Marte Vatn

Sleep characteristics in esport players and associations with game performance

Master's thesis in Sport Science

Supervisor: Stig Arve Sæther
Co-supervisor: Frode Moen

May 2021

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Sociology and Political Science

NTNU
Kunnskap for en bedre verden

Marte Vatn

Sleep characteristics in esport players and associations with game performance

Olympiatoppen
Midt-Norge

Master's thesis in Sport Science
Supervisor: Stig Arve Sæther
Co-supervisor: Frode Moen
May 2021

Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Sociology and Political Science

NTNU
Norwegian University of Science and Technology

Abstract

The current study aimed to examine sleep characteristics in esport players and the stipulated effects of esport game performance on subsequent sleep using residual structural equation modeling (RDSEM). 27 esport players with a mean age of 18 ½ years who performed in the esport game Counter-Strike: Global Offensive (CS: GO) participated in the current study. Sleep was detected over a period of 56 consecutive days with a Somnofy sleep monitor that utilizes an impulse radio ultra-wideband pulse radar and Doppler technology. Results showed that the esport players were in the lower levels of the recommended guidelines for total sleep time and that sleep onset started later and sleep offset ended later than what is found in other sports. Moreover, the sleep efficiency and sleep onset latency found in the current study imply that the esport players struggled to fall asleep at night and had frequent awakenings from sleep onset to sleep offset. The present study results also showed considerable individual differences in sleep between the esport players who participated in the study and that sleep patterns were relatively consistent within players. The esport players displayed stable patterns regarding sleep onset, sleep offset, time in bed, sleep efficiency, and NREM RPM. Unstandardized cross-lagged paths showed that better esport game performance predicted earlier sleep offset. The standardized estimates of the cross-lagged paths revealed that better esport game performance in the current sample was a significant predictor of more time in deep sleep, less time in light sleep and in bed, lower NREM RPM, earlier sleep onset, and earlier sleep offset. The between-person associations showed that the esport players who performed better also had significantly longer total sleep time and scored lower on NREM RPM than the esport players who didn´t score as well on their game performances. The findings are discussed in terms of existing knowledge on the importance of sleep for optimal functioning and in light of the esport players´ game performances.

Sammendrag

Hensikten med denne studien var å undersøke søvn karakteristikk blant esport spillere og den stipulerte effekten av esport spill prestasjoner på påfølgende søvn ved bruk av residual structural equation modeling (RDSEM). 27 esport spillere med en gjennomsnittsalder på 18 ½ år som konkurrerte i esport spillet Counter-Strike Global Offensive (CS: GO) deltok i studien. Søvn ble målt over en periode på 56 sammenhengende dager med en Somnofy søvnmonitor som utnytter radar- og dopplerteknologi. Resultatene viste at esport spillerne var i den nedre grensen av de anbefalte retningslinjene for total søvn tid, og at de sovnet og våknet senere sammenlignet med studier blant andre idrettsutøvere. Videre viste resultatene at esport spillerne brukte relativt lang tid på å sovne, og at de hadde hyppige oppvåkninger fra da de sovnet og til endelig oppvåkning. Resultatene viste også at det var signifikante forskjeller i søvn mellom esport spillerne som deltok i studien og at esport spillerne hadde relativt konsistente individuelle søvnmønstre. Esport spillerne viste stabile mønstre i når de sovnet, når de våknet, tid i sengen, søvneffektivitet, og NREM respirasjonsrate. De ustandardiserte cross-lagged effektene viste at bedre esport spill prestasjon predikerte tidligere oppvåkning. De standardiserte estimatene av cross-lagged effektene viste at i dette utvalget var bedre esport spill prestasjon en betydelig prediker for mer tid i dyp søvn, mindre tid i lett søvn, mindre tid i sengen, lavere NREM respirasjonsrate, tidligere søvnstart, og tidligere oppvåkning. På gruppenivå viste resultatene at bedre esport spill prestasjoner var assosiert med lengre total søvn tid og lavere NREM respirasjonsrate. Funnene er diskutert i lys av eksisterende kunnskap om viktigheten av søvn for optimal funksjon og i lys av esport spillernes spill prestasjoner.

Preface

The planning of this master's project started already in March 2020, when I was so lucky to be invited to join a research project in collaboration with Olympiatoppen, on which this master´s thesis is based[1]. Since then, the road to the completion of this master´s thesis has been a long and challenging process, but first of all a rewarding and educational journey. I feel grateful for having had the opportunity to participate in a significant research project. Skilled professionals have surrounded me and allowed me to familiarize myself with a topic I consider essential and exciting.

Many deserve to acknowledge for help and contributions in the process leading up to completing this project. First of all, I would like to thank Frode Moen, the department head of Olympiatoppen Central Norway, who allowed me to participate in this research project. Your help and constructive guidance throughout the process are also deeply appreciated. Furthermore, I would like to acknowledge my supervisor at NTNU, Stig Arve Sæther. Thank you for all guidance and motivating words throughout the whole process. Additionally, Vera Skalicka deserves recognition for assisting me with the analyzes. Your knowledge and guidance have been essential to produce the results in the present research project. I also greatly appreciate the esport players and their teacher for the hospitality and kindness they met me with. Without your participation, this project would never have been possible, and I hope you will benefit from my work.

Finally, I would like to extend a big thanks to my family, friends, and fellow students for all their support and motivating words throughout the process. All of you made the road more accessible and more rewarding.

Marte Vatn

Trondheim, May 2021

[1] Moen, F., Vatn, M., Olsen, M., Haugan, J. A., & Skalicka, V. (2021). *Sleep characteristics in esport players and associations with game performance: Residual Dynamic Structural Equation Modelling.* Submitted 19. April 2021 to Journal Frontiers in Sports and Active Living.

Table of contents

1.0 Introduction

The esport industry has been rapidly growing during the last decade, with an increasing number of players, tournaments, prize money, audience, and sponsors (Newzoo, 2020). There is, however, important to highlight that there is still an ongoing debate around esport and how to define it. See, for example, the different definitions suggested by Wagner (2006), Newzoo (2020), Pedraza-Ramirez et al. (2020), or Jenny et al. (2017). Although the definitions differ in some areas, one can agree that esport are more comprehensive than just playing video games. To clarify, we will adopt the definition proposed by Pedraza-Ramirez et al. (2020), where esport is defined as the organized and competitive way of playing video games that provide professional and personal development to the player. Moreover, esport is established by ranking systems and are regulated by official leagues. The structure includes mastering expertise in fine motor coordination as well as perceptual cognitive skills of the players (Pedraza-Ramirez et al., 2020).[2]

There are different categories of esport games on the market, and some of the most popular are fighting games, real-time strategy (RTS), first-person shooters (FPS), and multiplayer online battle arena games (MOBA). In esport games, players are typically seated in front of a screen where he/she has to handle the movements and decisions of a virtual avatar through a controller (Sainz et al., 2020). The controller is optimally held by fine motor hand movements of the player, and thus developing fine motor movements are key in esport on an elite level (Bonnar et al., 2019). Moreover, esport games are typically played in dynamic environments, and the players need to process and make quick decisions in response to the rapidly changing information they are exposed to (Bonnar et al., 2019). Accordingly, esport are demanding on several cognitive processes (Bonnar et al., 2019; Martin-Niedecken & Schättin, 2020; Taylor, 2012). Especially expertise within the mental skills that are involved in perceptual cognitive processes are needed (Pedraza-Ramirez et al., 2020). Perceptual cognitive functions such as selective attention, updating, inhibition, cognitive flexibility, working memory, and strategic thinking are all involved in esport games (Bonnar et al., 2019; Martin-Niedecken & Schättin, 2020; Taylor, 2012). Thus, esport players need both physical skills such as fine motor hand movements (Bonnar et al., 2019; Martin-Niedecken & Schättin, 2020), but first of all, their mental skills, such as their perceptual cognitive skills (Martin-Niedecken & Schättin, 2020). Esport players are therefore often referred to as "cognitive athletes" (Martin-Niedecken & Schättin, 2020).

