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Stress and recovery of players in Kontinental Hockey League

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There are a lot of information about physical stress in different exercises and competition situations, but not so much research about recovery in professional team sport. The aim of this study was to produce new information about stress and recovery of the players in the international league. Another objective was to find out the individual differences of the stress and recovery of the players, when the program is the same for all. The big amount of games during the season has increased requirement of good recovery of the athlete.

The subjects (31) of this study are professional ice hockey players of Finnish club team Jokerit in Kontinental Hockey League. The average age was 29 years, height 185 cm, weight 91 kg and VO2max 54 ml/kg/min. The autonomic regulation of HRV was measured during the season in 12 different periods lasting 2-6 days. The autonomic regulation of heart rate variability (HRV) was measured by using Firstbeat Sport and Firstbeat Life Assesment methods. R-to R interval were acquired with the Firstbeat Bodyguard 2 wearable heart rate monitor on 1ms resolution.

According to over 100 night recovery measurements the average time when recovery started, was 7 hours and 42 minutes after the ended game. The average duration of the night recovery was 5 hours and 33 minutes. One of the most notable finding was really big individual differences of the night recovery between the different players. The fastest recovery started two hours after the game and the slowest player didn’t recover at all during the night.

A player has to be an athlete 24 hours in a day and 7 days in a week. The physical and mental stress of the ice hockey game is so big that it delays the start of the recovery. Finding a balance between playing load and recovery is a key factor to maintain good athletic performance. Regular recovery assessment is a key factor in successful athletic programming. Firstbeat assessment methods are easy-to-use methods to assess the recovery of an athlete or a team. .

Keywords

Ice hockey, Kontinental Hockey League, recovery, heart rate variability

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1 Introduction

There are a lot of information about physical stress in different exercises and competition situations, but not so much research about recovery in professional team sport. The big amount of games during the season has increased requirement of good recovery of the athlete. Without good recovery it is difficult to maintain a good physical performance state.

When a hard playing period that causes a significant disturbance in body's homeostasis is followed by sufficient recovery, an athlete is able to maintain a good performance state. The importance of sufficient recovery is due to the fact that performance improvements actually occur during recovery, not during workouts. In precise and effective training and playing management, player and coaches should assess the load and effectiveness of different playing sessions, but especially recovery from these sessions. Finding a balance between playing load and recovery is a key factor to maintain good athletic performance.

The subjects of this study are professional ice hockey players of Finnish club team Jokerit, Helsinki. The team participated to Kontinental Hockey League (KHL) first time on the season 2014-2015. The biggest difference of the KHL compared to national leagues is travelling and the long distances between cities. The playing program of the KHL is based on longer road trips as a guest team and also fewer home games in a row. Usually one road trip includes three or four games in a row. The team plays every second day and travels after the game to the next city by a plane. Jokerit is travelling inside 4 hour time zone. Normally after the visiting games the team has three or four home games.

The autonomic regulation of HRV was measured by using Firstbeat Sport and Firstbeat Life Assessment. The both tools are based on a computer program that analyses beat-by-beat heart rate and heart rate variability to provide information about different aspects of stress and recovery. Firstbeat assessment methods are new easy-to-use methods to assess the stress and the recovery of an athlete or a team.

The aim of this study is to produce new information about stress and recovery of the players in the international league. Another objective is to find out the individual differences of the stress and recovery of the players, when the program is the same for all.

2 Physiological demands of ice hockey

The demands of the sport require ice hockey players to have relatively highly developed aerobic and anaerobic capacities, upper and lower body strength, power, agility and flexibility (Rhodes & Twist 1993, 69-70).

2.1 Physiological stress of ice hockey game

In hockey, duration of the one shift is on average 30-60 seconds. During an entire game, player skates approximately 5-7 kilometers, and 250-300 meter during a shift. The game itself and skill performances involve short-term, maximum power efforts. In ice hockey, speed, in addition to meaning skating speed, also refers to changes of rhythm and direction, reaction speed, fakes and agility. The energy required for the muscle contractions of these short-term strength and speed efforts in supplied to the muscle tissue directly from the muscle's adenosine triphosphate (ATP) and creatine phosphate (CP) sources. These reserves last only for few seconds in a maximum performance, and therefore, the energy required to continue the work is then acquired through anaerobic glycolysis. (Summanen & Westerlund 2001, 14-21.)

Anaerobic glycolysis is the main source of energy for a single shift. During ice hockey game, lactic acid concentrations vary between 3-14 mmol/l depending on the individual and the playing position. The stress of the game has also been studied by monitoring heart rates. The heart rate provides an overall picture of stress level. In a ice hockey game, the average working heart rates of the players vary between 170-174 beats per minute. The recovery time after a 30-60 second work period varies between 3-5 minutes on average. The durations of the rest period is individual and might change between different players. During the resting, heart rates can drop to 110-120 beats per minute. (Summanen & Westerlund 2001, 14-21.)

Forwards require a higher recovery time and play less shifts than defensemen due to the tasks they perform; they cover more surface are, are required to change directions and generate increases in skating velocity more frequently than defensemen.

Defensemen engage in similar activities, with similar intensities, the difference in frequency of the demands, necessitates forwards play less shifts, and recover longer. (Twist & Rhodes 1993, 44-46).

The average National League Hockey player receives less than 16 minutes of actual playing time extended over 3 hours; however some players may receive as much as 35 minutes playing time (Cox, Miller, Rhodes & Verde 1995, 185).

In addition to the bioenergetics demands of ice hockey performance, the practicing strength and conditioning professional must have a biomechanical understanding of the movement patterns associated with the sport. Task analysis indicates that hockey involves coordinated multi-joint, multi-limb movement patterns, and rapid rates of force development in executing the technical skills of skating, passing, shooting, and body checking. (Allen 2002, 42-52.)

Playing skills combine qualities from different areas. Those are tactical, technical, psychological and physical. When attempting to develop and exercise a quality, the coach should be aware that all of the qualities are strongly interdependent and all have an impact on the whole. (Summanen & Westerlund 2001, 14-21).

In hockey, performance is high powered, thus, excess formation of lactic acid should be avoided. The anaerobic threshold is a good performance indicator for an ice hockey player. An ice hockey player's anaerobic threshold levels vary between 70-80 % of the maximal oxygen uptake (Summanen & Westerlund 2001, 14-21). Elite ice hockey forwards and defensemen require a maximum oxygen consumption rate of 60ml/kg/min and 50ml/kg/min respectively. (Twist & Rhodes 1993, 44-46.)

Although ice hockey emphasizes the portion of anaerobic energy production, aerobic energy production is the foundation for a player's performance. Good aerobic fitness allows a player to save the anaerobic energy production mechanism. The higher the aerobic capacity, the faster lactic acid can be eliminated from the blood. Furthermore, with good aerobic endurance, the faster a player can refill his short-term energy reserves (ATP and CP) on the bench. Good ice hockey endurance means the ability to play 20-25 shifts during a game, play 3-4 league games per week, exercising between the games and play tournaments and playoffs, all under tight schedule. (Summanen & Westerlund 2001, 14-21.)

2.2 Different season in hockey

Season can be divided into 4 distinct season; the off-season, pre-season, in-season, and off-season. Each season have different training priorities (Table 1) (Allen 2002, 42-52).

Table 1. Example of Training Phase Priorities (Allen 2002, 42-52).

Season	Dates	Training
Off-season	June - August	Strength, power and endurance. Aerobic and anaerobic capacity. Improving technical skills
Pre-Season	Semptemper	Returning to "Game shape" Refining sport specific skills and movement patterns. Developing team chemistry and bonding.
In-Season	October - February	Muscle strength, power, and endurance maintenance. Aerobic and anaerobic capacity maintenance. Injury prevention.
Post-season	March- April	Muscle strength, power, and endurance maintenance. Aerobic and anaerobic capacity maintenance. Injury prevention.

Pre-season purposes are to refines sport specific skills, movement patterns and develop team chemistry. This season usually includes training camps, practices, exhibition games, team meetings, traveling, and off-ice conditioning. Aerobic and anaerobic energy system development is integrated into the pre-season phase. While the athlete will be engaged in significant on-ice skating drills designed to prepare the physiologic demands of performance, it is highly recommended that the athlete participate in high intensity cycling twice a week. (Rosene 2002, 22-28.)

In-season the athlete must no longer be concerned about developing an increase in muscular strength, power or energy system capacity. Purpose is to maintain the physiological abilities developed through the off-, and in-seasons. Also have to focus on injury prevention. (Rosene 2002, 22-28.)

Off-season conditioning is the training phase that is structured to develop increases in lean muscle mass, peak strength, peak power, and peak aerobic and anaerobic profiles. The off-season begins following post season testing and a week or two of rest. Rest and recovery is important at this time of the season as players have been physically and psychologically engaged in intense competition. They have been away from family, and require time to recover from the volume of the year. (Rosene 2002, 22-28.)

3 Autonomic nervous system

The autonomic nervous system (ANS) is largely autonomous; it is almost fully independent of our will. It maintains the homeostasis of the body by controlling heart rate (HR), blood pressure, body temperature, respiratory airflow, papillary diameter, digestion, energy metabolism, defecation, and urination in response to daily challenges, such as exercise or postural changes. (Martinmäki 2009; Saladin 2008, 469.)

There is a complex interaction between the two portions of ANS to maintain a dynamic adaptive state in response to internal and external demands: sympathetic (SNS) and parasympathetic (PNS, also known as vagal) divisions. The two divisions differ in anatomy and function but they often innervate the same target organs and may work together oragainst each other in their function. Both of these divisions are concurrently active but according to the needs of the body the balance between the sympathetic and parasympathetic tone changes. (Martinmäki 2009; Saladin 2008, 469.)

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

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

PNS and SNS are reciprocally innervated and their effects on a specific organ are antagonistic. This coordination ensures that the body reacts to both internal and external demands and to maintain homeostasis and physiological stability. The autonomic nervous system acts as an indicator of homeostasis. (Porges 1992, 498-504.)

3.1 Heart rate variability

Heart rate variability (HRV) is the temporal beat-to-beat variation in successive RR intervals on an electrocardiographic (ECG) recording, and it reflects the regulation of the heart rate (Nicolini, Ciulla, Asmundis, Magrini & Brugada 2012, 621-637). Although heart rate is relatively stable, there can be considerable differences in the time between two heart beats (Routledge et al. 2010). HRV is generally accepted as an estimate of the autonomic, especially parasympathetic, control of the heart. (Nicolini et al. 2012, 621-637.)

