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The effect of recovery during sleep in working-age adults

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Abstract

In working-age adults, the amount of recovery during sleep can vary significantly due to various factors. Recovery and sleep affect each other greatly, so it is important to understand both. The prevalence of sleep issues has been increasing in the recent years and therefore this topic should be included in physiotherapy education. An independent study material could be the solution for this problem and benefit many health care professionals and patients.

The aim of this thesis was to understand how people recover during sleep, what affects nocturnal recovery and what tools physiotherapists can use to help patients with sleep and recovery issues. Objectives of the thesis were to gather evidence-based information through a literature search and to compose an independent study material to Moodle platform for physiotherapy students.

This thesis consists of a theoretical and practical part. It started with collecting and understanding basic background knowledge about sleep physiology, autonomic nervous system and factors affecting nocturnal heart rate variability. Literature search continued with finding relevant tools that physiotherapists can use for assessment and treatment, with a greater focus on tools that have a higher level of evidence.

After completion of the thesis, an independent study material was done in a Moodle platform in co-operation with SAMK. Contents to this interactive study material were chosen to give physiotherapy students the basic knowledge and tools to use in their future career.

Key words
Physiotherapy, sleep, recovery, heart rate variability, working-age adults

CONTENTS

Abbreviations

ANS	Autonomic nervous system
BMI	Body mass index
BP	Blood pressure
CVD	Cardiovascular disease
HF	High frequency (component of HRV)
HR	Heart rate
HRV	Heart rate variability
LED	Light-emitting diodes
LF	Low frequency (component of HRV)
MSK	Musculoskeletal
NREM	Non-rapid eye movement
PA	Physical activity
pNN50	Percentage of the number that differ between successive inter-beat intervals over 50 milliseconds
PT	Physiotherapy/physiotherapist
REM	Rapid eye movement
RMSSD	Root mean square of successive differences between heartbeats
SDNN	Standard deviation of normal inter-beat intervals

INTRODUCTION

Sleep has an essential part of our physical and mental health. Sufficient sleep helps us recover and wake up energized the following day, however inadequate amount can cause daytime sleepiness and decrease cognitive skills. Prolonged sleep deprivation is a risk factor for many serious health disorders. With all the affecting factors, sleep is a very complex process, but it is necessary for majority of humans physiological functions. (Website of National Sleep Foundation 2020)

Importance of sleep can be easily overlooked with a fast-paced lifestyle, where exercise and nutrition are considered the key factors of a healthy lifestyle. Physiotherapy students should have more in-depth information about what affects recovery during sleep and what tools they could use for improving it. As there is no study material about recovery during sleep currently available, this thesis could enrich physiotherapy education.

This thesis includes a theoretical background of sleep physiology, factors affecting recovery during sleep in working-age adults and information about practical tools what physiotherapists can use to assess and treat problems with sleep and recovery. Based on gathered literature, an independent study material was made on Moodle. This interactive study material could be used during the exercise physiology course and was done in co-operation with the SAMK's physiotherapy degree program.

1 THE AIM AND OBJECTIVES

The aim of this thesis is to understand what affects recovery during sleep in working-age adults and how physiotherapists can improve it. There are two objectives for this thesis. The first objective is to gather theoretical knowledge through a literature search about physiology of sleep, factors that affect recovery during sleep and physiotherapeutic tools to improve sleep quality and recovery during sleep. The second objective is to create an independent study material for physiotherapy students about the effect of sleep on recovery. The study material will be available on Moodle platform as a part of exercise physiology course.

2 RECOVERY DURING SLEEP

2.1 Sleep physiology

Many factors around human physiology are controlled by a cycle of about 24 hours. In our hypothalamus, suprachiasmatic nuclei are creating a pattern called circadian rhythm. One circadian period equals about one day. Humans internal clock is largely affected by the environment, especially the light-dark cycle. Suprachiasmatic nuclei follow the cycle of humans internal clock and trigger sleep and tiredness. Excessive light in the evening can disturb the circadian cycle, which usually tries to make us sleep from around 11pm to 4am. (Wilson & Nutt 2008, 3) Sleep is defined as a state when a person is passive and unconsious, therefore not affected by external surroundings. Generally, during sleep, we are lying down and have our eyes closed. While we sleep, both our body and mind have time to rest and revitalize for the next day. (Yaremchuk & Wardrop 2011, 19)

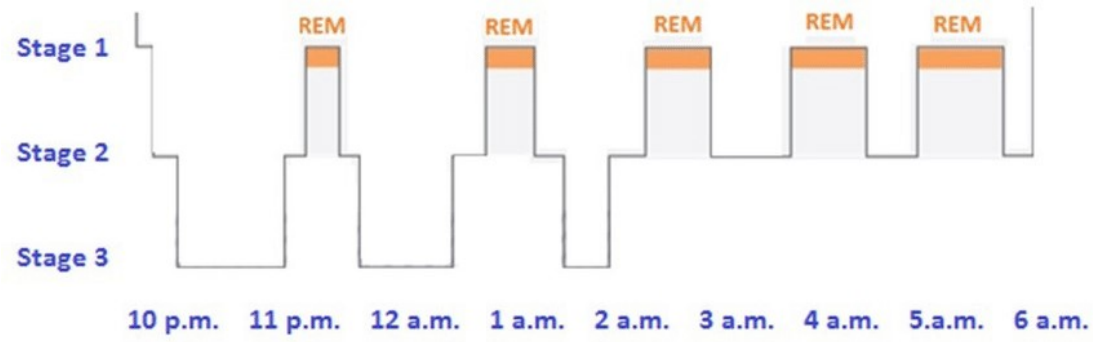

Figure 1. The normal nocturnal sleep cycles (Smiley, Stephen & Nissan 2019).