In addition to the fact that esport players are reliant on their cognitive abilities to perform (Bonnar et al., 2019; Martin-Niedecken & Schättin, 2020; Taylor, 2012), the players are constantly faced with being evaluated for their performances in gaming statistics and ranking systems based on the games they complete (Pedraza-Ramirez et al., 2020; Taylor, 2012). Thus, the esport players´ performances are always in focus, which potentially can be a stressor to the players. A stressor can be defined as environmental demands encountered by the individual (Fletcher et al., 2006, p. 9), while the consequence of a stressor is often referred to as the stress response (Selye, 2013). Both internal and external stressors have been identified among high-level competitive esport players (Smith et al., 2019). Internal stressors were associated with issues such as in-game communication, criticism, and lack of confidence, while external stressors included elements such as event audience and media (Smith et al., 2019). Accordingly,

[2] See Pedraza-Ramirez, I., Musculus, L., Raab, M., & Laborde, S. (2020). Setting the scientific stage for esports psychology: A systematic review. *International Review of Sport and Exercise Psychology*, 1-34. https://doi.org/10.1080/1750984X.2020.1723122 for the whole definition.

esport players are faced with pressure to perform at their best in every game they play, and such demands will typically lead to the experience of high loads caused by stress (Fletcher et al., 2006; Hanton et al., 2005; Mellalieu et al., 2009).

Competing in esport are mentally and cognitively demanding, and tools that can optimize the esport players´ cognitive and emotional abilities should therefore be crucial for their performances. According to Bonnar et al. (2019), sleep can be considered as such an element. Indeed, sleep has especially been found to be critical for emotional regulation (Goldstein & Walker, 2014; Mauss et al., 2013; Palmer & Alfano, 2017) and perceptual cognitive functioning (Alhola & Polo-Kantola, 2007; Fullagar et al., 2015; Jarraya et al., 2014; Stickgold, 2005). Also, sleep is essential to ensure optimal daily function and overall health and well-being of esport players (Hirshkowitz et al., 2015; Martin-Niedecken & Schättin, 2020; Watson, 2017). Interestingly, research claims that esport players potentially suffer from suboptimal sleep because of potential risk factors such as caffeine use, competing across multiple time zones, light exposure caused by significant time in front of screens, staying focused over significant periods of time, and potential lack of physical activity (Bonnar et al., 2019).

Stress is found to be a crucial element that disturbs sleep (Eliasson & Vernalis, 2011; Morin et al., 2003). Accordingly, stress related to esport players´ performances might function as an essential element that has implications for their sleep. However, previous research has devoted little attention to the role of esport players´ performances on their subsequent sleep. Also, we still lack empirical studies describing esport players´ sleep patterns to the author´s best knowledge. Therefore, the current study aims to examine sleep characteristics in esport players and investigate whether and how esport game performance are associated with the esport players´ sleep.

1.1 The importance of sleep

Sleep can be explained as an actively regulated process with a reorganization of neural activity (Hobson, 2005). In general, it is a vital element for overall health and well-being, including cognitive performance, physiological process, emotion regulation, and physical development (Hirshkowitz et al., 2015). Sleep is considered the most valued recovery tool for the mind and body because of consolidation and reconstruction of virtually all systems required for human progression (Bonnar et al., 2019; Nédélec et al., 2015; Venter, 2012). Accordingly, sleep is recognized as a crucial element for athletes to ensure adequate recovery from the physical and mental loads they are exposed to (Bird, 2013; Fullagar et al., 2015; O'Donnell et al., 2018; Watson, 2017), enabling progression and performance improvement (Kellmann et al., 2018). Despite this, the guidelines regarding sleep duration and sleep quality for athletes are limited (Watson, 2017). However, there is suggested that athletes may require more sleep than the general population because of the heavy physical and mental stress they are exposed to. Perhaps closer to 9-10 hours of sleep each night (Bird, 2013; Watson, 2017), instead of 7-9 hours which is the general recommendation for young adults (18-25 years) (Hirshkowitz et al., 2015).

In addition to the recommendation of total sleep time, the continuity and regularity of it is also considered as important elements of sleep (Ohayon et al., 2017). Shorter sleep latencies and fewer awakenings after sleep onset are recognized as indicators of good sleep quality. A sleep efficiency of ≥ 85 %, which is the time from sleep onset to wake-up time that was spent asleep, is identified as good sleep quality regardless of age (Ohayon et al., 2017). Moreover, practicing a systematic sleep pattern with regular sleep onset and offset are empathized as important elements of good sleep hygiene and sufficient sleep quality (Brown et al., 2002).

Sleep is typically distributed of a pattern of 4-6 cycles. Each cycle is lasting for about 90 minutes and is divided into rapid-eye-movement sleep (REM or just R) and non-REM sleep (NREM) (Carley & Farabi, 2016). NREM sleep is further divided into light sleep (N1 and N2) and deep sleep (N3, earlier N3 + N4) (Genzel et al., 2014). The different stages have their own adaptive and restorative functions both within the brain and the physiological processes in the body (Siegel, 2005; Stickgold, 2005). The sleep stages are classified according to variables such as electrical brain activity (EEG), eye movements, and the level of muscle tone (Keen & Hirshkowitz, 2011).

When esport players move from wakefulness to sleep they first enter the N1 stage, the lightest stage of NREM sleep (Carley & Farabi, 2016). N1 further follows by N2. N2 is characterized by sleep spindles and K-complexes, occurring on a low-voltage mixed-frequency background EEG and minimal slow-wave activity (Keen & Hirshkowitz, 2011). The light sleep stages (N1 and N2) makes up about 50-55 % of the total sleep time. The light sleep stages are important due to memory consolidation and sensory processing of external stimuli (Czisch et al., 2009). The esport players´ ability to identify and process situations they are exposed to during games are essential for their performances. Memory consolidation is significant since games are played in dynamic changing environments, and the memorizing of practical strategic actions is crucial for the esport players´ future performance development. Attention and working memory are essential in perception and detecting the situations that occur in the game. Attention is the executive brain function that decides what information is placed in working memory, and information about similar situations stored in long term memory is the natural response to the case (Furley & Memmert, 2013). Thus, the execution of decisions in esport games are normally governed by the perceptual cognitive process in the brain, and the light sleep stages are found to have a memory consolidatory function (Genzel et al., 2014). Additionally, light sleep and the sleep spindles that are predominately found in stage N2 of light sleep are associated with improved motor skill learning (Spencer et al., 2017; Walker et al., 2002). Thus, stage N2 of light sleep should be essential for the esport players´ abilities to develop the fine motoric hand-eye coordination skills needed to handle the controller in the games optimally.