Heart rate is continuously modulated by different competing influences, which make HR dynamic and responsive. Heart rate variability describes these variations of both heart rate and R-R intervals. HRV is due to the interplay of the sympathetic and parasympathetic nervous systems, which cause that HR is responding to plenty of stimuli such as the actions of ventilation, blood pressure control, thermoregulation and the renin-angiotensin system. The sympathetic nervous system increases HR. The parasympathetic nervous system decreases HR. The regulation is neural but also hormonal. (Winsley 2002, 328-344.)

The parasympathetic impulses more rapidly affect HR than sympathetic impulse (1 s versus 25 s), and also an increase in HR after withdrawal of vagal tone occurs faster than a decrease in HR after sympathetic impulses are stopped (2-5 s versus over 25 s) (Winsley 2002, 328-344). The human heart and ANS respond to environmental stimulation, and HRV is affected by both psychological and physiological stimuli. Chronic emotional stress seems to have an impact on vagal modulation of the heart regardless of age, gender, respiration rate or cardiorespiratory fitness. HRV is normally high during rest, especially during the night when you are sleeping. The night sleep seems to be the most important period for health because this is when both physiological and psychological recovery happen. (Hynynen, Nummela, Rusko, Hämäläinen & Jylhä 2006.) In healthy individuals HRV increases during nighttime.

HRV normally decreases with age because of a decrease in autonomic modulation and a decrease in aerobic capacity (Hynynen et al. 2006). This reduction begins in childhood. Infants have high sympathetic activity that quickly decreases between 5 and 10 years of age (Acharya et al. 2006). There are also heritable factors that affect variations in HR and HRV. Gender differences have been found but they could potentially have to do with other factors related to gender. (Hynynen et al.2006.) HRV is an effective tool in detecting stress in working population and in athletes. It has classically been used to measure resting autonomic control. (Sandercock & Brodie 2006, 302-313.)

3.2 Autonomic regulation and stress

There are many different ways to define a stress. There also are various types of stress such as mental, physical and exercise-related overtraining stress. Many studies have demonstrated that increased heart rate, increased cortisol levels and increased salivary IgA levels are characteristic of an acute stress response, suggesting that stress affects autonomic cardiovascular, neuroendocrine and immune responses. (Benhamn 2007, Dickerson & Kemeny 2004.) Alterations in the autonomic nervous system functions are involved in the physiological expression of stress. The purpose of the autonomic nervous system is to maintain homeostasis and react to both internal and external demands. Homeostasis reflects the dynamic feedback and regulation processes of visceral functions to maintain internal states within a functional range, and is mainly regulated by PNS. From this point of view, stress can be defined as the autonomic state, when homeostasis is disrupted and internal needs are subjugated in response to external challenges. According to this model, the parasympathetic tone is depressed to respond to the external needs, and stress may occur. In addition, stress responses and stress vulnerability may be indexed even if there is no shift in the SNS tone. In addition, people, who have problems with homeostasis, may have the greatest stress vulnerability. (Porges 1992, 498-504.)

Heart rate variability as a non-invasive technique that can be used to study changes in autonomic nervous system activity (Hautala, Kiviniemi & Tulppo 2009, 107-115). Parasympathetic tone has been considered as a novel index of stress vulnerability and reactivity, thus an accurate monitoring of the PNS state will provide a mechanism to assess stress (Porges 1992). During acute stress, the parasympathetic modulation of HR is depressed and HR increases, but during chronic stress, vagal tone is tonically depressed. In turn, during recovery the parasympathetic tone is predominant, HR is slow and there is a high degree of HRV. The high degree of HRV illustrates the efficiency of neural feedback mechanisms, because the variability is a result of dynamic feedback mechanisms, which are controlled mainly by PSN. Furthermore, the higher the variance of HRV is, the better the body´s ability to react to external signals, and the more flexible is the behaviour. (Porges 1992, Porges 1995.) Low vagal tone is associated with high work stress and high emotional self-perceived stress (Vrijkotte, van Doornen & Geus 2000, 880-886).

4 Methods to analyse recovery

Different methods available for assessing recovery from training are presented in appendix 1. Basic problems related to most of the methods include insensitivity or invalidity for this purpose, high cost or time consuming measurement and/or analysis. For these reasons, these methods cannot be used frequently enough to support training and coaching optimally. (Firstbeat Technologies 2009.)

4.1 Definitions for stress and recovery

The analysis of stress and recovery is based on the detection of sympathovagal reactivity of the heart that exceeds momentary metabolic requirements of the autonomic nervous system. Stress state is defined as increased activation in the body, induced by external and/or internal stress factors, during which sympathetic nervous system activity is increased and parasympathetic (vagal) activity is decreased (= sympathetic tone). In the described recovery analysis, stress is detected when heart rate is elevated and HRV is reduced and there are inconsistencies in the frequency distribution of HRV due to changes in respiratory period. (Firstbeat Technologies 2009.)

Recovery is defined as decreased activation in the body during relaxation, rest and/or peaceful working, related to lack of external and internal stress factors when parasympathetic (vagal) activity is great and sympathetic activity is low. Recovery is detected when HR is close to the resting level and HRV is great and regular according to the breathing rhythm. Figure 1 presents an example of the detection of stress and recovery during sleep. (Firstbeat Technologies 2009.)

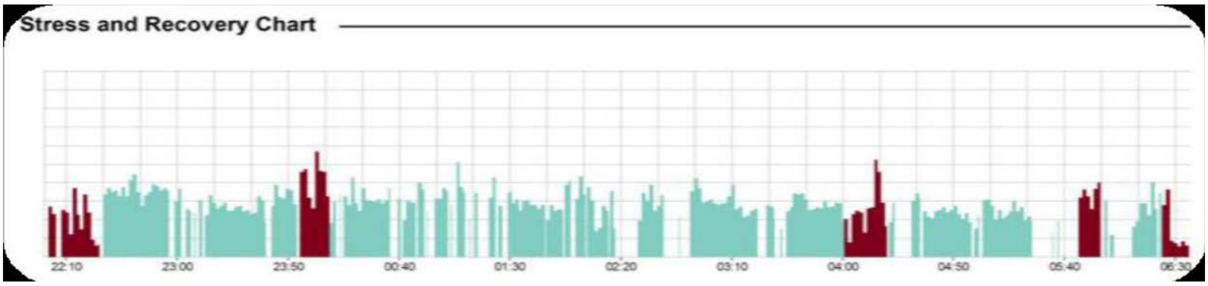

Figure 1. Example of stress (red) and recovery (green) detection during sleep (included in Firstbeat SPORTS and HEALTH softwares).

4.2 Heart rate variability based recovery analysis method

The heart rate variability based recovery analysis method has been designed to sensitively measure athletes' stress and recovery. The method is based on measurement of heart rate variability, which has been proven to be a valid measure for this purpose. (Uusitalo 2000, 4045-4050.) The method can be used to assess athletes' recovery and daily stress round the clock.

4.2.1 Recovery analysis during sleep

Recovery analysis is performed with data collected during night sleep to get the most accurate results. During sleep, all confounding factors are minimized, and the level of ANS activity is most reliably recognized. The recommended 4-hour window for determining the recovery index is set to start 30 minutes after going to bed. When used during the first four sleeping hours, Heart rate based recovery analysis was found to be the most sensitive recovery analysis method. Night time measurement is recommended if one wants to have the most accurate and reliable follow-up method to monitor athletes' recovery. (Hynynen et al. 2006.)

4.2.2 Validation of the method

The described method has been validated in a study including hospital employees (Rusko et al. 2006) as subjects. This study aimed to investigate whether stress and recovery states can be determined from HR and HRV. It was found that temporal percentages of stress and recovery were valid measures for employees' physiological resources. In another study including professional athletes (Hynynen et al. 2006) the aim was to investigate the effects of training on nocturnal cardiac autonomic modulation using new methods of heart rate variability analysis. The measures used were derivative from the present athlete recovery analysis method. It was concluded that the intensity of stress and recovery were the most valid measures to describe athletes' recovery status in all conditions when compared to the use of heart rate or high-frequency or low-frequency of heart rate variability.

5 Sleep as restitution

Sleep is considered a state, in which consciousness is reduced and movements of skeletal muscle and metabolism are decreased. Sleep is an important part of our lives: humans have a tendency to sleep about 7-8 hours per day (Zisapel 2007, 1174-1186). Although there is no clear consensus as to why humans sleep and why humans require sleep. According to the recent research results, there are different theories about importance of sleep. The first theory emphasizes that the abnormal regulation of metabolic processes is due to sleep deficit, and that is why sleep is essential in reducing energy demand and refreshing function of the immune and endocrine systems. (Halson 2008, 119-126; Mignot 2008, 0661-0669.)

During sleep, however, brain energy expenditure declines, and energy is saved for other processes. This model cannot explain the increase in energy expenditure during rapid eye movement sleep. (Mignot 2008, 0661-0669.)

The second model highlights that sleep is necessary for learning, memory and synaptic plasticity: during sleep synaptic downscaling occurs, which eliminates unnecessary connections and leaves only the strongest connections intact. Then, energy and space requirements are reduced, which provides the possibility to maintain crucial learned circuits. (Mignot 2008, 0661-0669.)

5.1 Sleep stages

Sleep can be divided in different stages in which physiological processes in the body are different according to each stage. Mainly sleep is divided in two basic stages: non-rapid eye movement (non-REM) sleep and rapid eye movement (REM) sleep. (Savis 1994, 111-125.)

Human sleep consists of 5-6 cycles of 90 minutes. During the first 90-min periods the portion of non-REM sleep is longer and during the last 90-min periods the portion of REM sleep is higher. (Zisapel 2007, 1174-1186.)

5.1.1 Non-REM sleep

Non-REM sleep is characterized by slow electrical fluctuations in the brain (Zisapel 2007, 1174-1186) and the frequency of fluctuations can be used to indicate sleep intensity or depth. Non-REM sleep can be subdivided in four stages: S1, S2, S3 and S4. During S1, the transition from wakefulness to sleep occurs, and respiration deepens, responsiveness to outside stimuli reduces, thoughts are drifting (Savis 1994), muscle activity is still quite high, and there may be some eye movements. The brain waves decelerate to 6-8 Hz and have low amplitude (Åkersted & Nilsson 2003, 6-12). In healthy sleepers, stage 1 is usually short, lasting for only few minutes.

In the second stage muscle tonus declines and cognitive processes are short and fragmented. About 50 % of total sleep time is spent at this stage, and it lasts 30 minutes in healthy sleepers. This stage does not have great functional importance, but it provides basic recovery. (Savis 1994, 111-125; Åkersted & Nilsson 2003, 6-12.)

