESS

Sleep quality and quantity can be measured in many different subjective and objective ways. Examples are methods such as sleep questionnaires, sleep diaries, polysomnography, ambulatory polysomnography, ballistocardiography, or actigraphy. As not all of them are practical to use in the athlete's typical environment, the most commonly used methods are actigraphy and polysomnography as objective measures, as well as sleep diaries, logs, and questionnaires as subjective means. (O'Donnell, Beaven & Driller 2018.)

A mixed-methods study was used in this thesis. The authors were looking to collect and compare qualitative data (perceived sleep recovery) to quantitative data (physiological sleep recovery). This method requires the collecting, assessing, separately analyzing, and comparing results of both sets of data and presenting both sets of data together. The advantages to using a mixed method is that contradictions between findings can be better understood, the participants' voices are heard, a bigger scope is added to multidisciplinary research, and it can provide a bigger picture than just one method by itself would. (Wisdom & Creswell 2013.)

Quantitative data about the sleep recovery of the athletes was obtained using the Firstbeat Bodyguard 2 devices. Qualitative data was collected through daily individual interviews. Subjective methods may increase the accuracy of objective measurements (O'Donnell, Beaven & Driller 2018; Sadeh 2011). Furthermore, through the interviews, the authors hoped to gain insight into the reasons for good or bad sleep recovery, as well as individual differences, which in turn may be of use for the coaches.

The measurements and interviews took place during a trip the team took between the 30.01.2020 and 04.02.2020. The measurements started on the 30.01., just before departure, and the interviews began on the morning of the 31.01.2020. The schedule for the team was as follows:

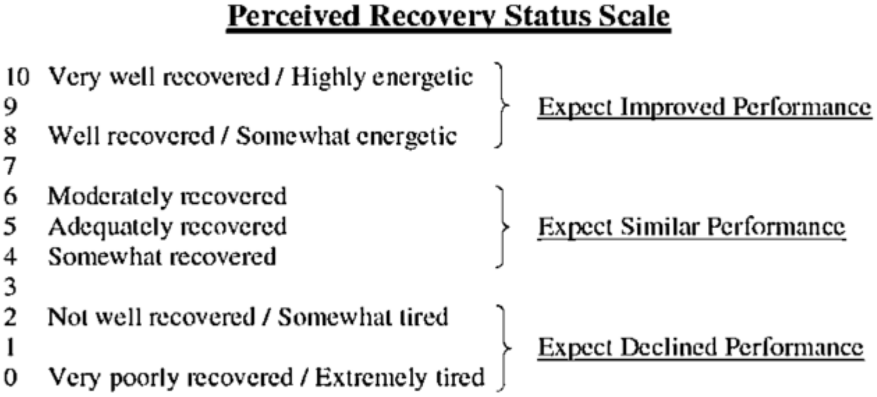
- *Day 1 Bus ride to Mikkeli*
- *Day 2 Mikkeli. Matchday: Jukurit – Ässät. Afterwards bus ride to Lappeenranta*

- *Day 3 Lappeenranta. Matchday: Saipa – Ässät. Afterwards bus ride to Tanhuvaara*
- *Day 4 Tanhuvaara. Recovery day*
- *Day 5 Tanhuvaara. Training and Bus ride to Kuopio.*
- *Day 6 Kuopio. Matchday: Kalpa – Ässät.*

9 INTERVIEWS

As mentioned earlier, the most common subjective methods to assess sleep quality and quantity are sleep diaries, logs, or questionnaires. In this study, a self-developed interview was used. To increase compliance and in the hopes of getting more detailed answers, the questions were asked personally on the phone. Interviews were held with each player individually on every morning from of day 2 until the morning of day 6 before the first training session of the day, either just before or following breakfast. With permission of the players (see appendix 1), the interviews were recorded using a phone and tablet, and the files deleted upon completion of this thesis.

To assess and compare the perceived recovery of the players, the perceived recovery status (PRS) scale, developed by Laurent *et al.* (2011, 620-628), was used. Similar to the VAS pain scale, the athlete describes his own perceived recovery with a number from 0-10, with 0 being *Very poorly recovered / Extremely tired* and 10 *Very well recovered / Highly energetic* (Figure 2). The PRS was originally used for endurance athletes and before as well as after warm-up, which would have been impractical in the given situation. However, Clemente, Rabbani, and Araújo (2019) also tested it in team sports and before the warm-up and got satisfactory results, hence making the PRS applicable for the current project. The day before the first interviews, the players were familiarized with the PRS and each of them was given a copy to take with them on the trip.



Perceived Recovery Status Scale

10	Very well recovered / Highly energetic	Expect Improved Performance
9		
8	Well recovered / Somewhat energetic	
7		
6	Moderately recovered	Expect Similar Performance
5	Adequately recovered	
4	Somewhat recovered	
3		
2	Not well recovered / Somewhat tired	Expect Declined Performance
1		
0	Very poorly recovered / Extremely tired	

Figure 2. The Perceived Recovery Status Scale (Laurent, *et al.* 2011, 621)

The players were also asked open questions such as how well they slept during the previous night; what time they went to sleep; how long they think it took them to actually fall asleep once trying to do so; and how they felt right before going to sleep and right after waking up. The answers to these questions were compared to the data provided by the first beat measurements which aimed to give an idea of how reliable the own subjective assessment of the recovery of the players is.

Additionally, the interviews aimed to determine possible factors that would affect the sleep quality and quantity of the athletes. They faced open questions such as “Why do you think you didn’t sleep so well?” and closed questions like “When was the last time you had any caffeine before going to sleep?”.

Further, the players were asked if they are or have been doing anything to improve their sleep quality or quantity; if they, for example, follow a special sleeping routine, practice mindfulness, or use any kind of medication. The interviews were held either in English or Finnish, depending on the preference of the player. The full structure of the interviews can be found in appendix two and three.

10 FIRSTBEAT RESULTS

The study data was collected during a 5-day long trial period. Only six of the initial eight players' data was used in the following analysis due to Firstbeat monitor malfunctions during nighttime recordings. Two players had missing nighttime data (>20%) on three of five nights. In the following lines, the data is separated as game nights (GN) (table 8) and non-game nights (NGN) (table 9).

10.1 Game nights

Total sleep time (TST) on average was over seven hours of sleep on GN. Only two players of six had a TST under eight hours. 80% of TST was measured as recovery sleep (RS) on average for the group. Two of the six players had a total RS >90%, both of which had <50 minutes of non-recovery sleep (NRS). The range of difference between awake and sleep HRV was between 14-70.2ms, the average difference being 39.1ms as a group (see table 8).

Table 8. Average away game night sleep values (2 nights). Total sleep time, total sleep recovery, % recovery sleep, awake and sleep HRV, and 24h heart rate (HR) average values per player are presented. Game nights were back to back on nights 2 and 3.

	TST (h:mm)	**Total recovery sleep (h:mm)**	**%Recovery sleep of TST**	**Awake HRV RMSSD (ms)**	**Sleep HRV RMSSD (ms)**	**Resting HR**	**Average HR**	**HR Max**
PLAYER 1	7:03	6:04	87%	30.3	72.5	36.5	67.5	181.5
PLAYER 3	8:07	7:10	88%	25.3	95.5	36	71.0	176.0
PLAYER 4	7:30	6:48	91%	59.0	97.5	32.5	64.5	182.0
PLAYER 6	8:12	7:25	90%	40.5	54.5	39	68.5	175.5
PLAYER 7	8:15	6:55	87%	34.5	71.5	44.5	75.5	197.5
PLAYER 8	8:29	7:21	84%	22.0	55.0	46.5	80.5	190.0
Team average	7:56	6:57	88%	35.3	74.4	39.2	71.3	183.8

10.2 Non-game nights

All players slept more than the recommended minimum seven hours of sleep on NGN. TST on average was over eight hours. Two of the six players TST was under eight hours of sleep. Eighty seven percent of TST was calculated as good RS on average for the group. Four out of six players had a total RS >90%, all of which had <50 minutes of NRS. One player did not have a nighttime HRV average higher than the day-time average (-15.3ms). However, the player's sleep recovery was still moderately good. The average HRV difference was 13.4ms as a group (see table 9).

Table 9. Average away non-game night sleep values (3 nights). Total sleep time, total sleep recovery, % recovery sleep, HRV during sleep, and 24h heart rate (HR) average values per player are presented. Non-game nights were on night 1, 4, and 5

	TST (h:mm)	Total recovery sleep (h:mm)	%Recovery sleep of TST	Awake HRV RMSSD (ms)	Sleep HRV RMSSD (ms)	Resting HR	Average HR	Max HR
PLAYER 1	8:32	7:47	89%	36.7	82	35.3	67.7	164.7
PLAYER 3	8:33	7:58	93%	60.0	92	34.7	60.3	158.3
PLAYER 4	7:35	7:04	95%	94.7	95.3	31.7	52.0	152.3
PLAYER 6	7:43	6:34	85%	53.0	37.7	37.3	60.0	155.7
PLAYER 7	8:22	5:12	66%	49.0	52.3	46.3	69.0	163.3
PLAYER 8	8:41	8:00	92%	32.7	47.0	44.0	71.7	158.0
Team average	8:14	7:06	87.0%	54.3	67.7	38.2	63.4	158.7

10.3 Total sleep time - game nights vs non-game nights

Players slept an average of 18 minutes longer on NGN compared to GN. Only one player slept on average >1h longer on NGN. Player 6 had a higher TST on GN compared to NGN. Other players TST was 5-29 minutes longer on NGN. Four of the six players slept longer on NGN, see figure 1.