After the light sleep stages, a sleep cycle is normally followed by the N3 stage. Stage 3 of NREM sleep is often referred to as deep sleep or slow-wave sleep because of the high-amplitude low-frequency waves seen during this stage (Keen & Hirshkowitz, 2011). N3 is the deepest and most restorative of all sleep stages, where the brain waves, the respiratory system, and muscle activity are at their lowest (Dijk, 2009). Growth hormone is released during this phase (Sassin et al., 1969), and deep sleep is thus recognized as essential for athletes on the basis of the increased need for physical restoration following exercise (Shapiro, 1981). However, more critical for esport players are the function deep sleep has on learning and memory consolidation, especially declarative memory (Aeschbach et al., 2008; Plihal & Born, 1997; Spencer et al., 2017). Declarative memory is vital in esport, since there is a lot of declarative information about the games and the possible functions within the games that have to be learned. Such memory formations are associated with brain plasticity, which refers to the brains´ ability to change and adapt as a result of stimulus and experience (Spencer et al., 2017). Research claims that deep sleep promotes brain plasticity (Spencer et al., 2017). Deep sleep is thus essential for the esport players´ abilities to learn and remember possible functions within the game. The distribution of deep sleep is at its highest in the first half of the night, and deep sleep usually makes up about 20-25% of the total sleep time.

Finally, a regular sleep cycle is further followed by the REM sleep stage. The first REM epoch usually occurs after about 90 minutes of sleep, and the prevalence of REM sleep is typically greater at the end of a night of sleep (Carley & Farabi, 2016). During REM sleep, the brain waves are relatively fast and have low amplitude and is pretty similar to the brain waves during wakefulness (Bjorvatn, 2016). Most of the dreams occur during this stage, the eyes are rapidly moving from side to side, and almost total muscle relaxation is often seen (Bjorvatn, 2016). Thus, esport players will experience dreaming in this sleep stage, and muscle atonia of arms and legs are temporally paralyzing the body to prevent people from acting out their dreams. REM sleep is associated with particularly high neural activity, and has therefore been found to be crucial for memory consolidation (Goldstein & Walker, 2014; Stickgold, 2005), especially procedural memory (Plihal & Born, 1997), and to prepare the organism for emotional functioning the next day (Goldstein & Walker, 2014). Research claims that REM sleep is especially vital due to emotional regulation (Goldstein & Walker, 2014; Palmer & Alfano, 2017). Emotional regulation refers to the process that influences which emotions individuals have, when they have them and how they experience and express these emotions (Gross, 1998, p. 275). In competitive environments, experiences of losses in games, mistakes that should have been avoided, successes in competitions, and critiques from both team players and opponents commonly influence emotional arousals. Emotional regulation is therefore essential among esport players as well as for athletes in any other sports. REM sleep is also associated with increased activation in the primary motor cortex, which indicates that learning and motor memory are associated with this sleep stage (Nishida & Walker, 2007; Walker et al., 2005). Thus, REM sleep should be necessary for emotional recovery and adaption, procedural memory consolidation, and the adaptation of fine motoric skills of the controller among esport players. REM sleep comprises typically about 20-25 % of the total sleep time (Bjorvatn, 2016).

1.2 Detecting sleep and characteristics in sports

The majority of studies that have investigated sleep within sport have measured sleep with actigraphy, a wrist activity monitor that is non-invasive, or sleep questionaries/diaries (Gupta et al., 2017; O'Donnell et al., 2018). These tools are suitable for athletes because they are easy to use and work in less controllable settings (Vlahoyiannis et al., 2020). However, although actigraphy and sleep questionaries/diaries are accepted in the literature, there should be noted that both actigraphy and sleep questionaries/diaries are faced with some methodological challenges (O'Donnell et al., 2018). For instance, actigraphy tends to overestimate total sleep time and sleep efficiency and underestimate sleep latency compared to PSG (Paquet et al., 2007). Similarly, the amount of sleep tends to be overestimated by the respondents in sleep diaries (Mukherjee et al., 2015). Also, neither of these measurements have sleep staging accuracy that is reliable and needed to explore associations between physical and psychological loads and recovery in depth. Only few studies among athletes have measured sleep with polysomnography (PSG), which is considered as the golden standard in objectively measuring sleep (Gupta et al., 2017; O'Donnell et al., 2018; Vlahoyiannis et al., 2020). PSG is precise both due to quality and quantity and is reliable for sleep staging (Vlahoyiannis et al., 2020). Unfortunately, PSG is not very practical in the sport environment because of the laboratory setting and the requirement of specialized skills to run the testing and score the exporting data (O'Donnell et al., 2018; Vlahoyiannis et al., 2020). Even less prevalent is detecting sleep with systems based on DR-technology, an unobtrusive tool for sleep assessment. Interestingly, sleep detected with systems based on DR technology and its associated algorithm has shown great validity compared to PSG (Pallesen et al., 2018). Accordingly, sleep assessment among athletes appears to be faced with some methodological challenges. Therefore, the validity of the current state of research should be carefully considered, and one should be aware of comparing results between studies were different measurement tools have been applied.

A systematic review including athletes between age 18-30 in a veritey of sports found the average total sleep time to be 7 hours and 18 minutes (SD = 42 minutes) each night, and the mean sleep efficiency to be 86 % (SD= 4) (Gupta et al., 2017). Moreover, the study reported that subjective sleep disturbance and insomnia symptomatology are common among athletes. The majority of the included studies used actigraphy or sleep diaries/questionnaires as measurement tool for the sleep assessment, while a few of them used polysomnography (Gupta et al., 2017). Leeder et al. (2012) investigated the sleep characteristics in a sample of 47 Olympic athletes from different sports over four days. Actigraphy was used as a measurement tool, and the athletes´ sleep was compared to an age and sex-matched non-athlete control group with 20 subjects. The average total sleep time among the athletes was 6 hours and 55 minutes (SD = 43 minutes), compared to 7 hours and 11 minutes (SD = 25 minutes) in the control group. Further, Leeder et al. (2012) found the average sleep efficiency to be 80.6 % (SD = 6.4) among the athletes and 88.7 % (SD = 3.6) among the non-athletes. Thus, these findings revealed a lower sleep quality among the Olympic athletes than the group of non-athletes (Leeder et al., 2012). A recent study with a longitudinal design showed that junior elite athletes in sport obtained on average 7 hours and 21 min of sleep per night (SD = 1 hour and 21 minutes) and a sleep efficiency of 89.5 % (SD = 5.5) (Hrozanova et al., 2018). Moreover, the study revealed that junior elite athletes didn’t hold a regular sleep-wake pattern. Instability in sleep parameters at both the micro-level (weekdays/weekend) and the macro-level (period of the annual training plan) was discovered. Sleep was detected with a non-invasive monitor that uses microwave DR-technology (Hrozanova et al., 2018).

Despite these findings, the sleep characteristics of athletes remain somewhat unclear. This may be due to the complexity of sleep and the variety of scenarios athletes are exposed to (Fullagar et al., 2015). For instance, the mental and physical stress athletes face can vary across different sports as well as from day to day, which may affect subsequent sleep patterns (Fullagar et al., 2015). In this regard, it may be a need for more longitudinal studies to follow different processes that can potentially interfere with athletes´ sleep over time. Based on the current research, assessing sleep patterns among athletes remains an essential area for further investigation (Fullagar et al., 2015).