Stages 3 and 4 are called as delta sleep, because the physiological processes in these stages are very similar. Delta sleep is the deepest stage of sleep and about 15-20 % of total sleep time is spent at this stage. (Savis 1994, 111-125.) This stage is considered to be essential for body restitution: growth hormone secretion and cell division peak and cortisol secretion suppresses during delta sleep (Savis 1994, 111-125; Åkersted & Nilsson 2003, 6-12). Metabolism declines while breathing, heart rate and cerebral blood flow slow down (Åkersted & Nilsson 2003, 6-12).

5.1.2 REM sleep

REM sleep differs a lot from non-REM sleep. Eye movements and dreams are typical in REM sleep, as is a virtual absence of muscle tonus in antigravity muscles. An awake brain is typical in REM sleep. Increased cerebral blood flow, brain temperature and brain protein synthesis are also associated with the awake brain. In addition, heart rate, respiratory rate, blood pressure and body temperature are almost the same as during wakefulness. (Savis 1994, 111-125.) REM sleep is associated with learning, memory and synaptic plasticity, and 20-25 % of total sleep time is spent in this sleep stage.

5.2 Stress and sleep

During normal sleep, HR and blood pressure decline, this is modulated by the ANS. During non-REM sleep, the PNS dominates, and the shift from sympathetic dominance to parasympathetic dominance appears to be mainly caused by changes in the PNS activity. Autonomic balance during REM sleep is quite similar to wakefulness. (Trinder et al. 2001, 253-264.) However, acute stress affects the autonomic modulation of sleep: parasympathetic modulation is decreased during non-REM and REM sleep, and sympathetic activity is increased during non-REM sleep (Hall et al 2004, 56-62). Also Brosschot, Van Dijk & Thayer (2007, 39) demonstrated that during stress and prolonged worrying, HR is increased and HRV is decreased during sleep. Decreased parasympathetic tone and increased sympathetic tone is associated with poorer sleep maintenance and lower delta activity, as well as, longer sleep onset time, and therefore, decreased parasympathetic activity disturbs sleep and may induce insomnia (Hall et al. 2004, 56-62). Disrupted sleep is associated with poorer restitution and recovery, because sleep is the most important restorative period in healthy people (Brosschot et al. 2007, 39).

6 Methods

6.1 Purpose of the study

The Finnish hockey team Jokerit participated Kontinental Hockey League (KHL) first time on the season 2014-2015. The biggest difference of the KHL compared to national leagues is travelling and the long distances between cities. The playing program of the Kontinental Hockey League is based on longer road trips as a guest team and also fewer home games in a row. Usually one road trip includes three or four games in a row. The team plays every second day and travels after the game to the next city by a plane. Jokerit is travelling inside 4 hour time zone. Normally after the visiting games the team has three or four home games. The objective of this research is to produce new information about stress and recovery of the players in Kontinental Hockey League. The physical stress is bigger than in national leagues during the season, because of the long travels and different playing schedule. That's why recovery has an important role during the season.

1. The main aim of this study is to get more information from the recovery of the players during the playing season. How to build practise and travel schedule of the team, so that there is enough time for recovering and the player's energy level would be optimal for the games?

2. Another objective is to find out the individual differences of the stress and recovery of the players, when the program is the same for all. How does the same program effect to the different players?

6.2 Subjects

The players used in the study were professional ice hockey players of Finnish club team (Jokerit, Helsinki) playing in the Kontinental Hockey League (KHL). Thirty-one (31) players of the team with an average age of 29 years participated in this study. Backround information of the subjects is presented in table 2.

Table 2. Subjects personal details

	Average	Maximum	Minium
Age (years)	29,32	36,0	20,0
Height (cm)	185,42	191,0	179,0
Body mass (kg)	91,24 kg	97,5	82,0
Fat (%)	12,94	14,8	9,9
VO_2max (ml/kg/min)	53,86	63,2	48,2

6.3 Procedure

In the present study, the autonomic regulation of HRV were measured during the season in 12 different periods lasting 2-6 days. This study focuses on the assessment and follow-up of recovery. That is why the measurements we recorded round the clock - 24 hours, but not during exercises and games. The first measurements were done for all players in the beginning of the season before hard training and playing period. The purpose of the first measurement was to get reference values in well recovered situation. It is difficult to detect inadequate recovery in later measurements if there is no reference level. Analysis in Firstbeat SPORTS automatically scales the recovery index according to the measured and analysed data. During the pre-season we had three different groups and every group included nine or ten players. Three measurements we made between 14.8-30.8 2014. Data was recorded during three or four days and each measurement included one practice day, game day and free day.

In regular season we had nine different measurement sessions. Each group included 4-9 players. Road trips were measured in 7 different sessions between 12.9.2014-3.2.2015. During the home period we had two measurement sessions. These measurements were made between 17.11-2.12.2014. The measurement schedule can be found from Figure 2.

Practice games:	Regular season: (Away)	Regular season: (Home)
• 14.8-18.8 (Home) – 9 players	12.9-16.9 (Away) Trip 1: First measument – 4 Players	17.11-19.11 (Home 1) – 8 Players
Practice-game-game-rest	Practice- game- travel –practice-game-travel	Rest- practice- practice
• 19.8-23.8 (Home) – 10 players	16.9-20.9 (Away) Trip 1: Second measurement – 5 Players	30.11-2.12 (Home 2) – 4 Players
Game-practice-game-practice	Practice- game- travel –practice-game-travel	Game- game- practice
• 26.8-30.8 (Away) – 9 Players	10.10-13.10 (Away) Trip 2 – 7 Players	
Practice- travel- practice- game –game- travel- rest	Game- travel– practice- game- travel- rest	
	26.10-29.10 (Away) Trip 3: First measurement – 8 Players	
	Travel- game- practice- game	
	31.10-2.11 (Away) Trip 3: Second measurement– 6 Players	
	Game- travel- practice- game	
	11.12-13.12 (Away) Trip 4 – 4 Players	
	Game- travel- practice- game- travel	
	3.2-6.2.2015 (Away) Trip 5 – 5 Players	
	Travel- game- rest- travel- practice- game - rest	

Figure 2. Measurement schedule

6.4 Measurement of stress and recovery

In the present study, the aim was to monitor stress and recovery of the players during different practicing and playing periods of 2-6 days. The autonomic regulation of HRV was measured by using Firstbeat Sport and Firstbeat Life Assessment methods. Both tools are based on a computer program that analyses beat-by-beat heart rate and heart rate variability to provide information about different aspects of stress and recovery.

6.4.1 Data acquisition

R-to-R interval were acquired with the Firstbeat Body guard 2 (BG2) wearable heart rate monitor on 1ms resolution. Firstbeat BG2 is a beat-to-beat heart rate monitoring device, which is targeted for long-term monitoring of heart rate variability (HRV) and physical activity. Device records Electrocardiography with electrodes, processes the signal with an integrated algorithm and provides beat-to-beat R-to-R interval (RRI) as an output with 1ms resolution. The BG2 and disposable electrodes were set up on a subject's body according to the instructions in the user manual. The disposable electrodes and cables were fastened with medical tape to decrease the level of possible motion artifacts.

6.4.2 Heart rate variability analysis

Firstbeat HEALTH (version 3.0.1.0, Firstbeat Technologies Ltd, Jyväskylä, Finland) and Firstbeat SPORT computer software application were used to analyse the provided data. The software analyses different HRV parameters, but also physiological variables describing stress and recovery. From traditional HRV parameters, which the software calculates, HR, root mean square of successive RRIs (RMSSD), high frequency power (HFP, 0.15–0.40 Hz), low frequency power (LFP 0.04–0.15 Hz), and total power (TP, 0.04–0.40 Hz) were chosen for this study.

Figure 3 shows how stress and recovery are illustrated in the results. These reactions are shown as various coloured graphs (physiological states).

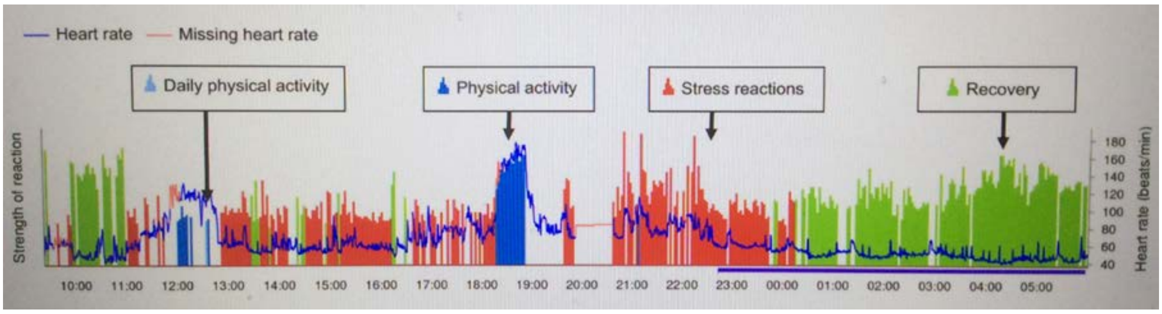

Figure 3. Stress and recovery chart and explanations of the colors. In addition to stress, recovery and physical activity, the chart shows work and sleep periods drawn from the person’s journal. The height of the bar indicates the strength of the stress or recovery reaction. Comparing the strength of stress and recovery reactions between different measurements or different people based on the height of the coloured bars is not purposeful.

In addition, the method can assess the balance between stress and recovery by taking into account the strength of the reactions and duration of the states when producing an estimate of whether the body’s resources have accumulated or been consumed during the measured period (see Figure 4).

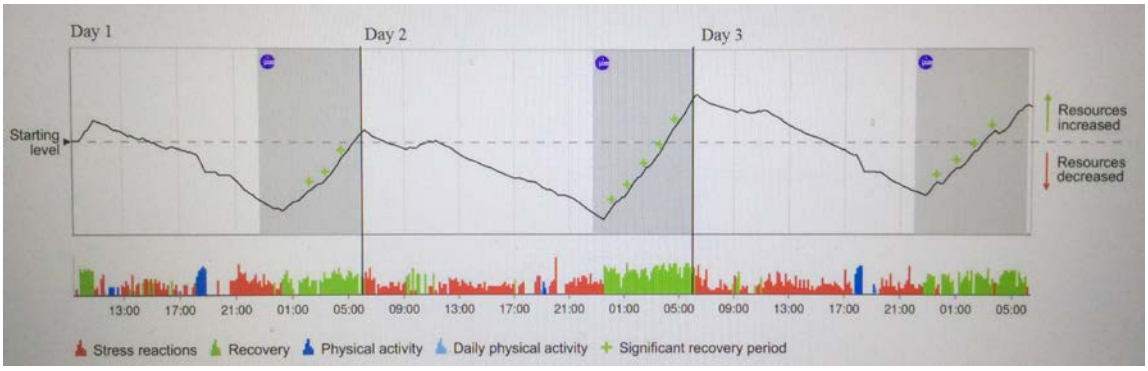

Figure 4. Body resources accumulate during recovery periods and decrease during stress reactions. Grey areas in the chart indicate sleeping periods.