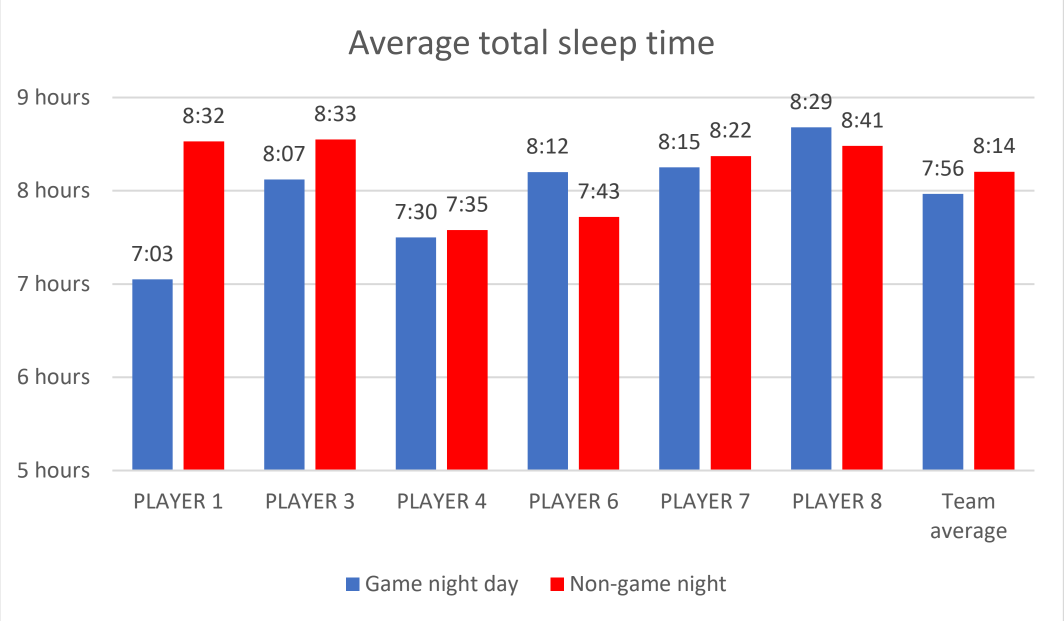


Figure 1. A comparison of game night to non-game night TST

10.4 Total recovery sleep - game nights vs non-game nights

Four of the six players recovered better on non-game nights than game nights. Player 1 on average got 1h 43min longer RS on NGN. Player 7, however, got 1h 43min longer RS on GN. Three players recovered on average between 15-50 minutes more on NGN, see figure 2.

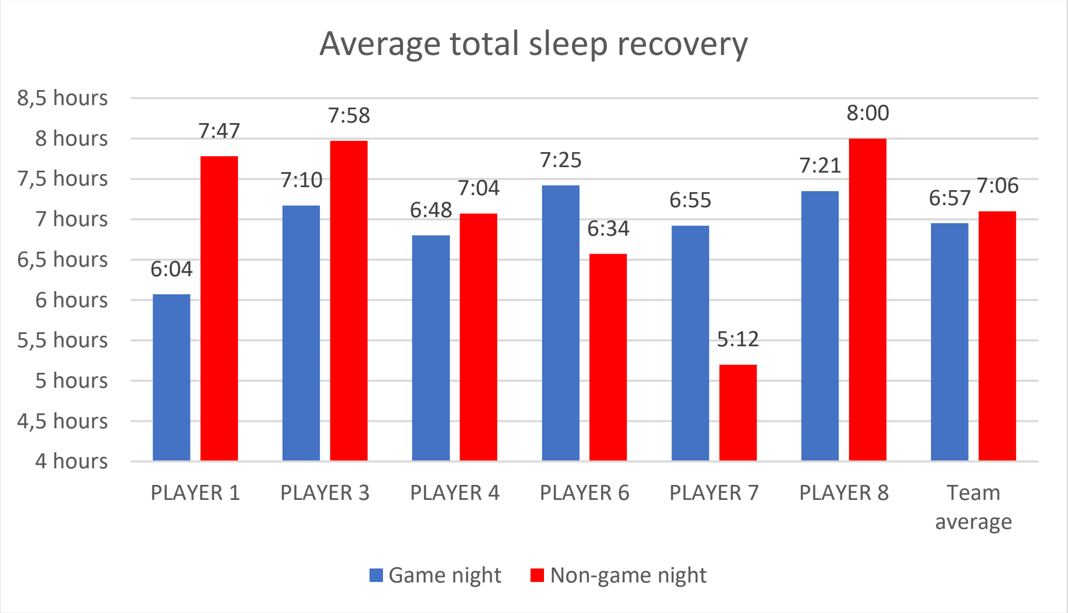


Figure 2. A comparison of game night to non-game night total recovery sleep

Five of the six players averaged >85% RS on GN. On NGN, five of six players also scored >85% sleep recovery. >75% RS is considered good RS (Firstbeat Lifestyle Assessment 2016, 9). However, player 7 got 21% less RS on NGN compared to GN. This shows that Player 7 recovered significantly better on GN compared to NGN. Three players had on average 5% better RS on NGN than GN, see figure 3.

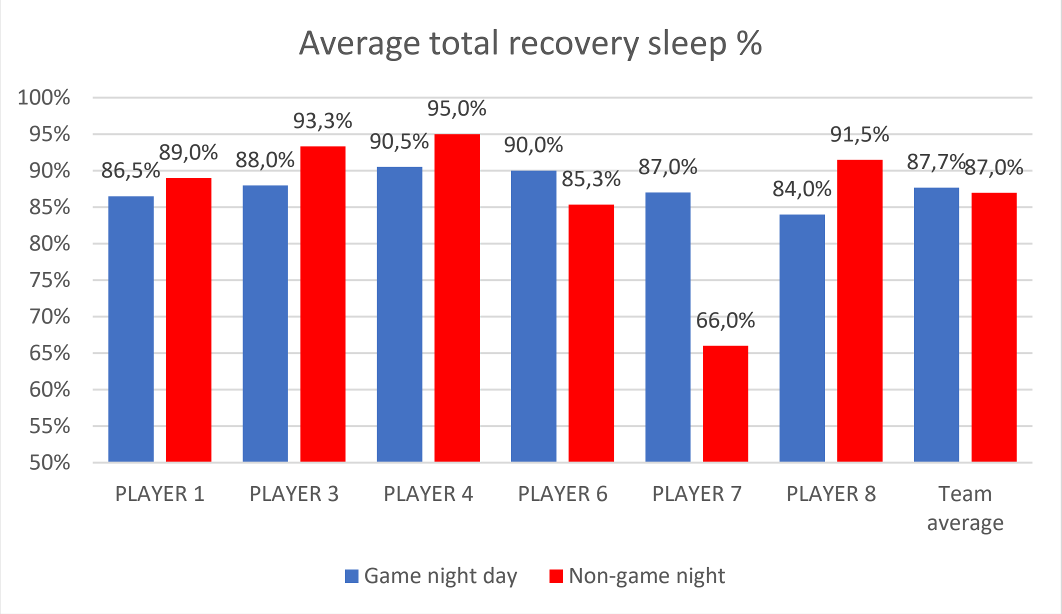


Figure 3. A comparison of game night to non-game night total sleep recovery percentage

10.5 Heart rate variability - game nights vs non-game nights

Five of six players had a higher HRV on GN vs NGN, Player 1 being the exception. Two players had a difference in average HRV between 15-20ms more on GN. Otherwise, HRV was on average <6ms higher or lower on either type of night. Furthermore, the team average on all nights was >50ms, which Firstbeat defines as above average for this reference group (Firstbeat Lifestyle Assessment 2016, 9). Three players had HRV averages below <53ms but ≥26ms, all of which were on NGN. Again, Firstbeat Lifestyle Assessment (2016) classifies the previously mentioned three players’ sleep as moderate RS. This range is still considered safe and players are not at risk of overload or fatigue, see figure 4.