Sleep in divided into two main stages, rapid eye movement (REM) and non-rapid eye movement (NREM) sleep based on physiological changes occuring during sleep. While we sleep, we rotate between different stages (Fig. 1.). NREM sleep is divided into N-1, N-2 and N-3 stages, which in total make up about 75-80% of our total sleep (Fig. 2.). N-1 stage starts when we fall asleep and it accounts for very little of our total sleep time. During N-1, muscle tone reduces, eye movements slow down and brain activity changes compared to being awake. About half of the time asleep, we are in stage N-2, which is the main part of NREM with around 45-55% of total sleep time. It is not easy to wake a person up during N-2 sleep, but it's even more challenging when

they are in N-3 stage, which is also called slow wave sleep and takes up between 20-25% of total time asleep. The same amount of time is commonly spent in REM sleep, where the muscle tone is very low and eye movements fast and sporadic. (Yaremchuk & Wardrop 2011, 21-22)

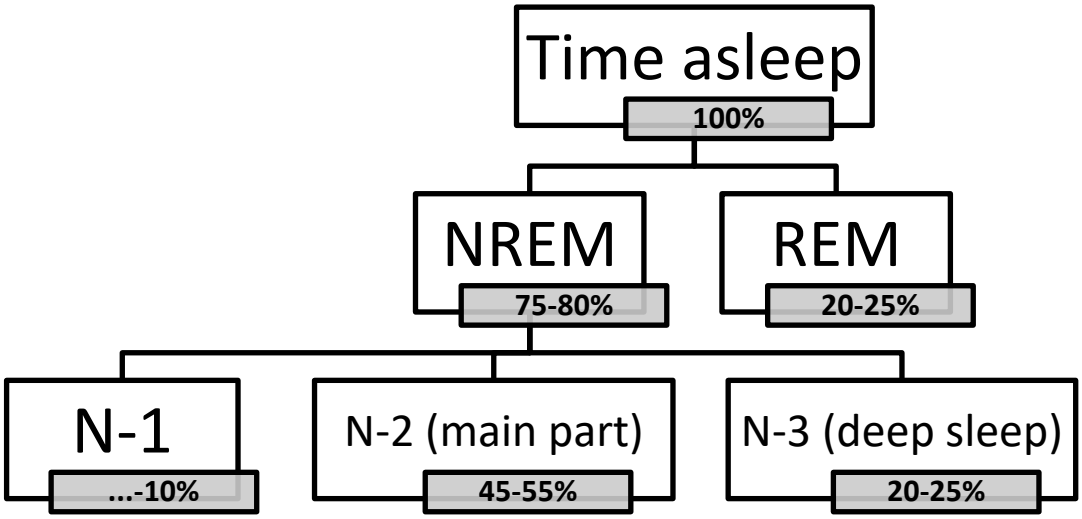

Figure 2. Percentage of total sleep duration spent in sleep stages.

2.2 Sleep recommendations for working-age adults

There has been a consensus, that for adults, 7-9 hours of sleep each night is best for optimal health. Under 7 hours of sleep regularly was linked to negative health effects like increased chances of cardiovascular diseases (CVDs), depression, pain, and decreased performance. For adults, it is not proven if sleeping more than 9 hours has negative effects on health. (Watson et al. 2015) The National Sleep Foundation agrees with that and recommends adults between 26-64 years of age to get 7-9 hours of sleep per night. According to them, some alternations can be acceptable, but less than 6 and more than 10 hours is not recommended. (Hirshkowitz et al. 2015) Even though there are general reference values for necessary sleep length, physiologically the differences between individual needs can be significant. Key point is to understand that people should sleep as much as they need to manage daily activities without daytime sleepiness. (Yaremchuk & Wardrop 2011, 163)

2.3 Autonomic nervous system

In the nervous system of a human, brain and spinal cord make up for the central nervous system and everything else belongs to peripheral nervous system. Peripheral nervous system can further be divided into three parts: somatic nervous system, autonomic nervous system (ANS) and enteric nervous system. Humans are not conciously activating their ANS and therefore not able to control it. (Tortora & Derrickson 2014, 400) ANS has two parts, of which first is a sensory part, where neurons take information from inside the body to the central nervous system, for example from pain in internal organs or blocked blood vessels. The other part of ANS is a motor, which regulates our bodily reactions involuntarily, for example changes in heart rate (HR). Based on the reactions, ANS is divided into sympathetic and parasympathetic nervous system. Sympathetic nervous system, also known as the fight-or-flight response, is activated when the body is under stress, which can be either physical or emotional. Among many responses, the body reacts to stress by increasing HR, blood pressure (BP) and blood flow to muscles, dilating pupils and airways, decreasing digestion and non-essential processes. On the opposite side we have parasympathetic nervous system, also known as the rest-and-digest response, which is activated when the body is resting and recovering. During which the body also has opposite reactions, therefore HR and BP decrease and focus goes on processes like digesting and forming urine. (Tortora & Derrickson 2014, 523-540) An important part of ANS functions is the regulation of heart rate variability (HRV) and through HRV analysis, it is possible to observe the balance between sympathetic and parasympathetic nervous system (Firstbeat Technologies Oy 2016, 29).