7 Results

During the KHL 2014-2015 Jokerit played 60 regular season games and had 12 measurement periods. Each period included 4-8 players and lasted 1-4 days. There were 78 stress and recovery analysis done during the season.

Reference measurements were done in the summer before hard training periods. Resting heart rate was one of the variables we used while measuring recovery (Figure 5). We compared night heart rate of different periods to the resting heart rate.

	Firstbeat	14-18.8	19-23.8	26-30.8	12-16.9	16-20.9	10-13.10	26-29.10	31-2.11	17-19.11	30-2.12	11-13.12	3.2.2015	Resting heart rate
Player 1			xxxxxxxxx	xxxxxxxxx		xxxxxxxxx								42
Player 2			xxxxxxxxx					xxxxxxxxx					xxxxxxxxx	45
Player 3				xxxxxxxxx			xxxxxxxxx							37
Player 4		xxxxxxxxx				xxxxxxxxx					xxxxxxxxx		xxxxxxxxx	38
Player 5		xxxxxxxxx			xxxxxxxxx					xxxxxxxxx				35
Player 6			xxxxxxxxx					xxxxxxxxx						32
Player 7			xxxxxxxxx				xxxxxxxxx							35
Player 8				xxxxxxxxx	xxxxxxxxx					xxxxxxxxx				39
Player 9		xxxxxxxxx					xxxxxxxxx							38
Player 10							xxxxxxxxx		xxxxxxxxx	xxxxxxxxx				35
Player 11			xxxxxxxxx					xxxxxxxxx						50
Player 12														
Player 13		xxxxxxxxx					xxxxxxxxx		xxxxxxxxx		xxxxxxxxx			43
Player 14				xxxxxxxxx						xxxxxxxxx				38
Player 15			xxxxxxxxx			xxxxxxxxx			xxxxxxxxx	xxxxxxxxx				40
Player 16			xxxxxxxxx					xxxxxxxxx						39
Player 17		xxxxxxxxx			xxxxxxxxx			xxxxxxxxx						35
Player 18		xxxxxxxxx	xxxxxxxxx		xxxxxxxxx			xxxxxxxxx						30
Player 19			xxxxxxxxx				xxxxxxxxx					xxxxxxxxx	xxxxxxxxx	37
Player 20												xxxxxxxxx		38
Player 21				xxxxxxxxx		xxxxxxxxx			xxxxxxxxx	xxxxxxxxx		xxxxxxxxx	xxxxxxxxx	42
Player 22				xxxxxxxxx					xxxxxxxxx	xxxxxxxxx				37
Player 23		xxxxxxxxx									xxxxxxxxx	xxxxxxxxx		38
Player 24				xxxxxxxxx			xxxxxxxxx		xxxxxxxxx	xxxxxxxxx				37
Player 25		xxxxxxxxx												
Player 26		xxxxxxxxx												34
Player 27														
Player 28				xxxxxxxxx		xxxxxxxxx								40
Player 29				xxxxxxxxx				xxxxxxxxx					xxxxxxxxx	42
Player 30											xxxxxxxxx			38
Player 31			xxxxxxxxx					xxxxxxxxx						42

Figure 5. All measurement periods of the present study and participation of the players. In the last row there are the resting heart rates of all participated players.

As a reference game, we had a practice game against Brynäs at home on 21.8. The Game ended at 21.00 and the average time players started to recover was 5 hours and 5 minutes (at 02.05). The duration of the night recovery was on average 6 hours. (Figure 6).

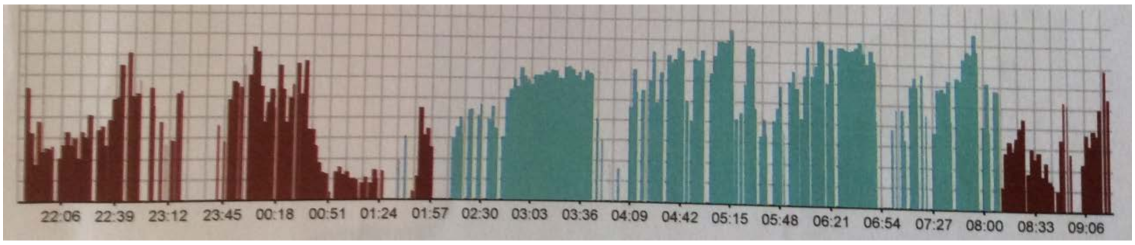

Figure 6. The stress and recovery curve of the player 15 after the practice game on 21.8. represents the average recovery result.

The fastest recovery started 3 hours 30 minutes (at 00.30) and the slowest 6 hours (at 03.00) after the game. The Longest night recovery was 8 hours and the shortest was 4 hours 30 minutes (Figure 7).

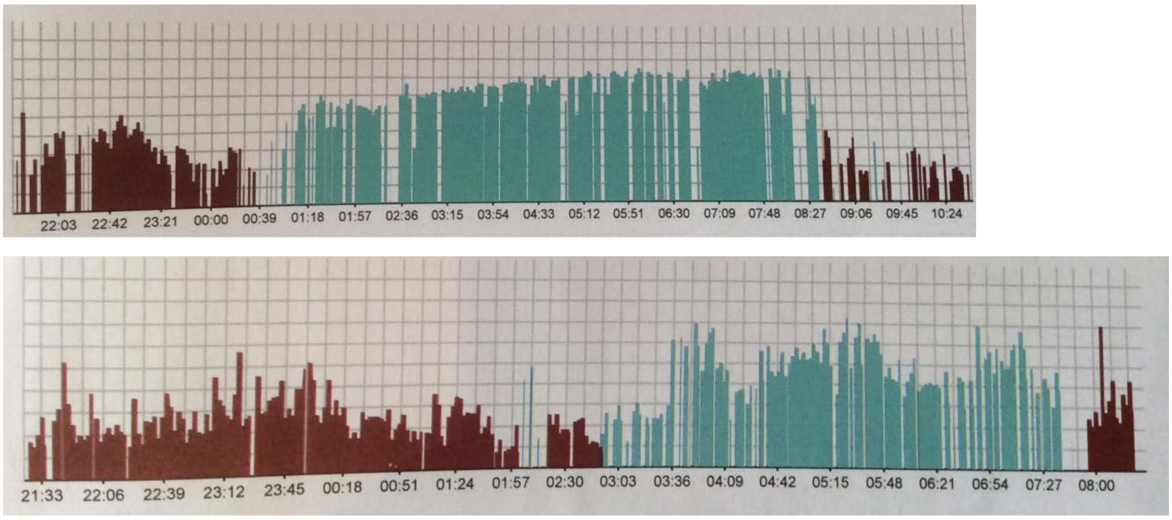

Figure 7. The upper curve shows the good night recovery of the player 6 and lower curve the poor recovery of the player 7 after the practice game.

7.1 The night recovery after the game

According to all measurement periods the average time when recovery started, was 7 hours and 42 minutes after the ended game. The average duration of the night recovery was 5 hours and 33 minutes. In the home games recovery started after 6 hours and 20 minutes and duration of the night recovery was 5 hours and 20 minutes. On the road trip the night recovery started on average 9 hours and 15 minutes after the game, and the duration of the night recovery was on average 5 hours and 10 minutes in all measurements (Table 3). On all road trips the team lived all the time in Finnish time zone.

Table. 3. Shows on average starting time and duration of the night recovery according to all measurements of the present study.

	Recovery starts:	Recovery duration:
Practice games	5 hours 36 minutes	6 hours 51 minutes
Home games	6 hours 20 minutes	5 hours 20 minutes
Away games	9 hours 15 minutes	5 hours 10 minutes
All games	7 hours 42 minutes	5 hours 33 minutes

7.2 The recovery during road trips

7.2.1 Two away games in three days

The away game SKA-Jokerit was played on Friday 10.10. The game ended at 21.00 and the recovery was measured by seven players. After the game the team arrived to the next city, Bratislava in Slovakia on Saturday at 02.35. An average time when the players started to recover after the game, was 10 hours 30 minutes. The fastest recovery started 8 hours 30 minutes (at 05.30) and slowest 14 hours 30 minutes (at 11.30) after the game. The duration of the night recovery was on average 4 hours. The longest recovery was 9 hours and the poorest didn’t recover at all during the night (Figure 8).

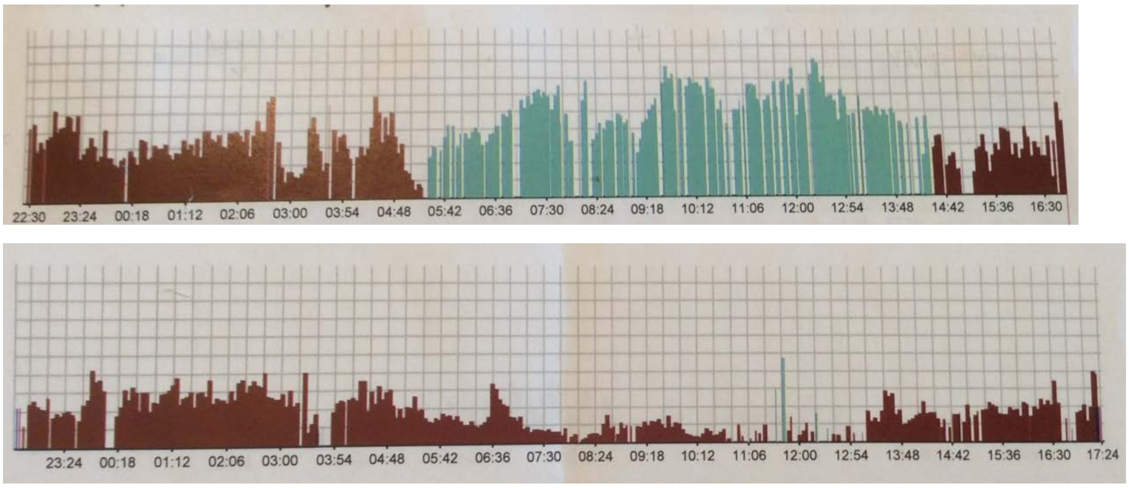

Figure 8. The upper curve shows the well recovered (Player 10) and lower curve the poor recovered (Player 19) example of the night recovery after the game SKA-Jokerit

On the next day the team practiced at 17.00 in Bratislava. The duration of night recovery after practice day was on average 5 hours 55 minutes. Player 13 didn't have any recovery during the night and Player 10 had 9 hour recovery.