1.3 Sleep and performance in sports

There is a lack of research investigating associations between sleep and performance in esport. However, previous reviews on sleep and performance have revealed a significant amount of evidence providing that sleep deprivation, both partial and total, negatively impacts cognitive performance (Fullagar et al., 2015; O’Donnell et al., 2018; Watson, 2017). The most frequent evaluated cognitive functions include different attention functions, working memory, long-term memory, visuomotor and verbal functions, and decision-making (Alhola & Polo-Kantola, 2007). However, despite that both total and partial sleep deprivation negatively impact cognitive performance, the underlying mechanisms of total and partial sleep deprivation seem to be somewhat different (Alhola & Polo-Kantola, 2007). Moreover, as with sleep in general, individual differences of sleep deprivation on cognitive performance are likely to appear (Alhola & Polo-Kantola, 2007). Nevertheless, although some studies have failed to detect any worsening in cognitive performance following sleep deprivation, the overall importance of sleep for cognitive performance seems to be genuinely documented (Alhola & Polo-Kantola, 2007; Fullagar et al., 2015; O'Donnell et al., 2018; Watson, 2017).

For instance, Edwards and Waterhouse (2009) investigated the effect of partial sleep loss upon throwing dart in 60 participants. The study revealed a link between decrease in alertness and accuracy after sleep loss when performing a psychomotor task that involved hand-eye coordination. Participants threw less accurately and less reliably and missed the target more frequently after a single night of 4 to 5 hours of sleep (Edwards & Waterhouse, 2009). Reyner and Horne (2013) investigated the effect of sleep restriction on serving accuracy among tennis players. The results revealed a significant reduction in doing precision following the sleep restriction period (Reyner & Horne, 2013). In another study, the effects of partial sleep deprivation on cognitive performance was investigated in a sample of twelve male handball goalkeepers (Jarraya et al., 2014). The study revealed a decrease in reaction time and attention following a partial sleep deprivation. Moreover, the cognitive performances decreased from morning to afternoon (Jarraya et al., 2014). While the majority of research has evaluated the effect of sleep deprivation (O'Donnell et al., 2018), Mah et al. (2011) exanimated the effect of extended sleep on athletic performance and a set of mental variables. The sample consisted of eleven male basketball players and the data collection was completed over a period of 5-7 weeks. The total sleep time duration of the participants increased by 110 minutes from baseline to the sleep extension period. It was found a significant improvement in shooting percentage, sprint times, reaction time, mood, fatigue and vigor (subjective feeling of energy and enthusiasm) following increased total sleep time (Mah et al., 2011).

Overall, research claims that sleep is crucial for athletes practicing in sports that require high cognitive capability (Fullagar et al., 2015; O'Donnell et al., 2018; Watson, 2017). Adequate sleep should therefore be key for esport players since they are particularly reliant on their cognitive skills to develop their performances. Interestingly, a recent study among chess players with a measurement that detected sleep staging indicated that sleep was associated with the players´ performances (Moen et al., 2020). Chess players, like esport players, also depend on their perceptual cognitive skills to develop their performances. However, whether it is sleep that is predictive of performance, or performance that is predictive of sleep, is still unclear. In sports where the game performances of the players´ always have a direct consequence for their ranking, such as in esport, their game performances might as well influence the players´ sleep. Thus, their game performances always impact their ranking, and if their performances do not relate to their expectations, they might experience negative stress as a result (Morin et al., 2003). For example, after losing a game, esport players will typically experience negative emotional changes, whereas winning a game will normally increase positive emotions. Indeed, research claims that appraisal, coping, and the emotions they result in are constantly influenced by feedback from how athletes perform (Lazarus, 2000). Coping refers to how people manage stressful conditions and is an essential component of stress and emotional reactions (Lazarus, 1999). Accordingly, if esport players struggle with their performance development and feel little confidence to cope with the demands they are faced with, emotions such as anxiety, panic, and hopelessness are likely to arise (Lazarus, 1999). Importantly, if athletes fail to regulate their stress response and emotions, the experience of stress is expected to sustain (Gross, 2002). There are brain structures and neurochemicals involved in the emotional regulation process, so emotional reactions will normally have implications for the athletes´ subsequent sleep (Palmer & Alfano, 2017). Interestingly, findings have revealed that higher levels of perceived stress are associated with disturbed sleep (Eliasson & Vernalis, 2011) and that arousal before bedtime and coping may have a mediating role in this relationship (Morin et al., 2003). Moreover, research claims that sleep and emotions appear to affect each other in a cycle where the two domains mutually interfere with each other (Kahn et al., 2013). Accordingly, how esport players preform in esport games might as well influence the players´ subsequent sleep.

1.4 The current study

There is a decent of research that investigates associations between sleep and athletic performance (Fullagar et al., 2015; O'Donnell et al., 2018; Watson, 2017). However, research that includes esport players with longitudinal designs and measurements that detect sleep staging is needed to fully understand associations between sleep, different loads, and their performances. Also, whether it is sleep that is predictive of performance, or performance that is predictive of sleep, is still unclear. To the author´s best knowledge, no earlier research has investigated sleep patterns among esport players, and neither how esport game performances are associated with the players´ sleep. Thus, the current study aims to examine sleep characteristics among esport players over time, and investigate whether and how esport game performances influence the players´ subsequent sleep. Since negative stress and emotional reactions are found to be predictive of sleep disturbances (Eliasson & Vernalis, 2011; Fullagar et al., 2015; Morin et al., 2003), we expect that better esport game performance is associated with subsequent better sleep. Therefore, the aims of the current study are twofold: 1) to describe sleep characteristics in esport players, and 2) to investigate potential associations between esport game performance and sleep.

2.0 Material and methods

2.1 Research design

To examine sleep characteristics among esport players, and investigate whether and how esport game performance are associated with the players´ sleep, the researchers in the present study applied a longitudinal design. As a solution to the methodological limitations in previous research in sports, the current study performed objective repeated measures of sleep by employing a novel and fully unobtrusive tool for sleep assessment in esport players. During sleep monitoring, we also performed repeated measures of game performances in esport players participating in the esport game Counter-Strike: Global Offensive (CS: GO). We employed repeated measures of esport game performance and sleep to examine whether and how esport game performance is related to subsequent sleep while taking into account (i) the time ordering of these processes, as well as (ii) their stability (e.g., autoregression of sleep and game performance, respectively). To separate the within-person dynamics from between-person differences in longitudinal intensive data, residual dynamic structural equation modeling (RDSEM) was applied (McNeish & Hamaker, 2020).

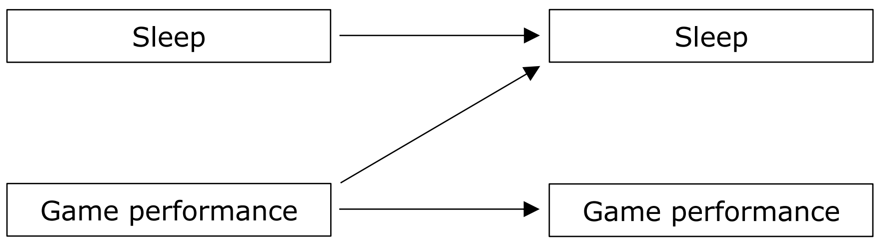

Figure 1: *With repeated measures of esport game performance and sleep, we aimed to examine sleep characteristics in esport players over time and the stipulated effects of esport game performance on subsequent sleep using residual structural equation modeling (RDSEM).*

2.2 Participants

Participants were recruited from a Norwegian high school in Mid-Norway that offers esport as an optional elite sports program subject. An optional elite sport program subject involves 5 hours of weekly training focusing on training planning, basic training, and skill development (Utdanningsdirektoratet, 2006). 32 players studied esport at the recruited school. All of them and the teacher of the players, who also is an esport player, were invited to participate in the current study. The entire group of 33 esport players was given information about the research project at their digital learning platform. The importance was to scope and explain the data collection process in detail. The information was given through the digital platform that the school used because of the COVID-19 virus that expanded in Norway. Out of the 33 esport players who were invited to participate in this study, 27 said yes to participate. The 27 esport players (24 males and 3 females, mean age 18.59 ±SD 2.80, range 17-32 years) were given a consent form approved by the local REC board and an agreement for the use of equipment. The esport players who signed and returned these qualified for participation in the present study.