2.4 Heart rate variability (HRV)

The difference of time between heartbeats is measured as HRV. HR and HRV influence each other greatly, but they are negatively correlated. For example, during rest, HR decreases and at the same time HRV increases. HRV depends a lot on the individual, but it is also affected by internal and external factors. In addition, negative emotions can decrease, and positive thoughts increase HRV. Higher HRV has been linked to better physical capabilities and cardiac health. (Firstbeat Technologies Oy 2016, 28-

29) However, there are a few exceptions, some cardiac diseases can increase HRV significantly, which is also a risk factor for mortality (Shaffer & Ginsberg 2017).

There are three main types of HRV measurements used: time-domain, frequency-domain and non-linear. From time-domain measures for example, standard deviation of normal inter-beat intervals (SDNN), measured for 24 hours is the basic tool used in clinical setting to assess cardiac risk. 24-hour SDNN result under 50 milliseconds is considered unhealthy, between 50-100 could be compromising and over 100 milliseconds stands for a healthy result. More calculations are included in finding the root mean square of successive differences between heartbeats (RMSSD), which is the most used of the time-domain measures to analyse HRV changes by vagal modulation. Percentage of the numbers that differ between successive inter-beat intervals over 50 ms (pNN50) is strongly correlated with 24-hour RMSSD measurements. (Shaffer & Ginsberg 2017)

For understanding how ANS controls bodily functions during sleep, it is important to recognize changes in HRV. HRV analysis is a safe method to assess cardiovascular health through fluctuations in ANS regulation during sleep onset and all sleep stages. Same is possible in sleep related diseases, like insomnia and sleep disordered breathing, where analyzing HRV can show changes in ANS during sleep. (Tobaldini et al. 2013) During a HRV analysis, we can follow changes in its frequency-domain components, most telling for us are very low frequency, low frequency (LF) and high frequency (HF) markers. LF is a marker for sympathetic regulation and HF for parasympathetic. The ratio between LF and HF indicates changes in the sympatho-vagal balance of ANS. (Tobaldini et al. 2016).

The way ANS and sleep stages affect each other is a complicated system (Fig. 3.). The ANS reacts from being awake to falling into NREM sleep by an increase of parasympathetic regulation, with decreasing HR, BP and LF component of HRV, while HF component increases. HR and BP decrease progressively until N-3 stage. On the contrary, transition from NREM to REM sleep shows increased sympathetic regulation, which can possibly activate the cardiovascular system more than while being awake. During the change from NREM to REM sleep, HR, and BP increase, and total HRV decreases, however there are constant fluctuations in cardiovascular control in this

sleep stage. It is also possible, that the level of sympathetic activation during REM sleep depends on the previous and following stage. (Tobaldini et al. 2013)

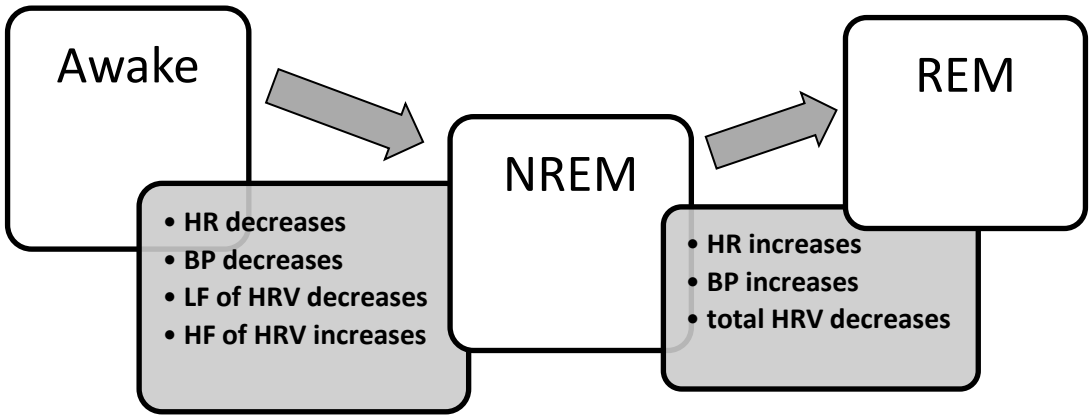

Figure 3. Changes in ANS function during transitions between sleep stages.

Correlations between HR, HRV and sleep stages have been studied in various types of people and results are not fully conclusive. In young adults, it has been found that during NREM sleep stages, both HR and HRV decrease. However, during REM sleep, both stats increase, the slow-wave sleep caused the HR to rise even higher than while being awake. However, evidence shows that this can change with age and older people more likely have higher HR and decreased HF of HRV during NREM sleep. Researchers have also found that other health conditions can affect the interaction between HRV and sleep stages. (Stein & Pu 2012)

2.5 Stress and recovery

Scientists have not fully agreed on a definition for stress, however if looked from the standpoint of ANS, then humans are under stress when sympathetic nervous system is dominant and recovering during parasympathetic dominance. The use of HRV as a measurement tool for stress and recovery has increased recently, with also analyzing HRV during sleep. (Crespo-Ruiz, Rivas-Galan, Fernandez-Vega, Crespo-Ruiz & Maicas-Perez 2018) For example, during a Lifestyle Assessment, the Firstbeat device measures the duration of sleep and recovery. It is considered good to have recovery during at least 75% of the whole sleep length. If the recovery percentage is lower,

possible affecting stress factors must be analyzed. The quality of recovery is based on nocturnal HRV, and higher values are associated with better recovery. The Lifestyle Assessment evaluates participants recovery good when HRV is higher than average of people of same age and gender. It is also possible to recover while being awake. Reading, meditating, and knitting are few of many options for relaxation during daytime. Of the 24-hour period, it is considered good, if the body is recovering for at least 30% of time. (Firstbeat Technologies Oy 2016, 12-13)