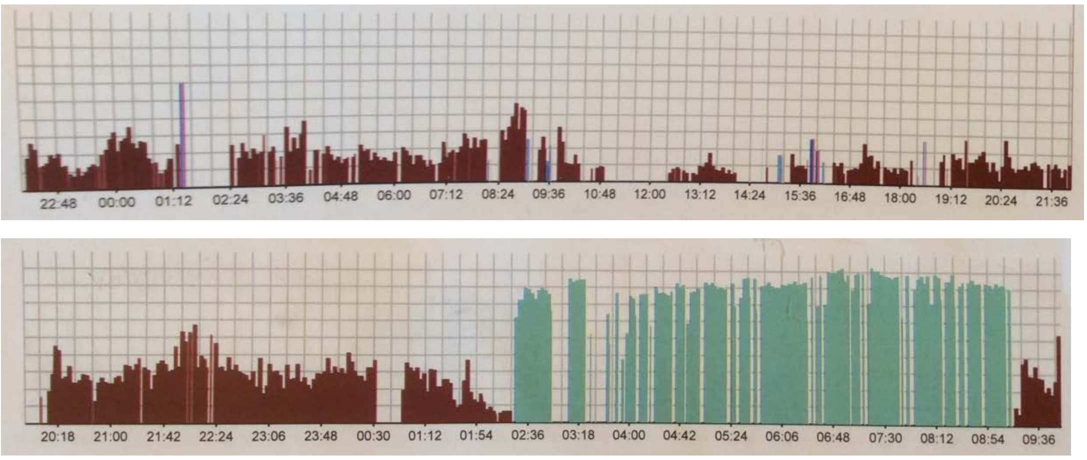

Figure 9. The night recovery of the Player 13 (upper) and Player 10 (lower) after the practice day.

The away game Slovan-Jokerit was played on Sunday 12.10. The game ended at 20.30 and the team arrived back in Finland at 01.00. An average time when players started to recover, was 7 hours 15 minutes from the end of the game. The fastest recovery started 6 hours (at 02.30) and the slowest 9 hours 30 minutes (at 06.00) after the game (Figure 10). The duration of the night recovery was on average 6 hours 5 minutes (the shortest 3 hours and the longest 9 hours). On the next day the team didn't have a practice or other team meetings.

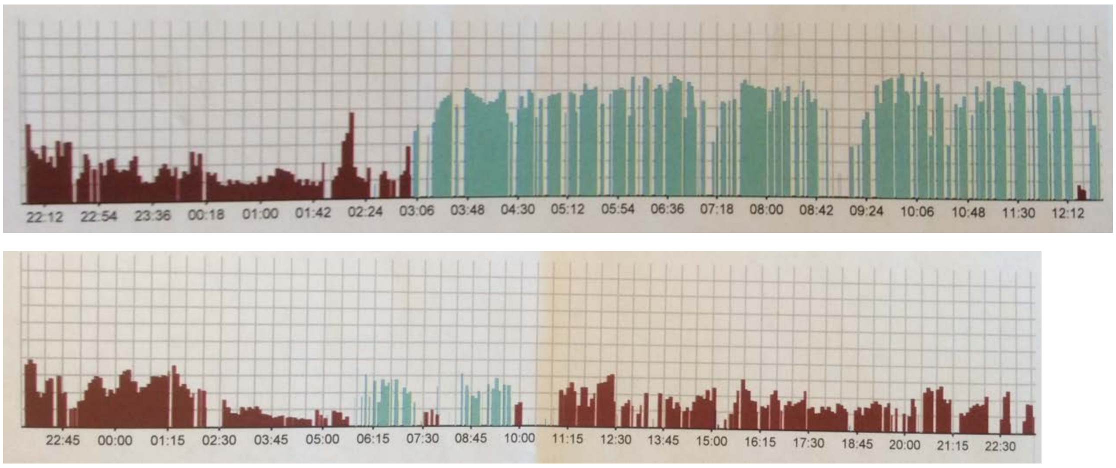

Figure 10. The upper curve shows the well recovered (Player 3) and lower curve the poor recovered (Player 19) example of the night recovery after the game and flight to Finland.

7.2.2 Two away games in four day

Before the road trip the team practiced at Hartwall arena in Helsinki. Flight to Moscow started at 15.00 after the practice and we arrived to the hotel at 19.30. The duration of the night recovery after the travel day was on average 6 hours 40 minutes. The shortest recovery was 4 hours and the longest 10 hours (Figure 11). Recovery was measured by eight players.

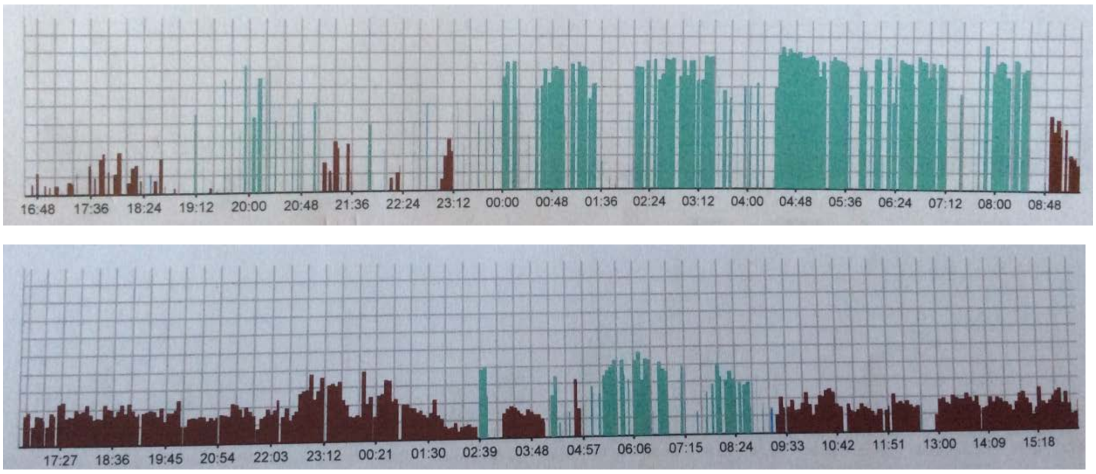

Figure 11. The upper curve shows the good night recovery of the Player 18 and lower curve the poor recovery of the Player 11 after the travel day.

The away game Vitjaz-Jokerit was played on Monday 27.10. The game ended at 21.00 and the team arrived to the next place, Yaroslav at 01.25. An average time when players started to recover, was 10 hours 15 minutes. The fastest recovery started 7 hours (at 02.30) and the slowest 14 hours 30 minutes (at 11.30) after the game. The duration of the night recovery was on average 3 hours 15 minutes. The shortest recovery was 1 hour and the longest 6 hours 30 minutes (Figure 12).

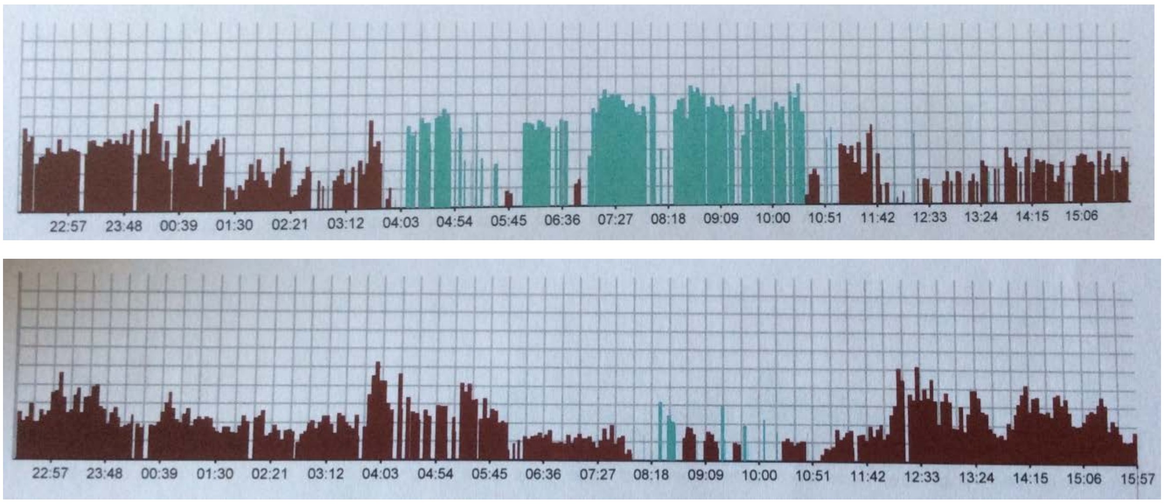

Figure 12. The upper curve shows the good night recovery of the Player 6 and lower curve the poor recovery of the Player 29 after the away game Vitjaz-Jokerit.

On the next day the team had practice at 16.00 in Yaroslav. The duration of night recovery after practice day was on average 7 hours. The shortest recovery was 2 hours and the longest was 9 hours (Figure 13).

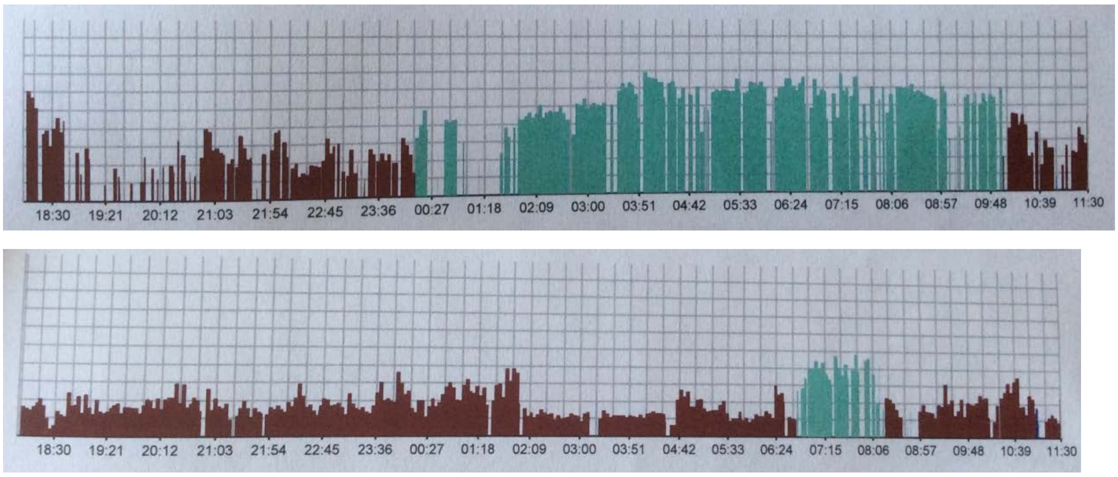

Figure 13.The good night recovery of the Player 6 (upper) and the poor recovery of the Player 11 (lower) after practice day in Yaroslav.