2.3 Esthetics statement

REC Central, the Regional Committee for Medical and Health Research Ethics in Central Norway, founded on the Norwegian law on research ethics and medical research, has approved the study (project ID 2017/2072/REK midt).

2.4 Procedure

Once the esport players returned the signed consent forms, the necessary equipment for sleep monitoring (Somnofy) was delivered along with instructions for correct use. The equipment was disinfected and packed in a case two days before it was individually delivered to the players because of the COVID-19 pandemic. The esport players were instructed on the correct placement of the sleep monitor and the importance of correct settings for optimal functionality. The esport players received the equipment at least seven days before the data collection started to see that everything worked properly and possibly have time to help them solve potential technical issues with the Somnofy. This was done to ensure no technical problems with the equipment that could interfere with the data collection.

Before the data collection with the Somnofy started, the esport players were invited by mail to complete a survey that included questions about demographics such as age and sex, subjective sleep, and time spent on digital screens each day. The data collection of sleep monitoring lasted for 56 days, from April the 13st to 7st of June 2020, and entailed day-to-day monitoring of the esport players´ sleep patterns. Researchers had access to a real-time overview of each esport player´s compliance with the study. We monitored the progress closely throughout the whole period of 56 days to address and solve any technical issues related to the sleep monitoring systems.

During sleep monitoring, the esport players reported gaming statistics from matches they completed in the esport game Counterstrike: Global Offensive (CS: GO). The esport players were instructed to document gaming statistics from a minimum of five games each week during data collection. If participants could not play five games one week, they were instructed to report statistics from more than five games another week. The requirement was statistics from at least 40 matches during the period of data collection. No maximum limit was set. The teacher of the esport group was in close dialogue with the players throughout the whole period and helped the researchers make sure that everything worked out properly with this part of the data collection.

2.5 Instruments

The instruments used in this study included Somnofy sleep monitor for the measurement of sleep and gaming statistics performed in the esport game CS: GO to measure esport game performances. Additionally, a digital survey was used to collect data about the esport players´ demographics, subjective sleep, and time spent on digital screens each day.

2.5.1 Subjective sleep

The esport players´ perceptions of their sleep routines were measured with a single item for satisfaction about their sleep and if they struggled to fall asleep using a 5-point Likert scale, ranging from 1 (never) to 5 (always): "*Do you feel that you get enough sleep?*" and "*Do you struggle to fall asleep when you go to bed?*".

2.5.2 Screen time

The esport players were also instructed to report the time they usually spent on the following screen activities each day: school, social media (e.g., Snap Chat or Instagram), gaming, streaming (e.g., You Tube or Netflix), and creative work (e.g., photography, video making, music making), using a 5-point Likert scale, where 1 = less than 1 hour, 2 = 2 hours, 3 = 3 hours, 4 = 4 hours, and 5 = 5 hours or more. An estimate of the esport players´ total screen time per day was calculated by summing across all of the five variables.

2.5.3 Objective sleep

The Somnofy sleep monitor is a novel and wholly unobtrusive tool for sleep assessment, which captures respiration and movement data from the person in bed to classify sleep stages using radar technology and machine learning (Toften et al., 2020). More specifically, the Somnofy monitor transmits radio ultra-wideband (IR-UWB) emits in the electromagnetic spectrum. The IR-UWB radar can move through soft materials (e.g., duvets and clothes) but are reflected by denser materials (e.g., human body). As the pulses are reflected, they are restored by the IR-UWB radar again. Further, time-of-flight is used to analyze the time it takes to cover the distance between the radar to the individual and then back to the radar. The sleeping person´s movement and respiration rates are derived from the IR-UWB radar by utilizing the Doppler effect and Fast Fourier Transform (Moen et al., 2020). Thus, Somnofy can monitor the vital signs of the person in bed with high precision and in real-time. The raw data (movement and respiration) from the radar are processed by a sleep algorithm, which uses machine learning to calculate sleep variables (Toften et al., 2020). Recently, Toften et al. (2020) demonstrated that Somnofy is an adequate measure of sleep and wake and can classify sleep stages with substantial agreement against polysomnography (PSG) in a healthy adult population. For this study, the following sleep variables were obtained from the Somnofy monitor: sleep onset, sleep offset, time in bed, sleep onset latency, total sleep time, time in each sleep stage (light, deep, and REM), sleep efficiency, and respiration rate. A short description of the sleep variables detected in the current study is shown in Table 1.

Table 1: *Complete list of sleep variables derived from the sleep algorithm used in the sleep monitor*

Sleep variable	Units	Characteristics of sleep variable
Sleep onset	hh:mm	Time when sleep starts
Sleep offset	hh:mm	Time of wake-up
Time in bed	h	The time spent in bed, including awake time
Sleep onset latency	h	The time it takes from when the participant intends to go to sleep and actually starts to sleep
Total sleep time	h	Total sleep time obtained from sleep onset to time at wake-up
Light sleep	h / %	Total amount of time / proportion in light sleep (stage N1 and N2)
Deep sleep	h / %	Total amount of time / proportion in deep sleep (stage N3)
REM sleep	h / %	Total amount of time / proportion in REM sleep
Sleep efficiency	%	The percentage of time from sleep onset to wake-up time that was spent asleep
NREM RPM	N	The number of respiratory ventilations per one minute

Notes. Abbreviations*: REM = rapid eye movement; NREM RPM = non-rapid eye movement respiration per minute*

2.5.4 Game performance

The esport players´ game performances are based on gaming statistics from games they performed in the esport game Counterstrike Global: Offensive (CS: GO). CS: GO is a multiplayer tactical first-person shooter (FPS) game. In FPS games, the players´ control an avatar from a first-person view, which implies that the only visible thing on the screen is the hands and the weapons that the avatars hold (Jonasson & Thiborg, 2010). CS: GO involves both tactical and precision pressure in a real-time setting of the players (Schmidt et al., 2020). The game provides a great diversity in its strategy skills because it´s played between two teams of five players (Makarov et al., 2018). In CS: GO, the players rank up in competitive matchmaking (Vaz, 2019), where an in-game ranking system sorts players into different groups based on their gaming skills (Poulus et al., 2020). The matchmaking in CS: GO is based on the Glicko-2 ranking system (Glickman, 2012), employing additional factors and modifications to adapt it to 5v5 scenarios (Vaz, 2019). Hence, players compete against random players worldwide ranked on about the same performance level.

For this study, gaming statistics from games the esport players performed in CS: GO (matchmaking mode) were continually documented in a form designed by the researchers. The form included the dates of the games they completed and the esport players´ ratings of kills and deaths in the current game. A weekly game score was obtained by calculating the average kills minus deaths ratings from all the games the players completed the current week. Thus, the weekly game score is used to measure the esport players´ performance the current week, wherein a higher game score indicates better performance. A description of the gaming statistics that were collected and the calculated game score are shown in Table 2.