3 FACTORS AFFECTING RECOVERY DURING SLEEP

3.1 Factors affecting HRV

HRV is affected by many factors, like age and gender. It has been studied, that HRV gets lower with age, starting to decrease already in childhood. Females tend to have higher HRV than males, however they also have bigger fluctuations. HRV is positively impacted by physical activity, it has been proven that athletes who are training in aerobic sports have higher HRV parameters compared to control group. Taking medication, smoking and alcohol consumption can negatively affect HRV parameters. Smokers usually have impaired ANS regulation and exposing a developing baby to cigarette smoke can lower their HRV and disturb ANS control after the baby is born. (Rajendra Acharya, Paul Joseph, Kannathal, Lim & Suri 2006)

In a cross-sectional study done in Finland, effects of factors like body mass index (BMI), physical activity (PA) and work-related stress, on recovery were analysed. For three consecutive days, HRV data of 16 275 working adults was measured using Firstbeat devices. Results showed that the individuals who do most physical activity have higher HRV and recovery index, and lower stress throughout the day. Even though intense physical activity may cause alterations in recovery of the following night, but in long-term, it improves fitness which increases recovery. It was also found that normal BMI correlates to higher HRV, therefore better recovery during sleep, compared to high BMI. Individuals with highest PA and normal BMI also had the least amount of stress during the day. (Föhr et al. 2016)

In a study done in Northern Germany, a comparative analysis of HR and HRV in intraoperatively stressed and non-stressed surgeons was done. In this study, there were no significant differences found in resting HR between stress groups. However, changes were seen in nocturnal HRV, where stressed surgeons had significantly lower values compared to non-stressed group. This indicates that stress can negatively alter nightly recovery in adults. (Rieger, Stoll, Kreuzfeld, Behrens & Weippert 2014)

In a study done by Pietilä et al. (2015), researchers investigated correlations between lifestyle factors and nocturnal HRV. They found that the factors most significantly altering recovery time were alcohol, sleep duration and PA. The effects of alcohol were found to depend on dosage per kilogram of consumer, therefore one or two servings did not make a big difference, but every extra alcohol serving, added to the decreased recovery. Increased sleep duration also meant longer recovery time, however sleeping around 7 hours showed highest percentual amount of recovery from the total sleep time, therefore it could be most economical. They also found that people with better aerobic fitness had increased recovery but reaching positive effects of physical activity takes time. During this research, they concluded that physical exercise does disturb recovery during the following night and decrease depends on the length of active time. (Pietilä et al. 2015) Another study by Pietilä et al. (2018) focused on effects of alcohol on recovery during the first 3 hours of sleep. They agreed that negative effects are depending on the doses, but also found that low doses of alcohol already affected recovery. Additional observation made was that gender, age or PA level did not matter when measuring effects of alcohol on nocturnal recovery. (Pietilä et al. 2018)

3.2 Sleep deprivation

Sleep deprivation means getting fewer hours of sleep than necessary, which according to the recommendations, for adults means under 7 hours of sleep per night (Website of National Sleep Foundation 2021). It has been found, that sleep deprivation decreases levels of performance, cognitive functioning, concentration, reaction time and memory (Yaremchuk & Wardrop 2011, 164). Sleep deprivation has been associated with CVDs

like hypertension, coronary artery disease, arrhythmias, and metabolic disorders (Tobaldini et al. 2016). It has been found that after sleep restriction, it takes at least three nights of recovery sleep for the ANS to regain its normal balance (Yang et al. 2019).

In a study by Lindholm et al. (2012), recovery during sleep and daytime sleepiness were compared between people with different working schedules. One group included 70 individuals with normal working hours and the second group had 70 people working in media with irregular shifts. Based on questionnaire results, frequency of daytime sleepiness was doubled in participants with irregular working hours. The same workers showed significantly lower HRV values between 11 p.m. and 3 a.m., which might indicate that irregular working hours can lead to poor nightly recovery, which causes daytime sleepiness. (Lindholm et al. 2012)

3.3 Musculoskeletal pain

A study on Danish hospital workers analysed correlations between perceived stress, musculoskeletal (MSK) pain and subjective sleep quality. They found out that both higher stress and pain levels can be linked to poor sleep quality, with a more significant connection between subjective stress and decreased sleep quality. (Vinstrup, Jakobsen, Calatayud, Kay & Andersen 2018) Connection between MSK pain and daily ANS balance has been investigated with a purpose to find out if poor ANS regulation can be associated with multisite MSK pain. For this, 568 of blue-collar workers were recruited and divided into 3 groups: pain-free, single-site pain and pain in two or more body parts. Alarming part was that 63% of participating individuals had multisite MSK pain. However, results showed no significant differences between the groups autonomic regulation during daily activities and sleep. Therefore, they concluded that there is no connection between multisite MSK pain and imbalanced ANS regulation. (de Oliviera Sato, Hallman, Kristiansen & Holtermann 2018)

In a small study done in Sweden, individuals with chronic pain in the neck and shoulder region were compared to a pain-free control group. During the 24-hour assessment, participants HRV, PA, stress, and energy levels were investigated. Throughout the 24 hours, pain group had higher HR and lower HRV compared to control group. The

whole 24 hours, but especially during sleep, pain group had significantly decreased values of pNN50. Their conclusion suggests that improving ANS regulation could be a part of chronic neck and shoulder pain treatment process. (Hallman & Lyskov 2012)