The away game Lokomotiv-Jokerit was played on Wednesday 29.10. Game ended at 20.30 and the team arrived to the next place, Sotshi at 01.40. After the game an average time when players started to recover, was 3 hours. Player 11 didn't recover during the night and Player 18 started to recover 9 hours (at 05.30) after the game. The duration of the night recovery was on average 3 hours. The longest recovery was 6 hours 30 minutes (Figure 14).

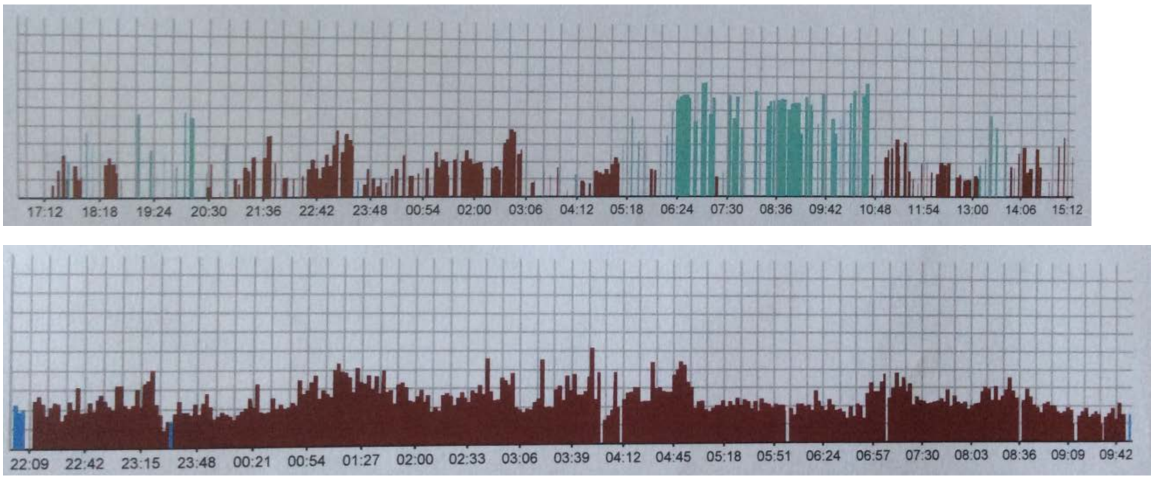

Figure 14. The upper curve shows the good night recovery of the Player 18 and lower curve the poor recovery of the Player 11 after the game and travel.

7.3 The night recovery during the home period

7.3.1 One home game and two preparing days

The home game Jokerit-Slovan was played on Sunday at 16.11. The recovery was measured by 6 players. After the game an average time when the players started to recover, was 5 hours 25 minutes. The fastest recovery started 3 hours (at 24.00) and the slowest 8 hours (at 05.30) after the game (Figure 15). The duration of the night recovery was on average 7 hours 10 minutes (the shortest 5 hours and the longest 9 hours). Next morning ice practice was optional for the players.

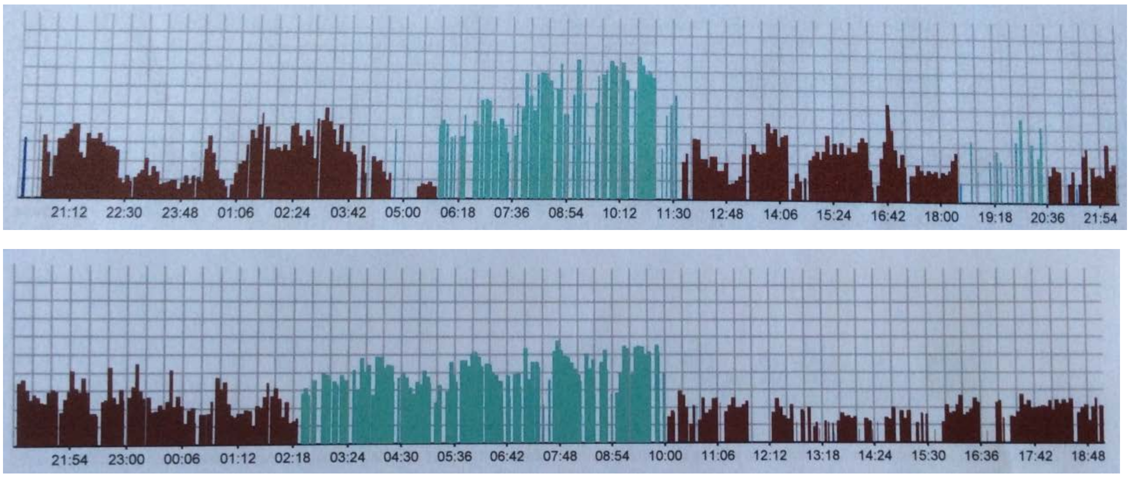

Figure 15. The upper curve shows the poor recovered and lower curve the well recovered example of the night recovery after the home game Jokerit-Bratislava.

Next day was free day. The duration of night recovery after free day was on average 8 hours. The shortest recovery was 4 hours and the longest was 10 hours (Figure 16).

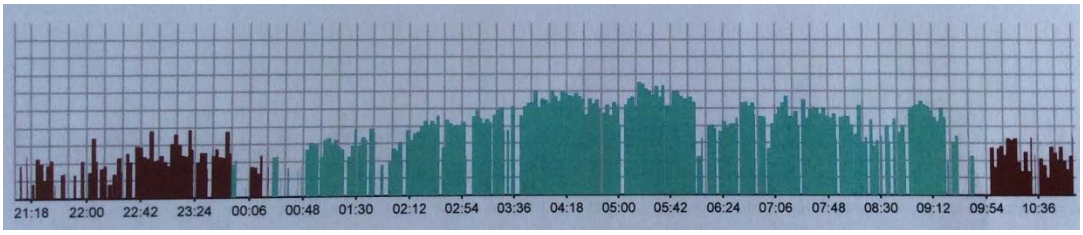

Figure 16. The example of the good night recovery (Player 5) after the free day.

On the second preparing day the team had ice practice at 11.00. The duration of night recovery after the second practice day was on average 7 hours 45 minutes. The shortest recovery was 4 hours and the longest was 8 hours 30 minutes (Figure 17).

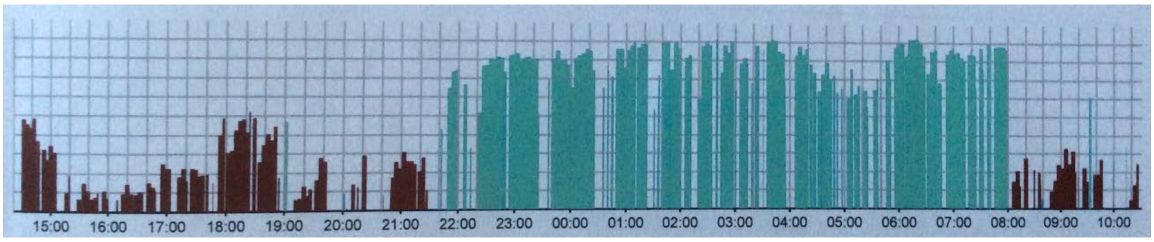

Figure 17. The example of the good night recovery (Player 22) after the practice day.

7.4 Individual differences of the recovery

7.4.1 Two home games in the row and day off

The home game Jokerit–Amur was played on Sunday 30.11. at 16.00. The recovery was measured by four players. After the game an average time when the players started to recover, was 8 hours. The fastest recovery started 2 hours (at 21.00) and the slowest 12 hours (at 06.00) after the game (Figure 18). The duration of the night recovery was on average 4 hours 35 minutes (the shortest 20 min and the longest 10 hours). The morning skate for the game of next day started at 11.00 a clock.

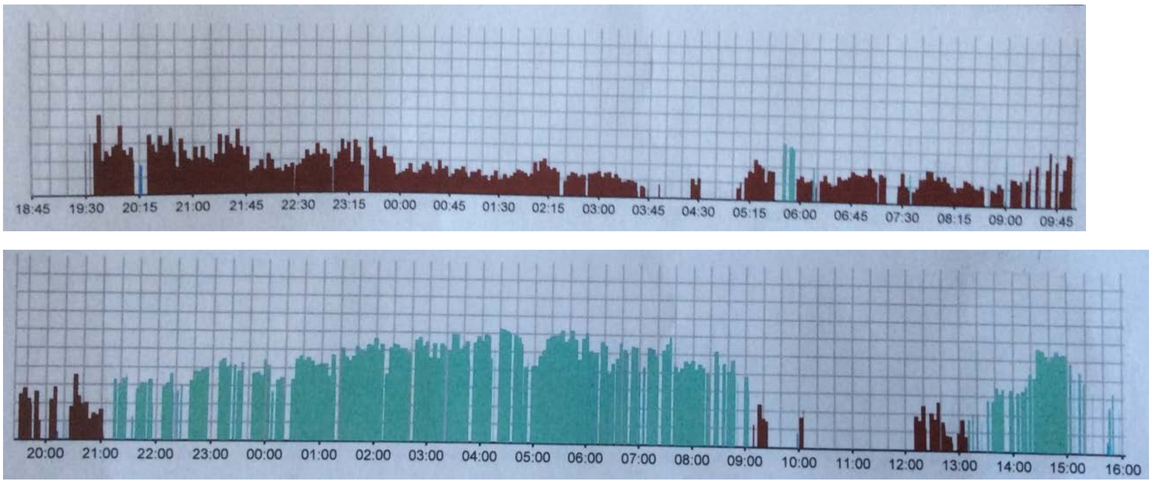

Figure 18. The individual differences of two players in night recovery (green coloured bar) after the home game on Sunday at 16.00. The upper curve shows the poor recovered and lower curve the well recovered example of the night recovery after the game.

The resting heart rate of the Player 4 is 38 in the upper curve of the figure 7. His lowest heart rate during this night was 50 b/min. The well-recovered Player 30 (resting heart rate 38) in the lower curve reached 40 b/min level.

After the second game of the next day (Jokerit-Kazan on Monday at 18.30) the average time when recovery starts, was 5 hours 45 minutes (about at 2.30). The fastest recovery started 2,5 hours and the slowest 8 hours after the game. The shortest duration of the night recovery was 30 minutes and the longest 9 hours (figure 19). The resting heart rate of the Player 4 is 38 in the upper bar of the picture. His lowest heart rate during this night was 48 b/min. In the lower bar the lowest heart rate of the Player 30 (resting heart rate 38) was 40.