Table 2: *Variables detected from gaming statistics in CS: GO*

Variable	Description
Games_wx	Total number of games completed week x
K_wx	Total number of kills from all games completed week x
D_wx	Total number of deaths from all games completed week x
Game score	(K_wx-D_wx) / Games_wx = Weekly game score: measure of the esport players´ performance the current week

2.6 Statistical analyses

Descriptive statistics was applied to obtain means and standard deviations for the survey, sleep parameters, and esport game performances. These analyses were conducted using IBM SPSS (version 25.0). Intraclass correlations were computed in Mplus Version 8.1 (Muthén & Muthén, 2017). Residual dynamic structural equation modeling (RDSEM) was applied to examine whether and how esport game performances relate to subsequent sleep in intensive longitudinal data (McNeish & Hamaker, 2020).

RDSEM is a slight variation of the DSEM model, which combines four different modeling techniques: multilevel modeling, time-series modeling, structural equation modeling, and time-varying effects modeling (Asparouhov et al., 2018). The multilevel modeling is based on correlations due to individual-specific impacts, and the time-series modeling is based on correlations due to proximity of observations. The structural equation modeling is based on correlations between different variables, while time-varying effects modeling is based on correlations due to the same stage of evolution. These techniques are used to model different correlations, thereby giving us a broader picture of the dynamics found in intensive longitudinal data (Asparouhov et al., 2018). In the employed RDSEM model, time-series measurements of sleep characteristics and game performance were partitioned into two levels. Level 1 encompasses within-person processes, and Level 2 describes the between-person differences (McNeish & Hamaker, 2020). Also, RDSEM separates the within-level dynamics into two parts: a structural part and an autoregressive residual part. Thus, RDSEM employs a simplified interpretation of the structural part of the model, and the autoregressive part of the model is absorbed in the residuals (Asparouhov et al., 2018). Therefore, RDSEM makes it possible to estimate within-person autoregression between the residuals for sleep characteristics and game performance (i.e., stability), respectively, and within-person regression effects of game performance on sleep characteristics (i.e., cross-lagged effects), while including time as a time-varying covariate. Therefore, we could examine the impact of esport game performance on subsequent sleep characteristics above and beyond preceding sleep. Additionally, RDSEM permits the examination of the between-person associations between game performance and sleep. The conceptual diagram of the employed model is illustrated in Figure 2.

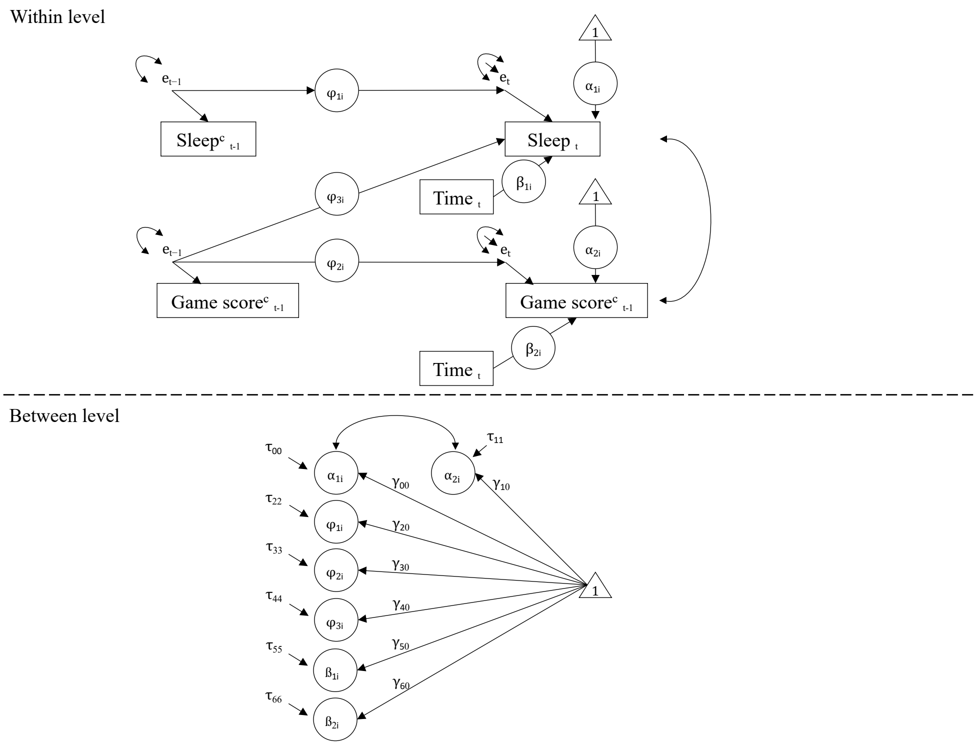

Figure 2: *Conceptual diagram of the employed study model. Level 1 encompasses the within-person dynamics of esport game performance and sleep (autoregression and cross-lagged effects). Level 2 describes the between-person associations between esport game performance and sleep.*

RDSEM was run in Mplus 8.1, using a Bayes full-information estimator with noninformative priors and no auxiliary variables. 2,000 Markov Chain Monte Carlo (MCMC) iterations were used. Ten parallel models for game performance and each sleep characteristics were fitted separately. To account for stability, daily sleep characteristics over a 56-days-period were regressed on sleep characteristics the preceding night (i.e., autoregression). Weekly game performance was also auto-regressed. Because sleep was measured daily, whereas game performance was assessed as a weekly average performance of the preceding six days, these six preceding days were coded as missing. RDSEM employs a Bayesian estimator, which uses all information available and provides estimates unbiased by missingness (Muthén & Asparouhov, 2012; Schuurman et al., 2016). In each model, within-person paths were estimated from game performance in the preceding week predicting subsequent sleep characteristics. RDSEM uses latent centering for all within-person lagged predictors (i.e., sleep and game performance) (Asparouhov & Muthén, 2019). To account for the concurrent associations between sleep and game performance, a covariance between these measures were estimated at Level 1. At the between-person Level 2, a covariance between mean levels of sleep and game performance were estimated. Random effects (i.e., between-person variances) of Level 1 paths (i.e., autoregressive and cross-lagged effects) were estimated at Level 2. To account for temporal trends, the estimates were portioned out from linear trends for each person (Curran & Bauer, 2011). Because Bayesian estimation is used in the residual dynamic structural equation modeling, 95 % credible intervals (CrI) are provided for all models. An estimate is significant if 0 is not within the 95 % credible interval (McNeish & Hamaker, 2020). Besides, R^2 - values, stating the explained variance in sleep, were reported for all models.

3.0 Results

Twenty-seven esport players signed the consent forms and enrolled the study. All of them completed the study. Thus, we have collected data in a sample of 27 esport players (24 males and 3 females, mean age 18.59 ±SD 2.80, range 17-32 years). For the objective sleep data, 1243 or 82%, of the potential 1512 data points of sleep were collected and analyzed. Data was mainly lost due to technical issues with connecting the Somnofy units to wi-fi, especially when participants were travelling away from their homes, such as to their cabins in weekends, and were unable to use the sleep monitoring device because of poor wi-fi connection.