3.4 Common diseases

Majority of sleep disorders' main symptoms include decreased amount of sleep, which is proven to be a risk factor for mortality. Recently, researchers have started to analyze more thoroughly connections between sleep disorders and CVDs, because negatively altered sleep physiology is a risk factor for CVDs and CVD-caused-death. Although studies are still limited, sleep disordered breathing, insomnia and sudden unexpected death in epilepsy are examples of sleep disorders that affect ANS regulation and increase risk of CVDs. Patients with obstructive sleep apnea, which is the most prevalent of sleep disordered breathing diseases, have higher resting HR, BP and their ANS balance is dominated by sympathetic activation, especially during apneic events. Similar predominance of sympathetic activity has been seen in patients with insomnia throughout sleep stages, but also while being awake. These changes compared to healthy ANS regulation can be linked to increased CVD risk and as there are many patients with insomnia, it has become clinically relevant. Patients with chronic epilepsy have been proven to have lower HRV and more alterations in ANS regulation during sleep. Epileptic seizures can cause changes in HRV through stimulating ANS during NREM sleep. If epilepsy can't be managed with pharmacology, patients' risk of sudden unexpected death in epilepsy is increased 24-40 times compared to average population. (Tobaldini et al. 2013)

In research by Zhang et al. (2019), associations between HRV during sleep and long-term CVDs were studied. The 2111 included individuals were followed for a median of 11.8 years. The results revealed that the group of subjects who developed CVDs during the follow-up period had lower nightly HRV at baseline measurements. Based on that, they concluded that nocturnal HRV analysis could be used as a tool for assessing long-term risk of getting CVD. (Zhang et al. 2019) Assessing other cardiac disorders like myocardial infarction, but also noncardiac diseases like multiple sclerosis and end stage renal disease can benefit from HRV analysis. It can also show more

about ANS in alcoholics and diabetes patients than normal tests. ANS is affecting directly to our HR and HRV, which means through analysing our hearts functioning, we have an insight to the ANS. Decreased HRV has been found in diseases like diabetes and congestive heart failure. Very low HRV can also be a risk factor for mortality. (Kleiger, Stein & Bigger 2005)

4 PHYSIOTHERAPEUTIC TOOLS FOR IMPROVING RECOVERY DURING SLEEP

4.1 Physiotherapeutic assessment

When conducting a physiotherapy (PT) session, patients sleep habits and possible disturbances should always be considered. Even though they might come to a PT visit for another reason, there could be underlying issues with sleep affecting the condition. If that can be found out during assessment, using general questions, then it might benefit the treatment process. (Siengsukon, Al-Dughmi & Stevens 2017) According to PTs, who regularly assess their patients sleep quality, six most common to have sleep problems are patients with fibromyalgia, acute or chronic back pain, acute or chronic neck pain or post-op pain (Siengsukon, Al-Dughmi & Sharma 2015). In USA, chronic insomnia, obstructive sleep apnea and restless leg syndrome are the most common sleep disorders among adults. Therefore, during assessments, PTs should consider how patients sleeping habits and physical condition affect each other. In Sleep Health Promotion: Practical Information for Physical Therapists, researchers published eight general questions that physiotherapists are recommended to ask patients during an interview (Table 1.). If the patient answers “yes” to question 6, 7 or 8, then further screening is recommended to assess possible presence of sleep disorders. (Siengsukon, Al-Dughmi & Stevens 2017)

1. How much sleep do you typically get?
2. Do you feel well rested when you wake up?
3. Is your condition impacting your sleep? If so, how?

4. How would you rate your sleep quality?
5. Does being sleepy during the day interfere with your daily function?
6. Do you have difficulty returning to sleep if you wake up in the middle of the night, or difficulty with waking up too early? (Possible sign of insomnia)
7. Do you snore loudly or frequently? Has anyone observed you stop breathing while you sleep? (Possible sign of obstructive sleep apnea)
8. Do you have a strong urge to continually move your legs while you sleep? (Possible sign of restless leg syndrome)

Table 1. General questions (Siengsukon, Al-Dughmi & Stevens 2017).

The Pittsburgh Sleep Quality Index was composed with an aim of providing clinicians and researchers a measurement tool during assessment of sleep quality (Buysse, Reynolds, Monk, Berman & Kupfer 1989). More recently, the reliability of PSQI was studied and results showed moderate to strong evidence in different settings (Mollayeva et al. 2016). Another available tool for PT assessment was developed in Nordic countries. The standardized Basic Nordic Sleep Questionnaire has been widely used as a trustworthy tool to measure sleep quality and issues in Nordic countries. The questionnaire has 21 questions with most having a scale from 1-5 for reference. (Partinen & Gislason 1995)

4.2 Patient education and sleep hygiene recommendations

Recommendations in sleep hygiene education are not focused only on recovery, but on overall sleep quality (Table 2.). They affect each other and therefore both must be considered. Educating patients with simple instructions about improving sleep hygiene could enhance sleep quality and therefore boost overall health. Patients whose sleep is affected by pain could possibly benefit from bed mobility instructions. Together with a physiotherapist they could try to find a sleeping position that causes none or minimal amount of pain, which therefore could improve sleep quality. However, this has not been researched enough to guarantee improvement. (Siengsukon, Al-Dughmi & Stevens 2017)