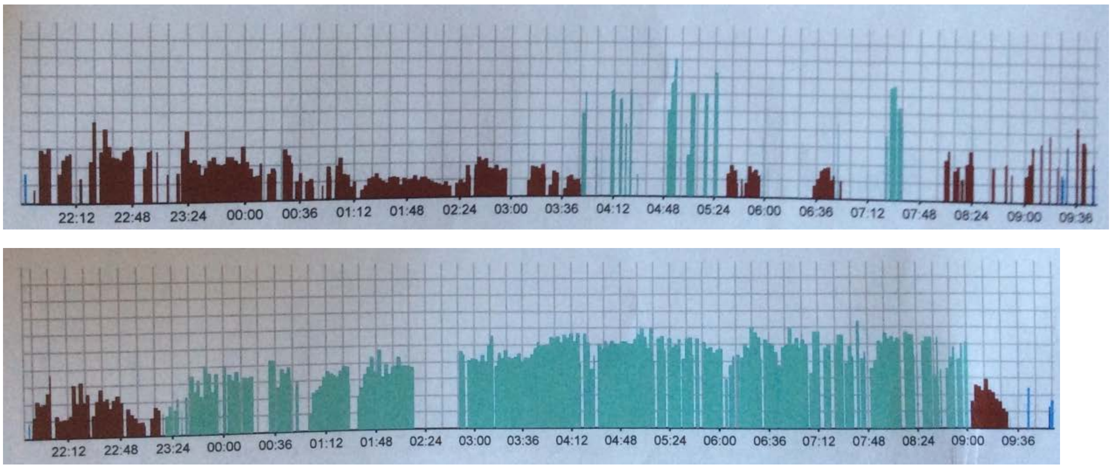

Figure 19. The individual differences of two players in night recovery after the second game on Monday at 18.30 The upper curve shows the poor recovered and lower curve the well recovered example of the night recovery after the second game.

The average night duration after following free day was 8 hours 20 minutes (shortest 3 h 30 min and the longest 11 h 30 min).

7.4.2 Heart rate variability as estimation of recovery

The figure 20 shows the good example of well recovered Player 18 one night before the game (26.10. Vitjaz-Jokerit). Under the stress and recovery chart is a heart rate variable (HRV) curve of the comparable period. The heart rate variability is high, on average 130-240 RMSSD, when the player recovers well.

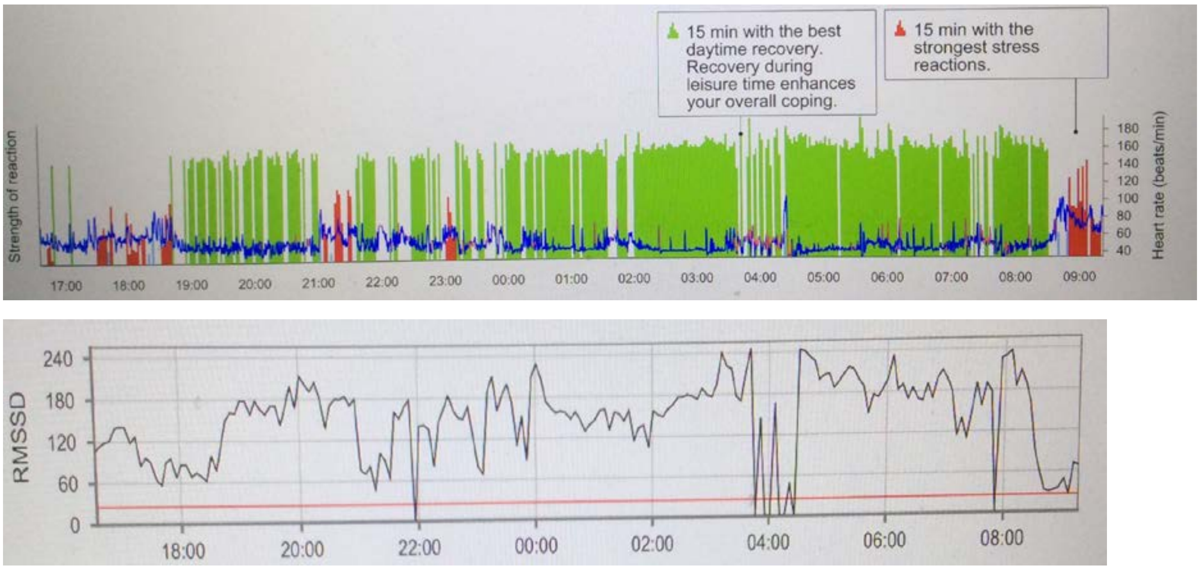

Figure 20. The stress and recovery chart as well as under that the comparable HRV-curve of the Player 18, when the recovery is good.

When recovering is poor, the HRV-level decreases (on average 90-160 RMSSD), as we see in the figure 21.

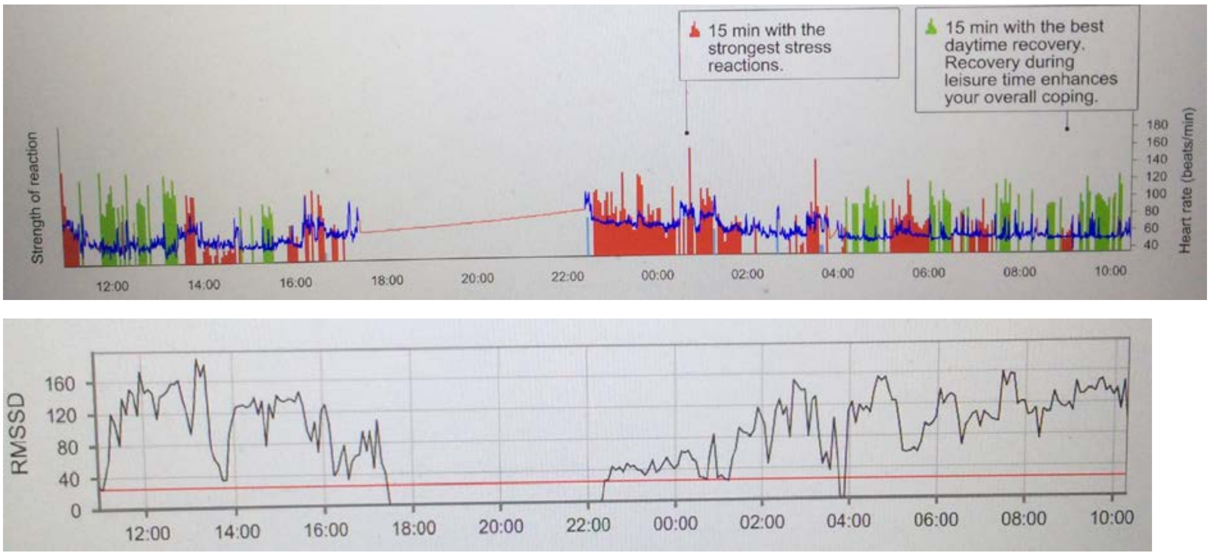

Figure 21. The stress and recovery chart as well as under that the comparable HRV-curve of the Player 18, when the recovery is poor. No measurements were done during the game at 18.00-22.00.

7.4.3 Accumulation of the body resources

Recovering during the day and night estimates whether the body's resources have accumulated or been consumed during the measured period. In the figure 22 we see body resource accumulation of the same Player 18 during the same measurement period. The nights before the games (26. and 28. 10.) The player recovers well and accumulates resources. Instead of the nights after the games (27. and 29.10) recovering is poor and consumes body resources.

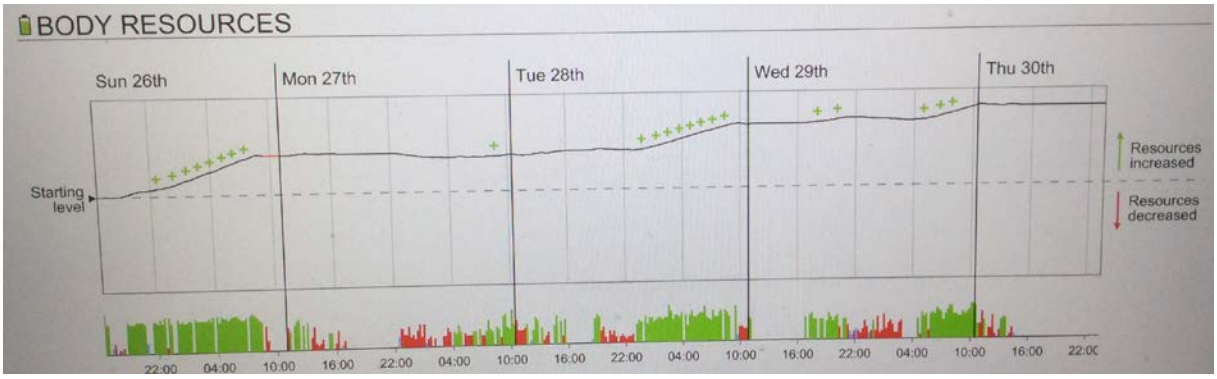

Figure 22. Body resources of the Player 18 accumulates before the games (26. and 28. 10) and decreases or stays on the same level after the games (27. and 29.10.)

8 Discussion

8.1 An athlete 24/7

There are a lot of research and information about physical stress in different exercises and competition situations. We know quite exact how different exercises and competitions influence to body functions. It has been noticed that exercise has a key role in improving athletes in professional sport. In addition to high training and playing load, also recovery plays an important role in athletic life.

In team sports and professional leagues the game schedule gives a structure for planning the athletic program of the team. The amount of games has increased all the time. Games and travelling also are activities, which consume most energy of the athlete. The competition on the international level has come harder and harder every year. It is not anymore enough to practice and compete well, it is more and more important, how athletes spend the time between physical activities. A player has to be an athlete 24 hours in a day and 7 days in a week.

But there is not so much information about recovery in professional sport. The main focus of this study was to provide new information from the recovery of the players during the playing season in Kontinental Hockey League. And still from a practical point of view, so that this study provides new information for coaches and players for planning athletic programs of the teams during the playing season.

8.2 The night recovery after the games

The first interesting result of this study was how long it took before a player started to recover after the game. The average time after the ended game, when recovery started, was 7 hours and 42 minutes. It means that if a game starts at 18.30, recovery starts on average about at 04.00 in the morning. In KHL teams fly to the next place after games. It delays the starting of recovery. According to this study recovery started on average 9 hours 15 minutes after the road games.

The second interesting finding was duration of the night recovery after the games. The average length of the night recovery was 5 hours and 33 minutes. And there weren't big differences between home and away games. Of course it depends on next day program how long players are able to rest. It shows at the present results that the night recovery and the schedule of the next morning and day are the decisive factors to maintain the balance between stress and recovery. In KHL the teams normally play every second day 3 or 4 games in the row. On the road trips they fly after the game to the next playing place. It is very important to maintain the balance between stress and recovery as well as good performance state during this kind of periods and the whole season.