3.1 Descriptive statistics

The esport players´ mean score on their subjective sleep satisfaction was 3.37 (SD=0.63), and their perception about if they struggled to fall asleep was 3.15 (SD=0.95), which indicates that the esport players in the current study only were partly satisfied with their sleep routines. The average time the esport players spent on digital screens during one day was 13.85 hours (SD=3.06), distributed on social media (1.93, SD=1.17), school work (2.59, SD=1.45), gaming (4.27, SD=1.12), streaming (3.33, SD=1.33), and creative work (1.67, SD=.96), which show that the esport players in the current sample spend a high amount of time in front of the screen each day. Table 3 below shows statistics about the esport players´ game performances during the period of data collection.

Table 3: *Descriptive statistics for the esport players´ game performances based on 8 weeks of data collection*

Gaming variable	**N**	**Min**	**Max**	**Mean**	**SD**
Game score_w1	26	-7.20	12.00	3.49	5.03
Game score_w2	26	-5.80	15.33	2.79	5.16
Game score_w3	27	-6.50	15.38	3.40	4.70
Game score_w4	27	-8.40	11.00	3.08	4.62
Game score_w5	27	-6.00	12.40	2.71	4.22
Game score_w6	27	-5.00	10.00	1.83	4.16
Game score_w7	25	-7.60	11.60	1.58	4.82
Game score_w8	26	-6.33	12.20	2.69	4.25

Notes. Abbreviations: *Game score_wx = (K_wx-D_wx) / Games_wx = Weekly gaming score: measure of the esport players´ performance the current week*

The esport players completed in average 5.77 games pr. Week, it was ranging from 0 to 19 games. The total number of games completed during the period was in average 46.15 games per player, ranging from 40 to 67 games. Thus, the data collection resulted in 1246 reported games that were collected and analyzed. Descriptive statistics of the esport players´ sleep patterns are shown in Table 4.

Table 4: *Descriptive statistics for the esport players´ objective sleep patterns based on 1243 nights of data collection*

Sleep variable	**Mean**	**SD**
Sleep onset (hh:mm)	02:09	02:01
Sleep offset (hh:mm)	10:10	02:32
Time in bed (h)	10:58	03:32
Sleep onset latency (h)	00:57	00:54
Total sleep time (h)	07:12	01:54
Light sleep (h) / (%)	04:01 / 55.9	01:17 / 7.5
Deep sleep (h) / (%)	01:23 / 20.0	00:25 / 6.6
REM sleep (h) / %	01:45 / 24.9	00:40 / 6.3
Sleep efficiency (%)	67.7	16.0
NREM RPM	14.75	2.2

Notes. Abbreviations: *REM = rapid eye movement; NREM RPM = non-rapid eye movement respiration per minute*

3.2 Residual Dynamic Structural Equation Modeling

Results from the residual dynamic structural equation modeling (RDSEM) analyses are presented in Table 5. First, we assessed how much variance in sleep that could be attributed to grouping within a person (ICC). The intraclass correlations (ICC) showed that in respect to NREM RPM, sleep efficiency, time in bed, sleep onset, and sleep offset, a considerable proportion of the variation could be attributed to individuals. In contrast, the ICC showed that light sleep, deep sleep, REM sleep, total sleep time, and sleep onset latency did not vary much between individuals but rather between measurement occasions. Further, the R^2 - values showed that the fitted RDSEM models explained between 6% (sleep onset latency) to 42 % (NREM RPM) of the within-person variability in sleep characteristics.

Table 5: *Unstandardized (Unst.) and standardized (St.) estimates*

		Sleep onset				**Sleep offset**				**Time in bed**			
ICC		.40				.29				.41			
DIC		14066.752				15676.156				15449.446			
		Unst.	95 % CrI	*St.*	95 % CrI	Unst.	95 % CI	*St.*	95 % CrI	Unst.	95 % CI	*St.*	95 % CrI
Correlation sleep with game score on the between level	*r*	-.12	-4.07 – 4.07	-.02	-.45 - .42	1.63	-2.05 – 6.67	.23	-.26 - .64	4.79	-.44 – 14.16	.40	-.04 - .72
Means													
Sleep	γ_{00}	26.20	25.56 - 26.94			10.54	9.79 – 11.38			11.09	10.06 - 12.24		
Game score	γ_{10}	3.16	1.13 - 5.16			3.74	1.86 – 5.51			3.67	1.69 – 5.77		
Slope													
Game →Sleep	γ_{40}	-.06	-.21 - .09	***-.09***	***-.23 - -.01***	***-.22***	***-.41 - -.004***	***-.21***	***-.36 - -.09***	-.28	-.61 - .08	***-.16***	***-.27 - -.02***
Autoregression													
Sleep	γ_{20}	***.20***	***.08 - .31***	***.20***	***.10 - .29***	***.02***	***.004 - .07***	***.09***	***.002 - .18***	***.13***	***.01 - .24***	***.13***	***.03 - .23***
Game score	γ_{30}	-.002	-.22 - .23	-.004	-.20 - .20	.07	-.14 - .27	.07	-.13 - .25	-.08	-.29 - .14	-.08	-.27 - .12
Variances													
Sleep	τ_{00}	2.74	1.41 – 5.68			3.50	1.80 – 7.35			7.09	3.45 - 14.56		
Game score	τ_{11}	19.37	9.61 – 42.71			16.00	7.68 – 34.98			22.50	11.41 – 48.27		
Game→Sleep	τ_{44}	.11				.19	.09 - .40			.64	.33 - 1.29		
R^2		.38	.32 - .44			.30	.24 - .37			.39	.33 - .46		

Table 5: *Unstandardized (Unst.) and standardized (St.) estimates*

		Sleep onset latency[1]				Total sleep time				Deep Sleep[2]			
ICC		.14				.06				.11			
DIC		7863.043				14812.543				10129.128			
		Unst.	95 % CrI	*St.*	95 % CrI	Unst.	95 % CrI	*St.*	95 % CrI	Unst.	95 % CI	*St.*	95 % CrI
Correlation sleep with game score on the between level	*r*	-.10	-.30 - .04	-.34	-.72 - .15	***1.14***	***.03 – 3.20***	***.55***	***.01 - .86***	.10	-.24 - .54	.18	-.35 - .63
Means													
Sleep	γ_{00}	.94	.79 – 1.10			7.28	6.99 – 7.60			1.40	1.33 – 1.48		
Game score	γ_{10}	.01	-.33 - .34			3.35	1.40 – 5.28			3.73	1.85 – 5.48		
Slope													
Game →Sleep	γ_{40}	--	--	--	--	-.06	-.22 - .10	-.06	-.22 - .08	.03	-.004 - .05	***.20***	***.05 - .33***
Autoregression													
Sleep	γ_{20}	.03	-.06 - .13	.03	-.05 - .10	-.006	-.10 - .10	-.01	-.09 - .08	.01	-.08 - .10	.01	-.07 - .10
Game score	γ_{30}	.03	-.06 - .13	.03	-.05 - .10	-.11	-.35 - .06	-.10	-.35 - .05	.13	-.25 - .54	.12	-.23 -.53
Variances													
Sleep	τ_{00}	.13	.07 - .27			.29	.09 - .79			.02	.01 - .05		
Game score	τ_{11}	.66	.25 – 1.36			17.08	8.92 – 38.03			15.98	7.94 – 34.92		
Game→Sleep	τ_{44}	--	--			.12	.06 - .24			.002	.001 - .006		
R^2		.06	.03 - .12			.25	.18- .32			.15	.08 - .21		