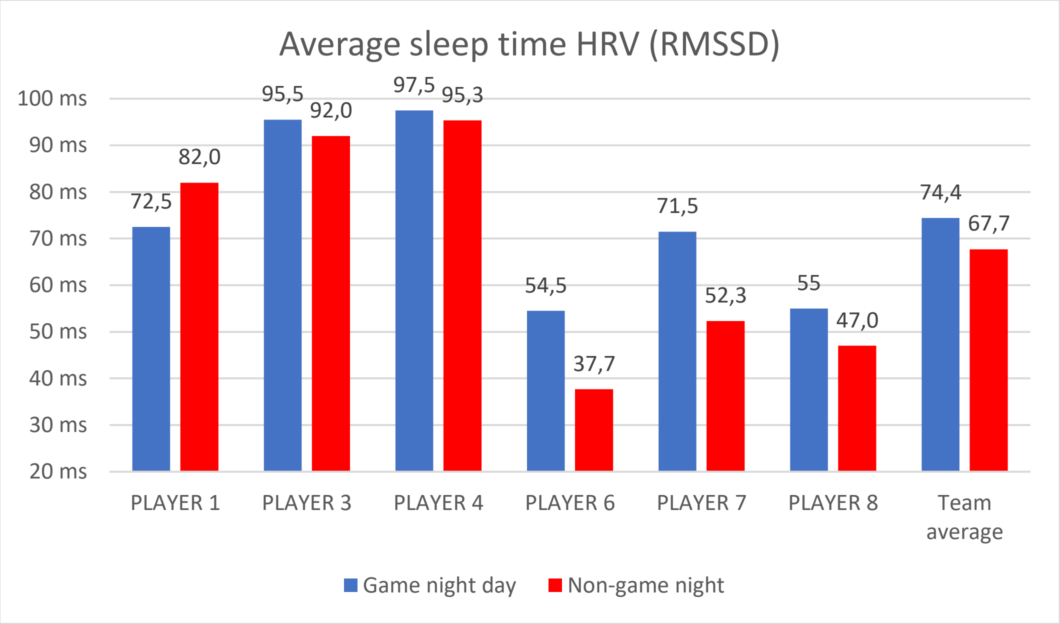


Figure 4. A comparison of game night to non-game night sleep time HRV (RMSSD)

11 INTERVIEW RESULTS

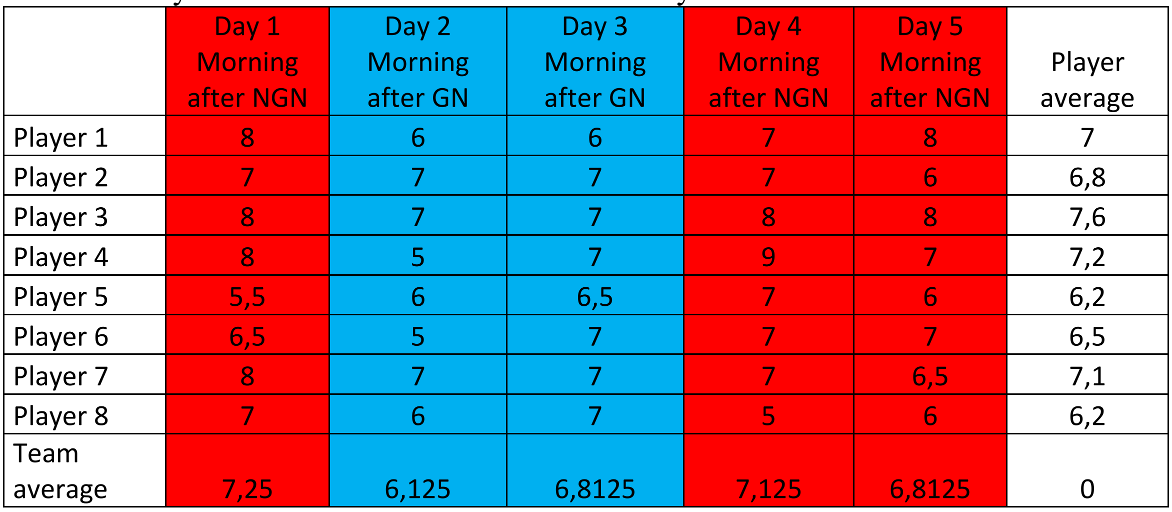
All eight players who participated in the study were interviewed on each morning during a 5-day long trial period shortly after waking up. Interviews were intended to be held right after waking up and before breakfast. However due to the individual morning schedules, this was not always possible. Consequently, some of the interviews were held after breakfast.

11.1 Perceived recovery

The perceived recovery was enquired through open ended questions such as “How are you feeling today?”, as well as through the already mentioned Perceived Recovery Status Scale (PRS). Most of the time, the majority of the players stated in the morning to feel well, although there were individual differences. Noteworthy, however, is that after the first game night, five out of the eight players mentioned immediately that they felt very tired. Similarly, six players told that they did not sleep well during that night and that they felt they got rather light sleep. This also shows in the perceived recovery scale where almost every player gave a worse score than on the first day. Apart from that night, most of the players felt like they slept well during most nights and that they got fairly deep sleep. Also here individual differences could be seen. Especially one player reported most of the time to have slept poorly. Only one player told every morning that he slept well and felt like he got deep sleep. The rest of the players had at least one night in which they felt they didn´t get satisfactory sleep quantity and / or -quality.

On average, players gave slightly better values on the PRS on mornings after non-game nights (7,07) than after game nights (6,47). The individual answers to the PRS on each day are found in table 10. The development of said scale for each player can be seen in figure 5.

Table 10. Players’ answers to the Perceived Recovery Status Scale



	Day 1 Morning after NGN	Day 2 Morning after GN	Day 3 Morning after GN	Day 4 Morning after NGN	Day 5 Morning after NGN	Player average
Player 1	8	6	6	7	8	7
Player 2	7	7	7	7	6	6,8
Player 3	8	7	7	8	8	7,6
Player 4	8	5	7	9	7	7,2
Player 5	5,5	6	6,5	7	6	6,2
Player 6	6,5	5	7	7	7	6,5
Player 7	8	7	7	7	6,5	7,1
Player 8	7	6	7	5	6	6,2
Team average	7,25	6,125	6,8125	7,125	6,8125	0

Red: Morning after non-game night
Blue: Morning after game night

Average non-game night: 7,07
Average game night: 6,47

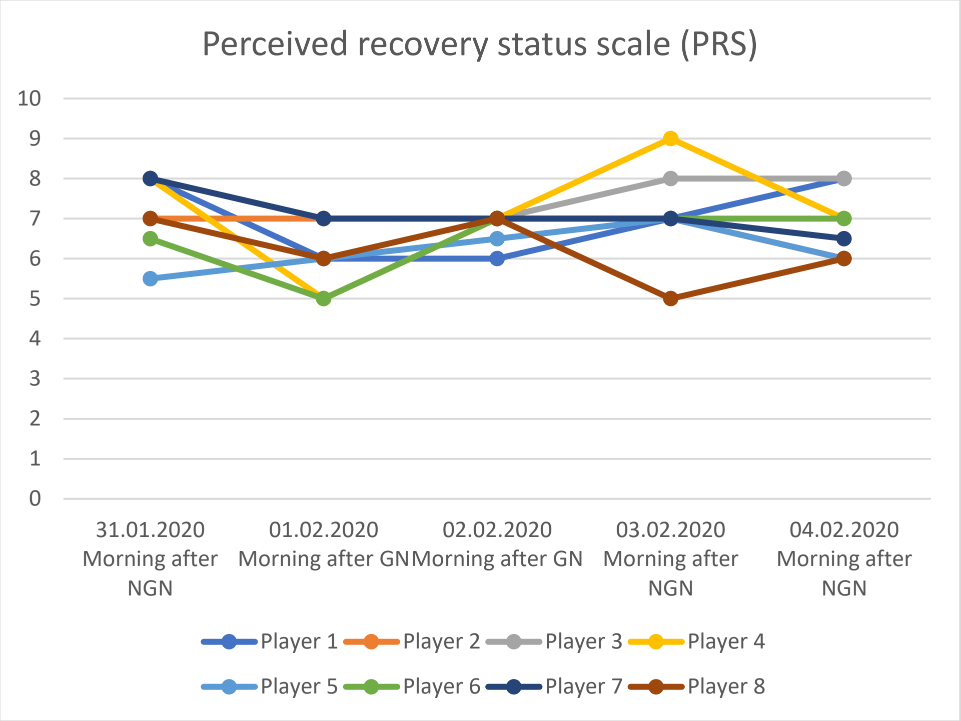


Figure 5. Development of the players' answers to the Perceived Recovery Status Scale

11.2 Factors identified by players

Several factors were identified by the players as detrimental for their sleep quality or -quantity. Some of these were brought up through direct questions, i.e. "did you have any issues with the bed?". Others were told directly by the players.

11.2.1 Previous or upcoming competition

Four players stated at least once that the game they played in the evening had a negative impact on their sleep. Mentioned reasons for that were that the players were feeling stressed / "pumped up" or reviewing situations from the game in their heads. When asked directly, none of the players stated to be thinking or feeling nervous about the upcoming game before going to sleep. On the other hand, players expressed to be more relaxed on the evenings before the non-game days.

11.2.2 Bedroom surroundings

Three out of eight players mentioned at least once problems with the beds. In their opinion, the beds were either too small or generally uncomfortable. Two players mentioned being disturbed by noise. One heard his teammate snoring and another one heard noise from the corridor, causing him to wake up a couple of times.