Jokerit utilized this information during the season by changing totally programming between the games. The first change was to give more time for recovery. The team didn't have the common morning practice and players got chance to sleep longer in the morning. And depending on the playing time of the next day game, the team practiced between games only once, either on afternoon or in the morning of the next game day. The purpose was to give more time to recover after the game but also to confirm that the players can compensate the poor recovery after the game on the good recovery of the next day and night. On all road trips the team lived all the time in Finnish time zone.

The body resource curve describes well the importance to utilize the free day and next night for good recovering. Recovering during the next day and night after the game day defines whether the body's resources have accumulated or been consumed during the measured period. According to the present findings the game and the night after the game consumes energy and correspondingly the next day and night before the new game has to use to fulfill the energy resources.

In precise and effective training and playing management, player and coaches should assess the load and effectiveness of different playing sessions, but especially recovery from these sessions. There has to be a good balance between stress and recovery. When a hard playing period that causes a significant disturbance in body's homeostasis is followed by sufficient recovery, an athlete is able to maintain a good performance state. The importance of sufficient recovery is due to the fact that performance improvements actually occur during recovery, not during workouts. Finding a balance between playing load and recovery is a key factor to maintain good athletic performance.

8.3 Differences of night recovery on away and home playing periods

A major challenge in professional leagues is how to optimize playing and recovery for all team players because individual differences in the ability to recover from playing. In team sports players are playing and practicing together. They travel and eat together. The team has a common schedule, especially on road trips.

The first hypothesis was that road trips are the biggest problem to optimize the stress and recovery on individual level: to play every second day 4 games in the row and to fly after the games to the next playing place. How would it be possible to plan the team schedule so that recovery occurs well and players maintain a good athletic performance state?

The results of this study show that there is not so big difference of the night recovery between away and home game periods. The most important difference is a delay of recovery because the travelling after the game compared on home games. The recovery starts about 3 hours later after away game but the duration of the night recovery is on average the same after away and home games. That is why there is sense to delay also the start of the next day and give to players more time to recover. The duration of the night recovery is the same but on the road a team is able to move the awakening time later. Actually on the road trip the team is able to plan the schedule on condition of playing And of course there is many different factors the coaches and teams are able to use to optimize a balance between stress and recovery: when does the team travel, immediately after the game or in the morning; does the team practice on the next day and when is it practicing, extension.

One interesting finding of the present results was importance of returning from the road trip back to home. The physiological and mental stress after one week journey is big. Time difference can make it still worse. That's why Jokerit planed the schedules and lived in Finnish time on all road trips, to make it easier to come back to home. The biggest time difference was 4 hours.

Also has to remember a human side of the life. When a player returns back to home, there often are many expectations by a family or other interest groups. Because of the daily routines time to recover often is too short. And of course the situation is the same during the home game periods. Professional sport players have also normal responsibilities of life. The hypothesis in the beginning was that it is most difficult to optimize the balance between stress and recovery during the road trips. Actually the present results show, in spite of bigger stress, that on road trip it is easier to plan the daily programs so that recovery is optimal. Because players only can concentrate on sport and they don't have any other responsibilities.

8.4 Individual differences of the night recovery

One of the most notable finding of this study was really big individual differences of the night recovery between the different players. And it only wasn't after game recovery but overall night recoveries.

The first remarkable difference was that when recovery started after the game. The fastest recovery started two hours after the game and the slowest player didn't recover at all during the night. The physical and mental stress of the ice hockey game is so big that it delays the start of the recovery. The second important difference is in relation to the starting time of recovery. The late start of recovery of course causes big differences in the duration of the night recovery.

In this study 6 players from total 30 players had big problems to recover sufficiently especially after the games. Correspondingly there were 8-10 players, who recovered well after the games. Of course there are many different reasons, which cause an unsufficient recovery. Understanding importance of the good recovery and having a proper attitude to take good care of that, are main factors for good recovery. The continuing desire to improve yourself is one of the most important values in professional sport. Coaches and athletes should understand that recovery has a big role in improvement. And coaches also should help athletes individually so that they learn the proper ways how to recover well.

Good aerobic condition is the best prevention of exhaustion state (Summanen & Westerlund 2001, 14-21). If Jokerit decreased practices on ice, correspondingly the players did more off ice practices. Training effect refers especially to the development of cardiorespiratory fitness. Good aerobic condition is related to the ability to perform moderate to high-intensity physical activity for prolonged periods and also to recover better (Firstbeat Technologies 2009). Effective exercise sessions must be performed often enough and easier exercise sessions must be included regularly between the more demanding sessions. In addition to the changes in daily training load, also weekly and seasonal training must include variation.

8.5 Recovery measurement during the season

The big amount of games during the season requires a good ability to recover. Nowadays a good ice hockey player also is a good athlete 24 hours in a day. Without good recovery it is difficult to maintain a good physical performance state. Too hard physical load without sufficient rest may lead to exhaustion, which is characterized by decreased performance and in the worst case also other harmful effects on health.

If playing load is high for prolonged periods and proper recovery is neglected, exhaustion may occur. This means that fatigue accumulates from one game to another in such a manner that the athlete is actually exhausted in some point of the season.

It shows according to these results that the night recovery after the game is most significant factor to cause a disturbance in body's homeostasis. If an individual's recovery is incomplete, it may lead to decreased personal performance or even exhaustion or injury, which of course affects the whole team. In addition to attempting to provide an equal or appropriate playing and training load for all team members, also individual recovery of the players should be controlled. Prevention of exhaustion is therefore crucial, and is possible by systematic assessment of the athlete's recovery.

Firstbeat is a new easy-to-use method to assess the recovery of an athlete or a team. The coach can either track the whole team or assess a few players who are suspected of having difficulties with recovery. A recovery test for the whole team can be managed by collecting overnight heartbeat data from all players. Analysis is highly automated and quick to perform. Night time recovery measurements have been widely applied among international level endurance athletes. Night time heartbeat recording does not disturb sleep significantly or at all. Regular recovery assessment is a key factor in successful programming.

8.6 Conclusion

There is not so much information about recovering in professional team sport. The main focus of this study was to provide new information from the recovery of the players during the playing season in Kontinental Hockey League. And still from a practical point of view, so that this study provides new information for coaches and players for planning athletic programs of the teams during the playing season.

1. Importance of recovery in athletic life – 24/7

The competition on the international level has come harder and harder every year. It is not anymore enough to practice and compete well, it is more and more important, how athletes spend the time between physical activities. A player has to be an athlete 24 hours in a day and 7 days in a week. In addition to high training and playing load, also recovery plays an important role in athletic life.

2. The night recovery after the games - most crucial phase to maintain good athletic performance state

The physical and mental stress of the ice hockey game is so big that it delays the start of the recovery. It shows according to these results that the night recovery after the game is most significant factor to cause a disturbance in body's homeostasis. If an individual's recovery is incomplete, it may lead to decreased personal performance or even exhaustion or injury,

3. The athletic programming of the team – more time recovering

The importance of sufficient recovery is due to the fact that performance improvements actually occur during recovery, not during workouts. Finding a balance between playing load and recovery is a key factor to maintain good athletic performance. In precise and effective training and playing management, player and coaches should assess the load and effectiveness of different playing sessions, but especially recovery from these sessions.

4. Big individual recovering differences in a team – learning to recover

One of the most notable finding of this study was really big individual differences of the night recovery between the different players. Understanding importance of the good recovery and having a proper attitude to take good care of that, are main factors for good individual recovery. Coaches also should help athletes individually so that they learn the proper ways how to recover well.

5. Key for better recovering - systematic assessment of the athlete's recovery.

Firstbeat is a new easy-to-use method to assess the recovery of an athlete or a team. Analysis is highly automated and quick to perform. Night time heartbeat recording does not disturb sleep significantly or at all. Regular recovery assessment is a key factor in successful athletic programming.

In the present study the autonomic regulation of HRV was measured mainly by using Firstbeat Sport method. Thinking afterwards by using Firstbeat Life Assesment method there would have got more detailed information for example from HRV parameters as RMSSD or body resources accumulation.

This study has been a huge learning process for me as a student. Learning to measure recovery practically and working with the professional team in international league has been an interesting experience: to combine theoretical and practical thinking in real circumstances. Of course the biggest challenge was been to put together this thesis. It has been difficult to work sustained for getting all pieces together and at the same time maintain some kind of structure and intrigue of this thesis.

I would like to express my gratitude to Jokerit players, who act as subjects in this study. In addition I thank Jarmo Koivisto who helped me in practical measurements and the coaching team of Jokerit (Erkka Westerlund, Hannu Virta, Kalle Kaskinen and Markus Ketterer) for help and assistance during the work and for the opportunity to be involved in this team.

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Appendices

Appendix 1. Comparison of different methods evaluating athletic recovery.

Method	**Physiological and scientific basis**	**Advantages**	**Limitations**
Lactate measurements	Lactate is formed in anaerobic metabolism. Observations have been made about reduced lactate levels in fatigued state, usually when the muscles are emptying of glycogen.	Relatively easy to measure. Inexpensive.	Cannot distinguish between overreaching and overtraining. Requires control exercise. Usually needs to be combined with information on subjective feelings. Mainly measures short term recovery after a single training session.
Hormonal, immunological and biochemical measurements	Poor recovery, overreaching and overtraining may be detected by observing hormonal, immunological and/or biochemical markers (e.g. cortisol)	Specificity: Possible to locate the "problem area" precisely if changes in these markers are detected.	Not sensitive enough for the measurement of daily training status. Expensive. Instant feedback is not possible.
Orthostatic test	Cardiac reactivity to postural changes has been found to be associated with	Inexpensive. Relatively easy and quick to perform.	Other factors, such as mental arousal or anxiety may confound results.

	recovery state.		Heart rate level may either increase or decrease due to high training load.
Subjective feelings (e.g. Profile of Mood States, other questionnaires or personal feeling of recovery or fatigue)	Training induced fatigue is linked to psychological factors. Experienced athletes can feel when they are recovered.	Inexpensive and easy to assess.	Not objective.
Traditional HRV-analysis	Single HRV indices (e.g. HF power, RMSSD) have been found to detect excessive training load either alone or combined with orthostatic test.	Inexpensive. Relatively easy and quick to perform.	Necessary artefact correction requires signal analysis skills. If done awake, other factors such as mental arousal or anxiety may confound results. Traditional HRV indices are hard to interpret.
Firstbeat Recovery Test	Based on advanced HRV analysis and physiological modeling of body functions.	Very fast measurement, automated analysis and interpretation. Has been found to be sensitive than traditional ways	Beat-by-beat HR recording is required.