The human body produces a hormone called melatonin to regulate the circadian rhythm. Melatonin levels start to increase in the evening, as brain prepares the body for sleep. People with irregular sleeping schedules are prone to use melatonin supplements. As the research comparing benefits and side-effects is not conclusive and studies about effects of long-term melatonin use are lacking, consulting a doctor before using supplements is recommended. In addition, if a PT notices that the patients sleeping problems are increasing, continuing for a long period of time, or causing serious health risks, then they should be encouraged to consult their doctor. Through them, a referral to a sleep specialist could be beneficial for the patient. (Website of National Sleep Foundation 2020)

SLEEP HYGIENE RECOMMENDATIONS
1. HAVE A ROUTINE. Before going to bed, use the time for relaxing activities. Go to sleep and wake up at the same time every day, try to keep the cycle. Don't nap during the day, if necessary, then maximum of 30 minutes.
2. BED IS ONLY FOR SLEEPING. Avoid eating, working, or lying in bed during the day. If you can't fall asleep in 20 minutes, do something else and come back to bed when you're sleepy.
3. DO NOT EXERCISE BEFORE GOING TO SLEEP. Regular exercise can improve sleep and should be done. However, not 2-3 hours before going to bed, because the body can be stimulated.
4. MAKE BEDROOM COMFORTABLE. Choose an appropriate temperature, not too cold or warm. Keep it dark and quiet, for example using an eye mask or ear plugs. Avoid electronics (phone, TV etc.) 30 minutes before sleep.
5. AVOID STIMULANTS BEFORE BED. Don't consume caffeine, alcohol or smoke 3-4 hours before going to sleep. Avoid large/spicy meals and excessive liquids 2-3 hours before bed. These stimulants can cause problems with falling asleep or disturb sleep quality.
6. CONSULT A PROFESSIONAL. Don't use sleeping pills if they haven't been prescribed to you. If problems continue, see a doctor.

Table 2. Sleep hygiene education (Siengsukon, Al-Dughmi & Stevens 2017).

However, from a public health standpoint, many of individual sleep hygiene recommendations have insufficient evidence behind them and conclusions are often made based on excessive doses, for example in case of caffeine or nicotine use. Researchers agree, that sleep hygiene education could be the solution for improving sleep in a societal level. However, further research about individual variations is essential for understanding impact of sleep hygiene thoroughly. (Irish, Kline, Gunn, Buysse & Hall 2015)

4.3 Electronic devices

Light-emitting diodes (LEDs) are very commonly used for illumination, also in electronic devices that people use daily like computers, TVs, and smart phones. Early research on rats shows that negative effect on circadian rhythm by the same amount of artificial light can be multiplied at night, compared to daytime. For example, using e-readers just before going to bed could alter the circadian rhythm and disturb sleep. (Tosini, Ferguson & Tsubota 2016) Knowing that our biological clock and therefore circadian rhythm are affected by light can be beneficial for people who work night shifts and need to improve their alertness. However, in other people it can negatively affect sleep and cause issues. In a small study, effects on participants were compared using computers with LED screens to ones without LEDs. The group using LED-screens had a decreased melatonin production throughout the computer use and they reported less sleepiness. This shows initial evidence of using LED devices, but long-term effects on sleep health have not been researched enough. (Cajochen et al. 2011)

4.4 Nutrition and stimulants

Importance of well-balanced nutrition has been studied extensively, however the research behind effects of different foods on our sleep is still in early stages. People with shorter sleep duration have shown to have higher caloric intake, especially from fat-rich foods, compared to people with normal sleep length. Foods like fruit, vegetables, fish, and milk products could have a positive effect on sleep, but ultimately more substantial evidence is needed in this topic. (St-Onge, Mikic & Pietrolungo 2016) Some

studies show that after myocardial infarction, fish oil and/or n-3 fatty acid intake could potentially increase HRV and improve cardiac control (Singh et al. 2001).

Caffeine is a universally used stimulant that can be found in many drinks, foods, and medications. Effect of low, moderate, and high caffeine intake on subjective sleep quality and duration has been researched, but studies have had mixed results. No conclusions can be made based on subjective answers, but most of studies that investigated sleep quality agree that caffeine influences duration and efficiency of sleep by reducing both. Also, caffeine can delay sleep latency and wake time after sleep onset. In studies focusing on dose-response and timing-response caffeine intake, some evidence can be seen that both increased caffeine intake and consumption later in the evening affect sleep quality parameters negatively. However, there are also some studies, which haven't seen significant effect, therefore the results are not conclusive. (Clark & Landolt 2017)

In a small laboratory study, twelve participants were followed for 18 days and effects of caffeine intake on sleep deprived patients was investigated. Researchers compared placebo, 200mg and 300mg of caffeine consumption. They found that 200mg of caffeine reduces HR compared to placebo and 300mg, which were not significantly different. Both 200mg and 300mg caffeine consumed participants showed an increase in HF component of HRV, which illustrates increased parasympathetic modulation. However, this study did not focus on the LF component, and they mention that conflicting results exist, so this topic needs further research. (Crooks, Hansen, Satterfield, Layton & Van Dongen 2019)

4.5 Prescribing exercise

Regular PA is one of the key points in sleep hygiene recommendations and plenty of research shows the effects exercise has on ANS regulation, both during and after PA. However, evidence behind associating time-of-day and exercise is still lacking. In 2011, Finnish researchers found that late exercise doesn't affect HRV or subjective sleep quality but does increase HR during first three hours of sleep. (Myllymäki et al.