One player felt disturbed by light coming out of the bathroom the last night. Two players mentioned at least once that the temperature in the room was not ideal for them. The other players mentioned not to have any problems with the hotel rooms. None of the players saw the unusual surroundings in general as a problem for their sleep.

11.2.3 Neurological stimulants and sleep routines

Each of the players used caffeine at least once before or during the games. The latest reported use was before the last third, at around 8pm. Also on days with no games, the majority of the players was regularly using caffeine up until the late afternoon. On the recovery day, however, half of the players did not consume any caffeine after the breakfast.

None of the players had any special sleep routine. Before going to sleep, they were either watching tv, playing cards with their teammates, or spending time on their phones. None of the players took any medication to improve their sleep quality or quantity, only one player mentioned to earlier have taken light sleep medication, but not anymore.

One player stated that he had tried mindfulness “some time ago” and thinks that it might be something that could work for some people, but at the time of the project, he did not do it. The other players have not tried anything like mindfulness or meditation and stated not to know anything about it either. Another player mentioned that he would “maybe consider trying in the future”. The only reported means to improve sleep were the use of earplugs and listening to podcasts, the latter not during this trip. Other players stated not to do anything in order to improve sleep quality or -quantity.

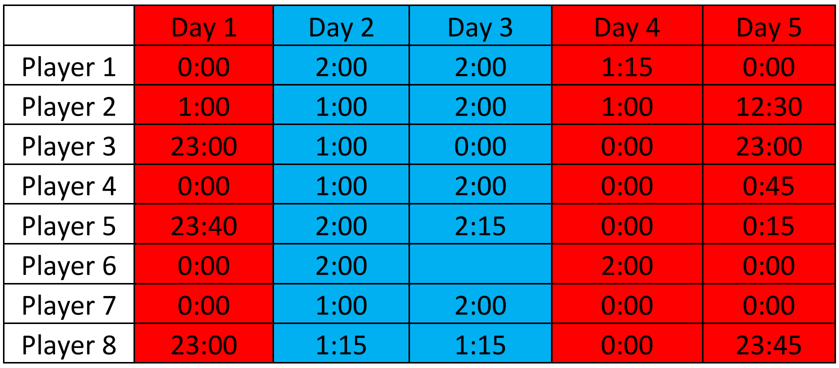
11.2.4 Other factors

One player told that he usually goes to sleep around midnight, so when he went to bed earlier than he was used to, at 11pm, it took him a long time to fall asleep. Most of the nights, the majority of the players said they felt calm, relaxed, and tired when going to sleep. Other times, however, players stated that they were not feeling tired when going to sleep, thinking about different things, or feeling nervous because they could not fall asleep quickly.

11.3 Bedtime and time to fall asleep

The earliest any of the players went to sleep during the trip was 11pm, the latest was 2.15am. For almost everyone, the two game nights were the nights they went to sleep the latest. The individual times for each player on each night are displayed in table 11.

Table 11. Reported times players went to sleep



	Day 1	Day 2	Day 3	Day 4	Day 5
Player 1	0:00	2:00	2:00	1:15	0:00
Player 2	1:00	1:00	2:00	1:00	12:30
Player 3	23:00	1:00	0:00	0:00	23:00
Player 4	0:00	1:00	2:00	0:00	0:45
Player 5	23:40	2:00	2:15	0:00	0:15
Player 6	0:00	2:00		2:00	0:00
Player 7	0:00	1:00	2:00	0:00	0:00
Player 8	23:00	1:15	1:15	0:00	23:45

Red: Non-game night

Blue: Game night

The times the players felt it took them to fall asleep varied strongly between each individual. The shortest reported time was five minutes, the longest time was “about two hours". Four of the players stated at least once that it took them 45 minutes or longer to fall asleep. Two of those players made this claim only once. The other two players reported long times to fall asleep at least twice. The other four players never said to have taken longer than 30 minutes to fall asleep during the measured five nights. As can be seen from the table 12, not all of the players were able to give specific times, leading to answers such as "not so long", "a long time", or "it took a while", which admittedly leaves room for uncertainty.

Table 12. Perceived time to fall asleep for each player / night

	Day 1 NGN	Day 2 GN	Day 3 GN	Day 4 NGN	Day 5 NGN
Player 1	15–30 min	at least 1 h	"not long"	"not long"	"not long"
Player 2	10 min	30 min	20 min	1 h	45-60min
Player 3	15 min	15 min	10 min	10–15 min	"took a while"
Player 4	20 min	30 min	20 min	15 min	15 min
Player 5	"long"	15–20 min	25 min	"long"	about 2 h
Player 6	"took a while"	15 min		10 min	5 min
Player 7	10–15 min	5 min	15 min	30 min	30 min
Player 8	45 min	20 min	10-15 min	20 min	10 min

Green: 0 – 15 minutes
Yellow: 15 – 30 minutes
Red: Over thirty minutes

12 CONCLUSION

The aim of this study was to compare the physiological and perceived recovery of elite hockey players ages 19-24. Only the 6 players with reliable Firstbeat measurements were compared to their individual interviews. The perceived sleep recovery by players was well supported by Firstbeat findings in that the hockey players got good recovery sleep. The main subjective factors found to have a negative effect on sleep were thoughts about the game and sleep environment.

In this study, all players got the minimum 7h of recommended total sleep time on game nights and non-game nights. Players went to sleep later on game nights while on the road but only one in six players had a significant difference in total sleep time between game nights (7h 3min) vs non-game nights (8h 32min). Although players reported feeling tired after game nights, Firstbeat data depicts that on average the team got >85% recovery sleep. Altogether, recovery sleep was better than the players' individual perceived recovery. Perceived sleep quality is consistent with Firstbeat data regarding good quality recovery sleep percentage. Neurological stimulants (e.g. caffeine, stadium lights, blue light exposure) appeared to have little effect on sleep recovery. Despite the demanding physiological and psychological requirements of elite hockey, the players' autonomic nervous systems are well balanced during sleep.

13 DISCUSSION

For many of today's top athletes, sport is their life. The quality and quantity of recovery sleep can have a significant impact on the success, especially if sleep is cut short. (Website of Sleep Foundation 2020). According to two systematic reviews, training and competition cycles, timing of events (late-evening competitions/games), circadian de-synchrony (jet lag), early practice times, large increases in training load, and exposure to hypoxia may all negatively affect athletes' sleep (Gupta, Morgan & Gilchrist 2017, 1326-1327, Roberts, Teo & Warmington 2019, 9). Although, circadian de-synchrony and hypoxia were not relevant in this study as players did not travel across time zones, play nor train at high elevations, all other factors did not appear to have an effect on sleep recovery.

Interestingly, despite previous findings in meta-analysis by Roberts *et al.* (2019), players were able to achieve the minimum recommended sleep of 7h every night. However, total sleep time findings support conclusions made by Roberts *et al.* (2019) that total sleep time was reduced on game night compared to non-game night, and that athletes normally achieve at least 7 hours of total sleep time on nights surrounding game nights, notwithstanding training and travel schedules. Although intense nighttime trainings before bed can have a negative effect on sleep recovery for some individuals (Website of Sleep Foundation 2020), this study shows that the hockey players appear well adapted to the high demands of intense physical activity and mentality of multiple away game nights.

When the effects of training, competition, and travel on sleep recovery are considered, such positive sleep recovery results could be an outcome of careful planning by the coaching staff. For example, travel time between hotels was around two hours in duration. The team stayed in Tanhuvaara one extra night which allowed for extra recovery and a shorter travel time to Kuopio the following day before the final game night of the road trip.

Notably, the players used in this study did not have issues falling asleep, let alone initiating the sleep recovery process on a game night. Contrary to findings by Dunican *et al.* (2018), caffeine intake pre- or intra-game time did not appear to delay sleep recovery. Additionally, the use of blue light emitting devices before bed did not appear to effect sleep recovery, supporting findings by Jones *et al.* (2018).

However, interviews revealed of two players not used in this study due to missing Firstbeat data, one of those players had great difficulties falling asleep. The player had reported repeatedly having slept poorly and taking a long time to fall asleep. This supports finding by Tuomilehto *et al.* (2017) in that one in four hockey players has trouble sleeping. However, lack of sufficient reliable Firstbeat data did not allow the authors to make this claim. On the other hand, one player in the study mentioned that his thought of why it took him longer to fall asleep was due to the fact he went to sleep 1-hour earlier than his normal bedtime. This could be linked to this individual player's sleep schedule and circadian phase (Samuels 2008, 171).

Due to the sudden change in the testing period by the hockey team's coaching staff, the authors of this study lost 4-weeks of preparation time to formulate a proper interview regime. Therefore, upon the completion of the analysis of data, the authors deemed some information from the interviews irrelevant to the study. Additional, insightful information could have been attained through better relevant questions such as: whether players felt they received sufficient amount of sleep; the total nighttime awakenings which occurred that night; whether a nap was taken that day and its duration (O’Donnell, Beaven & Driller 2018) ; dosage concerning caffeine intake; and if alcohol was consumed previous to bedtime (Thakkar, Sharma & Sahota 2015).

Limitations in Firstbeat measurements were also present. Some players used in this study had one night of missing data out of the five nights. Missing HR could be a result of devices detaching, batteries draining, and/or weak electrode-skin contact (Website of Firstbeat 2020) during sleep. Taking the precautions of charging the devices and their fixation to the body for example with additional medical tape prior to bedtime may have prevented these issues.

As requested by the coaching staff, this study focused entirely on away games. During the whole study, the players were sleeping in hotels and spent many hours traveling. Future studies could focus entirely on home games or, as originally planned for this study, comparison between home and away sleep recovery. Also interesting would be a longitudinal study in which measurements are taken in the beginning, the middle, and at the end of a season or postseason to track players sleep recovery progression.

In summary, this study provided insight into the sleep recovery on away games for elite hockey players. It was shown that, even though none of the players had any specific sleep routine, all six examined players recovered well during the night. Coaches can use the data of this study to further develop training intensities and continue to educate players on the importance of good sleep hygiene.

REFERENCES

Ahrberg, K. 2014. Der Einfluss von Schlaf auf die akademischen Leistungen. Dissertation. Munich: Ludwig-Maximilians Universität zu München.

Ahrberg, K., Dresler, M., Niedermaier, S., Steiger, A. & Genzel, L. 2012. The interaction between sleep quality and academic performance. Journal of Psychiatric Research. 46, 1618–1622.

Arain, M., Haque, M., Johal, L., Mathur, P., Nel, W., Rais, A., Sandhu, R. & Sharma, S. 2013. Maturation of the adolescent brain. Neuropsychiatric Disease and Treatment. 9, 449–461.

Azboy, O. & Kaygisiz, Z. 2009. Effects of sleep deprivation on cardiorespiratory functions of the runners and volleyball players during rest and exercise. Acta Physiologica Hungarica. 96, 29–36.

Bellenger, C.R., Fuller, J.T., Thomson, R.L., Davison, K., Robertson, E.Y. & Buckley, J.D. 2016. Monitoring Athletic Training Status Through Autonomic Heart Rate Regulation: A Systematic Review and Meta-Analysis. Sports Medicine (Auckland, N.Z.). 46, 1461–1486.

Blumert, P.A., Crum, A.J., Ernsting, M., Volek, J.S., Hollander, D.B., Haff, E.E. & Haff, G.G. 2007. The Acute Effects of Twenty-Four Hours of Sleep Loss on the Performance of National-Caliber Male Collegiate Weightlifters. The Journal of Strength and Conditioning Research. 21, 1146.

Bompa, T. & Chambers, D. 2003. Total Hockey Conditioning: From Pee Wee to Pro. Buffalo: Firefly Books.

Bradley, R.T., Tomasino, D., Atkinson, M., & Mccraty, R. 2009. The Coherent Heart Heart-Brain Interactions, Psychophysiological Coherence, and the Emergence of System-Wide Order. Integral Review. 5, 10-115.

Bracko, M., Fellingham, G., Hall, L.T., Fisher, A.G. & Cryer, W. 1998. Performance skating characteristics of professional ice hockey forwards. Research in Sports Medicine: An International Journal. 8, 251–263.

Buysse, D.J. 2013. Insomnia. JAMA. 309, 706–716.

CHA. Intermediate Level Manual. Ottawa, ON: Canadian Hockey Association, 1989.

Clemente, F. M., Rabbani, A. & Araújo, J. P. 2019. Ratings of perceived recovery and exertion in elite youth soccer players: Interchangeability of 10-point and 100-point scales. Physiology & Behavior 210.

Cox, M.H., Miles, D.S., Verde, T.J. & Rhodes, E.C. 1995. Applied physiology of ice hockey. Sports Medicine (Auckland, N.Z.). 19, 184–201.

De Meersman, R.E. 1993. Heart rate variability and aerobic fitness. American Heart Journal. 125, 726–731.

Diamond, A. 2013. Executive Functions. Annual review of psychology. 64, 135–168.

Dishman, R.K., Nakamura, Y., Garcia, M.E., Thompson, R.W., Dunn, A.L. & Blair, S.N. 2000. Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology. 37, 121–133.

Dumortier, J., Mariman, A., Boone, J., Delesie, L., Tobback, E., Vogelaers, D. & Bourgois, J.G. 2018. Sleep, training load and performance in elite female gymnasts. European Journal of Sport Science. 18, 151–161.

Dunican, I.C., Higgins, C.C., Jones, M.J., Clarke, M.W., Murray, K., Dawson, B., Caldwell, J.A., Halson, S.L. & Eastwood, P.R. 2018. Caffeine use in a Super Rugby game and its relationship to post-game sleep. European Journal of Sport Science. 18, 513–523.

Eagles, A.N. & Lovell, D.I. 2016. Changes in sleep quantity and efficiency in professional rugby union players during home-based training and match play. The Journal of Sports Medicine and Physical Fitness. 56, 565–571.

Ehrlenspiel, F., Erlacher, D. & Ziegler, M. 2016. Changes in Subjective Sleep Quality Before a Competition and Their Relation to Competitive Anxiety. Behavioral sleep medicine. 16, 1–14.

Electrophysiology Task Force of the European Society of Cardiology the North American Society of Pacing. 1996. Heart Rate Variability. Circulation. 93, 1043–1065.

Erlacher, D., Ehrlenspiel, F., Adegbesan, O.A. & El-Din, H.G. 2011. Sleep habits in German athletes before important competitions or games. Journal of Sports Sciences. 29, 859–866.

Firstbeat Life Assessment. 2016. Report Interpretation Guide. Referred 4.11.2020.

Firstbeat Technologies Ltd. 2014. Stress and Recovery Analysis Method Based on 24-hour Heart Rate Variability. White Papers. Referred 12.7.2019. https://www.firstbeat.com/en/science-and-physiology/white-papers-and-publications/

Firstbeat Technologies Oy. 2019. A Sleep Analysis Method Based on Heart Rate Variability. White Papers. Referred 27.10.2020. https://www.firstbeat.com/en/science-and-physiology/white-papers-and-publications/

Geisler, F.C.M., Vennewald, N., Kubiak, T. & Weber, H. 2010. The impact of heart rate variability on subjective well-being is mediated by emotion regulation. Personality and Individual Differences. 49, 723–728.

Green, H., Bishop, P., Houston, M., McKillop, R., Norman, R. & Stothart, P. 1976. Time-motion and physiological assessments of ice hockey performance. Journal of Applied Physiology. 40, 159–163.

Green, M.R., Pivarnik, J.M., Carrier, D.P. & Womack, C.J. 2006. Relationship between physiological profiles and on-ice performance of a National Collegiate Athletic Association Division I hockey team. Journal of Strength and Conditioning Research. 20, 43–46.

Gupta, L., Morgan, K. & Gilchrist, S. 2017. Does Elite Sport Degrade Sleep Quality? A Systematic Review. Sports Medicine (Auckland, N.z.). 47, 1317–1333.

Haack, M., Sanchez, E. & Mullington, J.M. 2007. Elevated Inflammatory Markers in Response to Prolonged Sleep Restriction Are Associated With Increased Pain Experience in Healthy Volunteers. Sleep. 30, 1145–1152.

Haack, M., Lee, E., Cohen, D.A. & Mullington, J.M. 2009. Activation of the prostaglandin system in response to sleep loss in healthy humans: Potential mediator of increased spontaneous pain: Pain. 145, 136–141.

Hainline, B., Derman, W., Vernec, A., Budgett, R., Deie, M., Dvořák, J., Harle, C., Herring, S.A., McNamee, M., Meeuwisse, W., Moseley, G.L., Omololu, B., et al. 2017. International Olympic Committee consensus statement on pain management in elite athletes. British Journal of Sports Medicine. 51, 1245–1258.

Hall, M., Vasko, R., Buysse, D., Ombao, H., Chen, Q., Cashmere, J.D., Kupfer, D. & Thayer, J.F. 2004. Acute stress affects heart rate variability during sleep. Psychosomatic Medicine. 66, 56–62.

Halson, S.L. 2014. Sleep in Elite Athletes and Nutritional Interventions to Enhance Sleep. Sports Medicine (Auckland, N.z.). 44, 13–23.

Hausswirth, C., Louis, J., Aubry, A., Bonnet, G., Duffield, R. & Le Meur, Y. 2014. Evidence of Disturbed Sleep and Increased Illness in Overreached Endurance Athletes. Medicine & Science in Sports & Exercise. 46, 1036–1045.

Hirsch, J.A. & Bishop, B. 1981. Respiratory sinus arrhythmia in humans: how breathing pattern modulates heart rate. The American Journal of Physiology. 241, H620-629.

Hirsch, J.A., Bishop, B. & York, J.L. 1996. Role of parasympathetic (vagal) cardiac control in elevated heart rates of smokers. Addiction Biology. 1, 405–413.

Irwin, M.R. 2015. Why Sleep Is Important for Health: A Psychoneuroimmunology Perspective. Annual Review of Psychology. 66, 143–172.