2011) A year later, in a study published in 2012, some of the same researchers investigated more thoroughly how exercise intensity and duration affects nocturnal HRV and sleep quality. Through a series of tests, they found that higher exercise intensity increases nocturnal HR, but doesn't affect HRV. Like intensity, it was seen that 90-minute training session increased nocturnal HR and decreased some HRV parameters more than 30- and 60-minute sessions. They concluded that 30 minutes of PA can have health benefits without affecting sleep, because no correlations between exercise intensity or duration and sleep quality were seen. However, seeing that longer training sessions affect ANS during the night, it could mean that sleep could be disturbed as well. Therefore, it could be recommended to do longer PA sessions earlier in the day for better nocturnal recovery. (Myllymäki et al. 2012)

In a study by Yamanaka et al. (2015), which was performed in a controlled living facility with dim lights and no indication of time, participants were divided into morning exercise, evening exercise and a control group. Purpose of the study was to see if there are any differences in circadian rhythm, HR and HRV depending on time of day of exercising. In the intervention, nocturnal HR was increased by evening exercise but did not change in the morning exercise group. On the opposite, morning exercise increased HRV components during sleep. Overall, it was seen that evening exercise affected the circadian rhythm by increasing sympathetic activity. (Yamanaka et al. 2015)

In a randomized controlled trial, female fibromyalgia patients were divided into two groups, control group had normal treatment without exercise while the other group did 45-60 minutes of aerobic exercise 2 times per week. Training sessions included exercise performed with a consistent HR and a part with interval training. After 24 weeks, patients in the exercise group showed an increase in HRV parameters compared to control group. (Sañudo, Carrasco, de Hoyo, Figueroa & Saxton 2015) Another randomized controlled trial was done to find out if exercise causes changed in moderate obstructive sleep apnea patients ANS regulation. During the 9-month intervention time, exercise group did 3 hours of PA per week, while control group continued with their normal life. After 9 months, the exercise group had no significant changes in their nocturnal HRV, but patients in the control group showed a decrease in HRV parameters. Based on these results, they could conclude that PA can be used as a tool for maintaining ANS regulation and preventing further CVDs. (Berger et al. 2019)

Even though it has not been researched much, there is some suggestions that the environment where we exercise, can also influence our recovery. In a small study, the effects of green exercise, in this case walking in nature during lunchtime, on sleep and recovery were assessed. The study suggests that possibly, walking in nature instead of a built environment, could increase nocturnal HRV and therefore improve recovery. (Gladwell, Kuoppa, Tarvainen & Rogerson 2016)

4.6 Tools for monitoring

Technology develops very fast and wearable tracking devices are constantly becoming more accurate, user-friendly, and available. In a comparing study about the accuracy of wearable devices, researchers found differences in measuring RMSSD of HRV. Overall, the most reliable results were from Polar H10 chest-strap connected to a smartphone app HRV4Training and an Oura smart ring. (Stone et al. 2021) In another test against an electrocardiogram, which is a gold standard tool for measuring HRV, Oura ring had very accurate results in detecting nocturnal HR and HRV. Based on these results, Oura ring could be used as a reliable tool for following long-term changes in ANS regulation during sleep. (Kinnunen, Rantanen, Kenttä & Koskimäki 2020) Oura ring was also tested against polysomnography, which is method of analysing sleep structure and physiological reactions during sleep. Results showed that most sleep statistics from Oura ring were in correspondence with polysomnography and only showed slight differences in detecting time spent awake and in the deep sleep stage. (de Zambotti, Rosas, Colrain & Baker 2017) Another trustworthy device for measuring sleep composition is actigraphy. When the validity of sleep monitoring of Oura ring and Samsung Gear Sport watch were tested against it, results showed that both devices are reliable, but Oura ring had slightly better results. (Asgari Mehrabadi et al. 2020)

5 THESIS PROCESS AND METHODS

5.1 Choosing a topic and literature search

The thesis process was started in the spring of 2020 with an idea from the supervising teacher to use this opportunity for making an independent study material. The possibility to make something beneficial for future physiotherapy students was very appealing. During PT studies, the exercise physiology course was good, but felt to be too short. Teachers agreed and suggested that the thesis could focus on recovery during sleep, as this is only briefly mentioned during the course, but still very important knowledge for students. The thesis plan was successfully presented in December of 2020, after which gathering of literature continued.

The original topic was focused more on nocturnal recovery, however during the literature search, it was evident, that sleep education must be included. As majority of recovery happens during sleep, factors affecting sleep quality and recommendations for good sleep hygiene were too important to be excluded. The chosen age group was working-age adults, which is population aged between 15-64 years (Website of Organisation for Economic Co-operation and Development 2021). Therefore, included in chosen literature were also studies on young and older adults.

This thesis includes a theoretical and a practical part. The theoretical material was collected through a literature search. Used databases were PubMed and ScienceDirect. Additional literature was found from SAMKs online library. Search terms used were “physiotherapy” OR “physical therapy”; “sleep” AND “recovery”; “autonomic nervous system” OR “heart rate variability”; “working-age adults”; “sleep hygiene”; “assessment” and “treatment”. Included literature was in English language and majority published between 2011-2021. Exception was made for a few older articles, oldest two being about compiling questionnaires, which were published in 1989 and 1995, but are still relevant and used today.