Jones, M.J., Peeling, P., Dawson, B., Halson, S., Miller, J., Dunican, I., Clarke, M., Goodman, C. & Eastwood, P. 2018. Evening electronic device use: The effects on alertness, sleep and next-day physical performance in athletes. Journal of Sports Sciences. 36, 162–170.

Juliff, L., Halson, S. & Peiffer, J. 2014. Understanding sleep disturbance in athletes prior to important competitions. Journal of Science and Medicine in Sport. 18.

Killgore, W.D.S. 2010. Effects of sleep deprivation on cognition. In Vol. 185. Elsevier Progress in Brain Research. 105–129.

Kimberly, B. & R, P.J. 2009. Amber Lenses to Block Blue Light and Improve Sleep: A Randomized Trial. Chronobiology International. 26, 1602–1612.

Kivlighan, K.T. & Granger, D.A. 2006. Salivary alpha-amylase response to competition: relation to gender, previous experience, and attitudes. Psychoneuroendocrinology. 31, 703–714.

Knufinke-Meyfroyt, M., Nieuwenhuys, A., Geurts, S., Møst, E., Maase, K., Moen, M., Coenen, A. & Kompier, M. 2017. Train hard, sleep well? Perceived training load, sleep quantity and sleep stage distribution in elite level athletes. Journal of Science and Medicine in Sport. 21.

Laurent, C. M., Green, J. M., Bishop, P. A., Sjökvist, J., Schumacker, R. E., Richardson, M. T. & Curtner-Smith, M. 2011. A Practical Approach to Monitoring Recovery: Development of a Perceived Recovery Status Scale. Journal of Strength and Conditioning Research 25, 620-628

Little, T. & Williams, A.G. 2005. Specificity of acceleration, maximum speed, and agility in professional soccer players. Journal of Strength and Conditioning Research. 19, 76–78.

Low, P. 2020. Overview of the Autonomic Nervous System. In: Merck Manual Professional Version. Referred 19.10.2020. https://www.merckmanuals.com/professional/neurologic-disorders/autonomic-nervous-system/overview-of-the-autonomic-nervous-system

Lund, H.G., Reider, B.D., Whiting, A.B. & Prichard, J.R. 2010. Sleep Patterns and Predictors of Disturbed Sleep in a Large Population of College Students. Journal of Adolescent Health. 46, 124–132.

Lundgren, T., Högman, L., Näslund, M. & Parling, T. 2016. Preliminary Investigation of Executive Functions in Elite Ice Hockey Players. Journal of Clinical Sport Psychology. 10, 324–335.

Malpas, S.C. 2010. Sympathetic nervous system overactivity and its role in the development of cardiovascular disease. Physiological Reviews. 90, 513–557.

Mastorakos, G., Pavlatou, M., Diamanti-Kandarakis, E. & Chrousos, G.P. 2005. Exercise and the stress system. Hormones (Athens, Greece). 4, 73–89.

McArdle, W., Katch, F. & Katch, V. 2015. Exercise physiology: Nutrition, energy, and human performance. Philadelphia: Wolters Kluwer.

McCraty, R. & Shaffer, F. 2015. Heart Rate Variability: New Perspectives on Physiological Mechanisms, Assessment of Self-regulatory Capacity, and Health risk. Global Advances in Health and Medicine. 4, 46–61.

McCraty, R., Mike, A., Tomasino, D. & Bradley, R. 2009. The Coherent Heart Heart–Brain Interactions, Psychophysiological Coherence, and the Emergence of System-Wide Order. Integral Review. 5.

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., Raglin, J., Rietjens, G., Steinacker, J. & Urhausen, A. 2013. Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM). European Journal of Sport Science. 13.

Mejri, M.A., Yousfi, N., Mhenni, T., Tayech, A., Hammouda, O., Driss, T., Chaouachi, A. & Souissi, N. 2016. Does one night of partial sleep deprivation affect the evening performance during intermittent exercise in Taekwondo players? Journal of Exercise Rehabilitation. 12, 47–53.

Mielgo-Ayuso, J., Calleja-Gonzalez, J., Del Coso, J., Urdampilleta, A., León-Guereño, P. & Fernández-Lázaro, D. 2019. Caffeine Supplementation and Physical Performance, Muscle Damage and Perception of Fatigue in Soccer Players: A Systematic Review. Nutrients. 11.

Montgomery, D.L. 1988. Physiology of ice hockey. Sports Medicine (Auckland, N.Z.). 5, 99–126.

Nagahara, R., Matsubayashi, T., Matsuo, A. & Zushi, K. 2014. Kinematics of transition during human accelerated sprinting. Biology Open. 3, 689–699.

Nedelec, M., Aloulou, A., Duforez, F., Meyer, T. & Dupont, G. 2018a. The Variability of Sleep Among Elite Athletes. Sports Medicine - Open. 4.

Neeld, K. 2018. Preparing for the Demands of Professional Hockey. Strength & Conditioning Journal. 40, 1–16.

Netzer, N.C., Kristo, D., Steinle, H., Lehmann, M. & Strohl, K.P. 2001. REM sleep and catecholamine excretion: a study in elite athletes. European Journal of Applied Physiology. 84, 521–526.

Noonan, B.C. 2010. Intragame blood-lactate values during ice hockey and their relationships to commonly used hockey testing protocols. Journal of Strength and Conditioning Research. 24, 2290–2295.

Novák, D., Lipinska, P., Roczniok, R., Spieszny, M. & Stastny, P. 2019. Off-Ice Agility Provide Motor Transfer to On-Ice Skating Performance and Agility in Adolescent Ice Hockey Players. Journal of Sports Science & Medicine. 18, 680.

O’Donnell, S., Beaven, C. & Driller, M. 2018. From pillow to podium: a review on understanding sleep for elite athletes. Nature and Science of Sleep. Volume 10, 243–253.

O’Donnell, S., Bird, S., Jacobson, G. & Driller, M. 2018. Sleep and stress hormone responses to training and competition in elite female athletes. European Journal of Sport Science. 18, 1–8.

Ohayon, M., Wickwire, E.M., Hirshkowitz, M., Albert, S.M., Avidan, A., Daly, F.J., Dauvilliers, Y., Ferri, R., Fung, C., Gozal, D., Hazen, N., Krystal, A., et al. 2017. National Sleep Foundation’s sleep quality recommendations: first report. Sleep Health. 3, 6–19.

Oliver, S.J., Costa, R.J.S., Laing, S.J., Bilzon, J.L.J. & Walsh, N.P. 2009. One night of sleep deprivation decreases treadmill endurance performance. European Journal of Applied Physiology. 107, 155–161.

Orvanová, E. 1987. Physical structure of winter sports athletes. Journal of Sports Sciences. 5, 197–248.

Parak, J. & Korhonen, I. 2013. Accuracy of Firstbeat Bodyguard 2 beat-to-beat heart rate monitor. White paper. Referred 15.7.2020. https://www.firstbeat.com/en/science-and-physiology/white-papers-and-publications/

Patel, S.R., Malhotra, A., White, D.P., Gottlieb, D.J. & Hu, F.B. 2006. Association between Reduced Sleep and Weight Gain in Women. American Journal of Epidemiology. 164, 947–954.

Peterson, B.J., Fitzgerald, J.S., Dietz, C.C., Ziegler, K.S., Ingraham, S.J., Baker, S.E. & Snyder, E.M. 2015. Division I Hockey Players Generate More Power Than Division III Players During on- and Off-Ice Performance Tests. The Journal of Strength & Conditioning Research. 29, 1191–1196.

Peyer, K.L., Pivarnik, J.M., Eisenmann, J.C. & Vorkapich, M. 2011. Physiological Characteristics of National Collegiate Athletic Association Division I Ice Hockey Players and Their Relation to Game Performance. The Journal of Strength & Conditioning Research. 25, 1183–1192.

Plews, D., Laursen, P., Stanley, J., Kilding, A. & Buchheit, M. 2013. Training Adaptation and Heart Rate Variability in Elite Endurance Athletes: Opening the Door to Effective Monitoring. Sports medicine (Auckland, N.Z.). 43.

Rea, P. 2015. Essential clinically applied anatomy of the peripheral nervous system in the limbs. Amsterdam: Academic Press

Roberts, S.S.H., Teo, W.-P. & Warmington, S.A. 2019. Effects of training and competition on the sleep of elite athletes: a systematic review and meta-analysis. British Journal of Sports Medicine. 53, 513–522.

Roth, T. 2007. Insomnia: definition, prevalence, etiology, and consequences. Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine. 3, S7-10.

Sadeh, A. 2011. The role and validity of actigraphy in sleep medicine: An update. Sleep Medicine Reviews. 15, 259–267.

Sajadieh, A., Nielsen, O.W., Rasmussen, V., Hein, H.O., Abedini, S. & Hansen, J.F. 2004. Increased heart rate and reduced heart-rate variability are associated with subclinical inflammation in middle-aged and elderly subjects with no apparent heart disease. European Heart Journal. 25, 363–370.

Samuels, C. 2008. Sleep, recovery, and performance: the new frontier in high-performance athletics. Neurologic Clinics. 26, 169–180; ix–x.