5.2 Importance of sleep education in physiotherapy degree program

In a survey done in USA, 76 physiotherapists answered questionnaires and shared their views on the importance of sleep. Most PTs agreed that assessment of sleep should be a part of a therapy session and that sleep can affect the rest of the rehabilitation process. 82% thought that PTs should ask their patients about sleep quality, but only 57% do it regularly. However, majority (75%) of them did not receive education about sleep as a part of their entry-level PT programme, and the ones who did, said that the education was minimal. Out of all responders, 95% thought that education about sleep is necessary and should be taught in school. They evaluated that most important areas PT education should cover are physiology of sleep, promotion of healthy sleep habits and sleep quality in addition to epidemiology, causes, prevention and medical treatments for sleep disorders. (Siengsukon, Al-Dughmi & Sharma 2015) Therefore, this thesis and the independent study material hopefully provides SAMKs physiotherapy students with crucial knowledge and tools to use in their future working life.

5.3 Study material

The independent study material was made in November of 2021. It is available on SAMKs' Moodle platform and created with the H5P program. The study material was created as an interactive book, which includes most important theoretical information for physiotherapy students and practical recommendations to use in a clinical setting. Besides theoretical information, the study material has illustrative figures, graphs, and videos. It has been designed to make students understand and analyse possible problems with nocturnal recovery, with independent tasks also focused on what they could include in the treatment process (Fig. 4.). The study material starts and ends with a test, so students can check their knowledge and get instant feedback.

Figure 4. Example of an assignment in the independent study material.

6 DISCUSSION

Importance of sleep and recovery often seems to be overlooked next to nutrition and exercise recommendations. Though more recently, this attitude shows signs of change. In author's opinion, there was not enough education about sleep during the bachelor's degree studies. Stress and recovery were mentioned during exercise physiology course, but practical implementation or PT tools were not included. Being aware, that

academic credits and contact hours are limited, an independent study material could solve this issue. The objectives of this thesis were to understand sleep physiology, factors affecting recovery during sleep and finding tools that PT students could use in the future. An interactive study material on Moodle could make learning easier and more attractive for students, as they can choose the time and place for studying according to their individual schedule.

Theoretical part of this thesis was compiled with the intention of providing most useful knowledge for PT students. It started with basic understanding sleep physiology and normal sleep structure throughout the night. For context, general recommendations for amount of sleep and recovery were given. Background information also included learning how the ANS functions and that during sleep, the parasympathetic nervous system is dominating and therefore regulating our bodily functions. Most of current literature uses nocturnal HRV as a measurement tool to assess changes in ANS, therefore following balance between stress and recovery. So, it was essential to explain what HRV is and how it changes while being awake and during different sleep stages.

After understanding the of concept HRV, the theory focused on affecting factors. It is important to know that HRV is very individual and depends a lot on age and gender. There are many things affecting nocturnal HRV, that most studies have limitations, but some factors with more reliable evidence stood out when doing the literature search and those were primarily included in this thesis. Majority of research associated stress and presence of pathological conditions with decreased HVR during sleep. However, increased physical activity, getting recommended amounts of sleep and good sleep quality were linked to higher nocturnal HRV. In addition, it has been proven that the use of external stimulants like alcohol, smoking and medication could have a negative effect. There were many studies that could not fully confirm their results, but it is obvious that some factors affect more than others.

The author felt that the most necessary part was including the physiotherapeutic approach. Finding out how minimal is education about sleep and recovery during bachelor's degree studies and how essential it is while working with patients in the future, motivated the author to compose a thesis and study material with useful information and tools for PT students. During a PT assessment, it could be beneficial to ask general

questions about sleep and subjective recovery. If the patient is expressing concerns, then further screening might be needed to eliminate sleep disorders. Otherwise, basic education about correct sleep hygiene can still have a positive effect on the treatment process. These recommendations included effects of use of electronic devices, stimulants, and eating before going to sleep, which have shown to negatively alter sleep quality and nocturnal HRV. However, more attention went towards exercise recommendations, as it was meant for PT students. Even though there is no certain evidence behind comparing different kinds of exercise, researchers agree that regular PA increases nocturnal HRV and improves cardiovascular health in long-term. Sleep hygiene education recommends avoiding exercise 2-3 hours before going to sleep. There is evidence behind possible negative effect on sleep and recovery of intense exercise late in the evening. However, researchers have not fully agreed on this topic and some studies claim that time-of-day of exercise does not matter when it comes to sleep quality and nocturnal HRV. This thesis also included two randomized controlled trials about positive effects of regular PA with patients diagnosed with a disorder, as examples for PT students. Another tool that is constantly becoming more available and trustworthy is the wide variety of wearable gadgets for monitoring sleep, HR and HRV. This could help patients follow their own data and benefit PTs who could use it for feedback.

In summary, the author understood the importance of this topic and was very motivated to investigate existing literature about it more thoroughly. All in the name of achieving set objectives and putting together a valuable study material. As this subject is very multi-layered and many aspects need further research, the author knows that this thesis includes some suggestions which do not have a high level of evidence yet. However, author believes, that the research will continue due to increasing amount of sleep issues universally. This topic could be incorporated into the PT degree program, at least as a small part of 1-2 lectures, because basic knowledge about sleep and recovery is necessary and could benefit PT students during their career as health care professionals.

As new literature is published constantly, this thesis could be continued by focusing on different age groups. It is well-known, that in children and adolescents, the physical development is very fast, but the author would suggest future thesis to research about sleep quality in those age groups and how the growing popularity of technology affects

it. Additionally, as recovery in athletes has been studied quite well, another suggestion is to make a thesis about adolescents with high training volumes and how much sleep and recovery they need. The author hopes that this thesis will inspire students to make more independent study materials with the H5P program, which is a good option to make online studying more appealing though interactive content. Through that, motivating students to continue learning and educating their patients about sleep and recovery.

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