Samuels, C. & James, L. 2015. Sleep as a recovery tool for athletes. Aspetar Sports Medicine Journal Post-exercise recovery. 48-52. Referred 5.11.2020. https://www.aspetar.com/journal/

Sargent, C. & Roach, G. 2016. Sleep duration is reduced in elite athletes following night-time competition. Chronobiology International. 33(, 667–670.

Schaal, K., Tafflet, M., Nassif, H., Thibault, V., Pichard, C., Alcotte, M., Guillet, T., El Helou, N., Berthelot, G., Simon, S. & Toussaint, J.-F. 2011. Psychological Balance in High Level Athletes: Gender-Based Differences and Sport-Specific Patterns. PLoS ONE. 6.

Schaal, K., Le Meur, Y., Louis, J., Filliard, J.-R., Hellard, P., Casazza, G. & Hausswirth, C. 2014. Whole-Body Cryostimulation Limits Overreaching in Elite Synchronized Swimmers. Medicine & Science in Sports & Exercise. 47.

Segen's Medical Dictionary 2011. Elite athlete. Retrieved 27.11.2019. https://medical-dictionary.thefreedictionary.com

Shaffer, F., McCraty, R. & Zerr, C.L. 2014. A healthy heart is not a metronome: an integrative review of the heart’s anatomy and heart rate variability. Frontiers in Psychology. 5.

Shearer, D.A., Jones, R.M., Kilduff, L.P. & Cook, C.J. 2015. Effects of competition on the sleep patterns of elite rugby union players. European Journal of Sport Science. 15, 681–686.

Shepard, J., Dawes, J., Jeffreys, I., Spiteri, T. & Nimphius, S. 2014. Broadening the view of agility: a scientific review of the literature. Journal of Australian Strength and Conditioning. 22, 6–30.

Sigmund, M., Kohn, S. & Sigmundová, D. 2016. Assessment of basic physical parameters of current Canadian-American National Hockey League (NHL) ice hockey players. Acta Gymnica. 46.

Souissi, N., Sesboüé, B., Gauthier, A., Larue, J. & Davenne, D. 2003. Effects of one night’s sleep deprivation on anaerobic performance the following day. European Journal of Applied Physiology. 89, 359–366.

Suetsugi, M., Mizuki, Y., Yamamoto, K., Uchida, S. & Watanabe, Y. 2007. The effect of placebo administration on the first-night effect in healthy young volunteers. Progress in Neuro-Psychopharmacology and Biological Psychiatry. 31, 839–847.

Svorc, P. 2018. Autonomic Nervous System. IntechOpen. Referred 01.06.2020. doi:10.5772/intechopen.73119

Thakkar, M.M., Sharma, R. & Sahota, P. 2015. Alcohol disrupts sleep homeostasis. Alcohol (Fayetteville, N.Y.). 49, 299–310.

Thornton, H.R., Duthie, G.M., Pitchford, N.W., Delaney, J.A., Benton, D.T. & Dascombe, B.J. 2017. Effects of a 2-Week High-Intensity Training Camp on Sleep Activity of Professional Rugby League Athletes. International Journal of Sports Physiology and Performance. 12, 928–933.

Tomlin, D.L. & Wenger, H.A. 2001. The Relationship Between Aerobic Fitness and Recovery from High Intensity Intermittent Exercise. Sports Medicine. 31, 1–11.

Tortora, G.J. & Derrickson, B. 2014. Principles of anatomy & physiology. Hoboken, NJ: Wiley.

Trommelen, J. & van Loon, L.J.C. 2016. Pre-Sleep Protein Ingestion to Improve the Skeletal Muscle Adaptive Response to Exercise Training. Nutrients. 8.

Tuomilehto, H., Vuorinen, V.-P., Penttilä, E., Kivimäki, M., Vuorenmaa, M., Venojärvi, M., Airaksinen, O. & Pihlajamäki, J. 2017. Sleep of professional athletes: Underexploited potential to improve health and performance. Journal of Sports Sciences. 35, 704–710.

Twist, P. & Rhodes, T. 1993a. EXERCISE PHYSIOLOGY: The Bioenergetic and Physiological Demands of Ice Hockey. Strength & Conditioning Journal. 15, 68–70.

Twist, P. & Rhodes, T. 1993b. EXERCISE PHYSIOLOGY: A Physiological Analysis of Ice Hockey Positions. Strength & Conditioning Journal. 15, 44–46.

Veale, J.P. & Pearce, A.J. 2009. Physiological Responses of Elite Junior Australian Rules Footballers During Match-Play. Journal of Sports Science & Medicine. 8, 314–319.

Vitale, K.C., Owens, R., Hopkins, S.R. & Malhotra, A. 2019a. Sleep Hygiene for Optimizing Recovery in Athletes: Review and Recommendations. International Journal of Sports Medicine. 40, 535–543.

Watson, N.F., Badr, M.S., Belenky, G., Bliwise, D.L., Buxton, O.M., Buysse, D., Dinges, D.F., Gangwisch, J., Grandner, M.A., Kushida, C., Malhotra, R.K., Martin, J.L., et al. 2015. Recommended Amount of Sleep for a Healthy Adult: A Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society. Journal of Clinical Sleep Medicine. 11, 591–592.

Website of the American swedenmedline Association. Referred 5.8.2020. https://www.apa.org/

Website of Firstbeat. Referred 2.11.2020. https://www.firstbeat.com/en

Website of Liiga. Referred 30.6.2020. https://liiga.fi/en/

Website of MedlinePlus. Referred 3.8.2020. https://medlineplus.gov/

Website of Mid Sweden University. Referred 15.6.2020. https://www.miun.se/en/

Website of the National Institute for Neurological Disorders and Stroke. Referred 7.10.2020. https://www.ninds.nih.gov/

Website of pdhpe.net. Referred 30.6.2020. https://www.pdhpe.net/

Website of Sleep Foundation. Referred 5.10.2020. https://www.sleepfoundation.org/

Wisdom, J. & Creswell, J.W. 2013. Mixed Methods: Integrating Quantitative and Qualitative Data Collection and Analysis While Studying Patient-Centered Medical Home Models. Rockville, MD: Agency for Healthcare Research and Quality. AHRQ Publication No. 13-0028-EF. Referred 10.11.2020. https://pcmh.ahrq.gov/

Wright, K.P., Drake, A.L., Frey, D.J., Fleshner, M., Desouza, C.A., Gronfier, C. & Czeisler, C.A. 2015. Influence of sleep deprivation and circadian misalignment on cortisol, inflammatory markers, and cytokine balance. Brain, Behavior, and Immunity. 47, 24–34.

Xie, L., Kang, H., Xu, Q., Chen, M.J., Liao, Y., Thiyagarajan, M., O'Donnell, J., Christensen, D.J., Nicholson, C., Iliff, J.J., Takano, T., Deane, R., et al. 2013. Sleep Drives Metabolite Clearance from the Adult Brain. Science. 342, 373–377.

Yilmaz, M., Kayancicek, H. & Cekici, Y. 2018. Heart rate variability: Highlights from hidden signals. Journal of Integrative Cardiology. 4.

Zhuang, Z., Gao, X. & Gao, S. 2005. The Relationship of Hrv to Sleep Eeg and Sleep Rhythm. International Journal of Neuroscience. 115, 315–327.

Informed consent
Information form for the Pori Ässät hockey player

This informed consent form is for 19-24 year old elite hockey players on the Pori Ässät team, and who we are inviting to participate in the thesis case study for sleep recovery. The title of our project is “Biological and perceived recovery comparison in 19-24 year old elite hockey players”.

Name of Principle Investigators
Gid Martinez and Felix Hauernherm
Name of Organization
Satakunnan ammattikorkeakoulu
Name of Project
Biological and perceived recovery comparison in 19-24-year-old elite hockey players

This Informed Consent Form has two parts:
Information Sheet (to share information about the research with you)
Certificate of Consent (for signatures if you agree to take part)

PART 1: Information Sheet

We are students of Satakunnan ammattikorkeakoulu. We are writing a thesis comparing biological sleep recovery and individual perceived sleep recovery in elite hockey players 19-24 years of age. This consent form may contain words you do not understand. In case you do not understand any part of this document, please ask either researcher any question(s) you may have now or in the future.

Purpose of the research

Elite athletes, coaches and trainers have identified sleep as critical for post-exercise recovery and also critical for optimal performance. Therefore, our purpose is to find out whether elite athletes, specifically hockey players, are recovering properly by comparing their biological findings using the Firstbeat bodyguard (2) heart rate variability monitoring device to the individual athlete’s own perceived recovery. The results of this thesis can be used to help the coaching staff manage rest and recovery periods of individual players.

Type of Research Intervention

The duration of this measurement is 5 days, and it will include the application of the Firstbeat Bodyguard (2) heart rate variability monitoring device. In addition to the Firstbeat Bodyguard (2) heart rate monitoring variability device, you will be participating in a daily morning interview by one of the researchers.

Participant Selection

You have been invited to participate in this study because you fit in the required criteria of age, date of birth, health, active roster position, and active contract.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. If you choose not to participate, it will have no effect with your position on the team. You may change your mind later and stop participating even if you agreed earlier.

Procedures

The Firstbeat Bodyguard (2) heart rate variability monitoring device will be worn for the full duration of the study. The device consists of two electrodes placed on the chest. One electrode will be placed on the upper right side of the chest under the collarbone and the other electrode on the middle left side of the rib cage under the left breast.

We are inviting you to take part in this research project. If you accept, you will be asked to participate in a daily pre-warm up interview with Gid Martinez or Felix Hauernherm.

During the interview, the interviewer will sit down with you in a comfortable place at the ice rink. If it is better for you, the interview can take place in a separate location before arriving to the ice rink. If you do not wish to answer any of the questions during the interview, you may say so and the interviewer will move on to the next question. No one else but the interviewer will be present unless you would like someone else to be there. The information recorded is confidential, and no one else except the interviewers and coaching staff will access to the information documented during your interview. The entire interview will be voice-recorded, but no one will be identified by name on the recording. The recording will be kept on two USB sticks. The information recorded is confidential, and no one else except Gid Martinez, Felix Hauernherm and the coaches will have access to the recordings. The recordings will be destroyed after the analyzation has been finished, however latest after four months.

Duration

The measurement takes place over 5 days in total. During that time, you will use the Firstbeat Bodyguard (2) heart rate variability monitoring device both day and night for 5 days.

In addition to wearing the Firstbeat device, we will visit you 4 times for interviewing you. Because 1 of those mornings you will be in another city, a 1-time Skype or phone call will be necessary for interviewing. The call will be made according to individual preference. The interview will be held every morning before beginning practice and should not exceed 20 minutes.

Risks

While using the Firstbeat Bodyguard (2) device, some participants may experience skin discomfort in the area where the electrodes are placed. To avoid skin problems, please follow these steps: Clean the electrode placement spots before attaching electrodes. Apply a thin layer of non-greasy basic body lotion to the spots where you are going to attach the electrodes. Wait for the lotion to dry (allow at least 10 min) to avoid electrode contact problems. Repeat this process each time you attach new electrodes. When removing and replacing electrodes, dampen the skin with a few drops of water to help avoid mechanical stress. You may also slightly change the new electrode placement.

There is a risk while wearing the Firstbeat bodyguard (2) device during practice or game time that the device feels restricting or bothersome. This inconvenience should pass after a short period. Be sure while placing electrodes that you do not place them too far apart. This will allow you to have full range of motion during activity.

During the interviews, there is a risk you may share personal information or that you may feel uncomfortable sharing it. However, we do not wish for this to happen. You do not have to answer any questions if you feel the question(s) are too personal.

Benefits

After the analysis of the data and interviews, you and the coaches will have data comparing your body's real recovery according to your own personal daily and nightly habits to your own perception of how well you rested and recovered from the previous day's schedule. This in turn can help the coaches and yourself to make the necessary lifestyle changes to improve your recovery in the future.

Confidentiality

The research being done in team may draw attention and if you participate, other team members may ask you questions. We will not be sharing information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the coach and researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except the coaches.

Sharing the Results

The knowledge that we get from this research will be shared with you and the coaches before it is made available to the public. Firstbeat Lifestyle report results will be given to you and the coaches after the study period.

Right to Refuse or Withdraw

You do not have to take part in this research if you do not wish to do so. You may also stop participating in the research at any time you choose. It is your choice and all of your rights will still be respected.

Who to Contact

If you have any questions you may ask them now or later, even after the study has started. If you wish to ask questions later, you may contact any of the following:

Gid Martinez 040XXXXX83
or
Felix Hauernherm 040XXXXX92

PART II: Certificate of Consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant in this research.

Print Name of Participant__________________
Signature of Participant ___________________
Date ___________________________
Day/month/year

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this informed consent form has been provided to the participant.

Print Name of Researcher/person taking the consent________________________

Signature of Researcher /person taking the consent__________________________
Date ___________________________
Day/month/year

APPENDIX 2

Structure for the interviews (English)

Structure for interviews

Part 1: Introduction

Introducing myself, quickly explaining again about the project, what we´re doing and why. Also remind about confidentiality. No one, except for the coaches and Gid & Felix will know who the answers come from.

Part 2: Perceived recovery

- How are you feeling today, in general?
- How recovered do you feel?
- PRS: On a scale from 0 – 10,
    - 10 Very well recovered / Highly energetic
    - 9
    - 8 Well recovered / Somewhat energetic
    - 7
    - 6 Moderately recovered
    - 5 Adequately recovered
    - 4 Somewhat recovered
    - 3
    - 2 Not well recovered / Somewhat tired
    - 1
    - 0 very poorly recovered / extremely tired
- How did you sleep last night, what do you think?
- What kind of sleep do you think you got? (Light / deep)
- Do you have any idea why that might be?
    - If any thoughts about the game mentioned, see section 4
- What time did you go to bed? How long do you think it took till you fell asleep?
- How did you feel lying in bed? (Stressed / calm for example)
    - If stressed: about what?
- When you woke up, how did you feel? Did you get up immediately or did you spend some time lying in bed?
- Did you use the snooze button? How often? Do you do that regularly?

- Do you remember your dreams from last night (no need to talk about them)? / Do you remember dreaming?

Part 3: "Hard" factors concerning sleep

Asking about things concerning sleep hygine such as:

- Do you have a set "sleeping routine" / rituals?
- ○ If you do, would you please describe it for me? What do you usually do the last one (or two?) hours before going to bed?
- How about last night? What did you do before going to sleep?
  - Watching TV
  - Using phone
  - Caffeine use (amount, time)
  - Medications
- Bedroom surroundings:
- ○ Noise
- ○ Light
- ○ Bed (+pillow + blanket) itself
  - ○ Was it comfortable?
- ○ Temperature (most probably subjective, also: do you think it was right for you?)

Part 4: "Soft" factors:

Psychological factors:

- Thoughts about competition (previous and / or coming)
- What kind of thoughts / feelings did you have (Nervousness for example)?
- …
- How are you dealing with that?
- Unusual surroundings

Only in the last interview:

- Do you have any ways / actions like for example meditation, mindfulness etc. that you use?
- If not, do you know about them?
- If not, would you be interested to hear about them some time?

Structure for the interviews (Finnish)

Osa 1: Johdanto

Esittelen itseni, selitän nopeasti uudelleen projektista, mitä teemme, ja miksi.

Osa 2: Koettu hyödyntäminen

- Kuinka voit tänään? (Yleisesti)
- Kuinka palautuneelta sinusta tuntuu?
- PRS:
    - 10 Erittäin hyvin palautunut
    - 9
    - 8 Hyvin palautunut / melko energinen
    - 7
    - 6 Melko palautunut
    - 5 Kohtalaisesti palautunut
    - 4 Jonkin verrran palautunut
    - 3
    - 2 Huonosti palautunut / hieman väsynyt
    - 1
    - 0 Erittäin huonosti palautunut / erittäin väsynyt
- Miten nukuit viime yönä?
- Millaisen unen luulet saaneesi viime yönä? (Syvä / kevyt)
    - Onko sinulla mitään käsitystä miksi?
    - *If answer relates to game or other psychological factors, jump to part 4*
- Mihin aikaan menit sänkyyn / nukkumaan? Kuinka kauan kesti, kunnes nukahtait?
- Miltä sinusta tuntui makaavan sängyssä? (stressaantunut / rentoutunut)

- Kun heräsit, milta sinusta tuntui? Nousitko heti tai vietitkö jonkin aikaa sängyssä?
- Käytitkö torkkupainikettä? Kuinka monta kerta? Käytätkö yleensä?
- Muistatko unesi viime yöstä? / Muistatko untasi?

Osa 3

- Onko sinulla ”nukkumisrutiini”? / Mitä teet yleensä ennen kuin menet nukkumaan?
- Entä viime yönä? Mitä teit ennen kuin menit nukkumaan?
    - TV
    - Puhelin (...)
- Milloin viimeksi joit kofeiinia ennen kuin menit nukkumaan?
- Käytitkö lääkeitä ennen kuin menit nukkumaan?
- Hotellihuone:
    - Oliko huoneessa paljon (/liian paljon) valoa?
    - Melu
    - Oliko sänky (+tyyny + lakana) mukava?
    - Oliko huoneen lämpötila sinun mielestäsi sopiva? (Liian kuuma / kylmä?)

Osa 4

- Ajattelitko peliä ennen kuin menit nukkumaan?
- Millaisia ajatuksia / tunteita sinulla oli pelistä?
    - Olitko esimmerkiksi hermostunut / innostunut?
- Kuinka käsittelet sitä?

Osa 5 ***ONLY IN THE LAST INTERVIEW***

- Käytätkö joskus jotain rentoutusta (/mindfulness) tai meditaatiota tai jotain sellaista? Tai oletko koskaan kokeillut?
- Jos ei, tiedätkö mitään tästä?

Jos ei, haluaisitko tietää enemmän siitä?