Table 5: *Unstandardized (Unst.) and standardized (St.) estimates*

		Light sleep				**REM sleep**				**Sleep efficiency**[3]			
ICC		.10				.06				.69			
DIC		13483.111				11815.578				20697.662			
		Unst.	95 % CrI	*St.*	95 % CrI	Unst.	95 % CrI	*St.*	95 % CrI	Unst.	95 % CI	*St.*	95 % CrI
Correlation sleep with game score on the between level	*r*	.75	-.26 – 2.38	.42	-.13 - .77	.32	-.03 - .96	.48	-.04 - .84	1.31	-.21.56 – 25.13	.03	-.43 - .48
Means													
Sleep	γ_{00}	4.10	3.88 – 4.34			1.76	1.66 – 1.87			66.66	62.19 – 71.15		
Game score	γ_{10}	3.29	1.36 – 5.16			3.23	1.39 – 5.08			3.51	1.67 – 5.39		
Slope													
Game →Sleep	γ_{40}	-.07	-.03 - .17	***-.14***	***-.26 - -.004***	-.03	-.08 - .03	-.10	-.24 - .04	.30	-.70 – 1.35	.04	-.10 - .16
Autoregression													
Sleep	γ_{20}	.07	-.03 - .17	.07	-.02 - .16	-.05	-.12 - .04	-.05	-.12 - .03	***.11***	***.01 - .21***	***.10***	***.02 - .19***
Game score	γ_{30}	-.15	-.39 - .10	-.15	-.38 - .08	-.08	-.30 - .12	-.08	-.29 - .11	-.02	-.32 - .29	.01	-.30 - .31
Variances													
Sleep	τ_{00}	.21	.08 - .48			.03	.01 - .08			115.07	61.57 – 232.99		
Game score	τ_{11}	18.10	9.10 – 40.28			16.16	7.90 – 36.24			15.12	7.43 – 33.03		
Game→Sleep	τ_{44}	.05	.03 - .11			.01	.01-.02			3.43	1.39 – 7.68		
R^2		.26	.20 - .32			.22	.16 - .28			.19	.11 - .26		

Table 5: *Unstandardized (Unst.) and standardized (St.) estimates*

		NREM RPM			
ICC		.77			
DIC		11556.281			
		Unst.	95 % CrI	*St.*	95 % CrI
Correlation sleep with game score on the between level	*r*	***-3.86***	***-.10.46 - -.11***	***-.44***	***-.75 - -.02***
Means					
Sleep	γ_{00}	14.60	13.78 – 15.48		
Game score	γ_{10}	3.12	1.08 – 5.05		
Slope					
Game →Sleep	γ_{40}	-.07	-.14 - .003	***-.21***	***-.33 - -.06***
Autoregression					
Sleep	γ_{20}	***.25***	***.13 - .36***	***.25***	***.16 - .33***
Game score	γ_{30}	.05	-.13 - .20	.05	-.10 - .19
Variances					
Sleep	τ_{00}	4.42	2.57 – 8.64		
Game score	τ_{11}	18.15	8.48 – 40.22		
Game→Sleep	τ_{44}	.03	.02 - .06		
R^2		.42	.37 - .47		

[1]Note: in order to reach convergence, this model was fit slightly differently: timepoint and game score were standardized, and several random effects were excluded from the analyzes (including the cross-lagged slope)
[2]Note: 5 clusters were removed
[3]Note: 3 clusters were removed
Note: R^2=explained variance in sleep, ICC=intraclass correlation, DIC= Deviance information criteria, CrI= Credible interval, bold and italics=significant values, Unst.=unstandardized estimate, St.=standardized estimate

Results from the RDSEM (table 5) show that the unstandardized autoregressive values for sleep characteristics were significant for some of the sleep measures (i.e., NREM RPM .25, sleep onset .20, time in bed .13, sleep efficiency .11, and sleep offset .02). These estimates suggest that after a night with rather high or low scores on these sleep characteristics, there is a rather weak tendency to stay high or low on these characteristics, before returning to individual's typical set point. Other sleep characteristics' (i.e. sleep onset latency, total sleep time, light sleep, deep sleep, and REM sleep) autoregressive effects turned non-significant, suggesting a strong attraction to individual's typical values after a night with high or low values. Similarly, there was no significant carry-over effect of preceding game performance on subsequent game performance in this period.

The cross-lagged unstandardized values revealed that, on average and across individuals, weekly game performance did not predict any of the subsequent sleep measures, with one exception: game performance was a significant predictor of sleep offset (-.22). This suggests that esport players who scored higher on their game performance compared to their personal mean would wake up earlier the following day. There was also a considerable variance around this slope (.19, with 95 % credible interval .09 -.40), suggesting that individuals vary in the extent to how much their performance influences their wake-up time. On the between-level, esport players with better game performance spent more time sleeping (total sleep time, r=.55) and scored lower on NREM RPM (r =-.44).

The within-level standardized estimates averaged over clusters cannot be used as an inference about a hypothetical population in the same way as the unstandardized results do, but merely describe associations in the present sample and enable effects comparison across different measures (Schuurman et al., 2016). Thus, the highest carry-over or stability in sleep characteristics was seen in NREM RPM (.25) and sleep onset (.20), whereas the autoregression estimates were smaller in respect to time in bed (.13), sleep efficiency (.10), and sleep offset (.09).

The within-level standardized cross-lagged effect of game performance on sleep was largest in respect to sleep offset (-.21) and NREM RPM (-.21), but it turned-out significant also for other sleep measures (i.e., deep sleep .20, time in bed -.16, light sleep -.14, and sleep onset -.09). These results revealed that in the current sample, players who scored higher in their esport game performance in the preceding week spent subsequently more time in deep sleep, less time in light sleep, scored lower on NREM RPM, spent less time in bed, woke up earlier, and also fell asleep somewhat earlier, compared to their typical personal-specific values.

4.0 Discussion

The current study aimed to examine sleep characteristics in esport players and investigate whether and how esport game performances were associated with the players´ sleep. There are currently no studies that document sleep patterns among esport players to the author´s best knowledge. The results in the current study showed that the esport players were in the lower levels of recommended guidelines for total sleep time and that sleep onset started later and sleep offset ended later than what is found in other sports. Moreover, the sleep efficiency and sleep onset latency found in the present study imply that the esport players struggled to fall asleep at night and had frequent awakenings from sleep onset to sleep offset. The current study results also showed considerable individual differences in sleep between the esport players who participated in the study and that sleep patterns were relatively consistent within players. The within-person standardized values showed that the esport players´ game performances were a significant predictor of sleep onset, sleep offset, NREM RPM, deep sleep, time in bed, and light sleep. The unstandardized estimates of the within-person values showed that the esport players´ game performances only were associated with their sleep offset. Further, the between-person associations showed that those esport players who performed better also had significantly more time in total sleep time and scored lower on NREM RPM. The hypothesis in the current study was thus only partly confirmed. A discussion of the findings will be addressed in the following in terms of existing knowledge on the importance of sleep for optimal functioning, and in light of the esport players´ game performances.

4.1 Sleep characteristics in esport players

4.1.1 Group characteristics

The esport players in the current study obtained a mean of 07:12h (SD=01:54) of total sleep per night during the 56 days of consecutive sleep monitoring. The amount of sleep that was detected is at the minimum level of the recommendations for the general population in this age group (7-9 h) (Hirshkowitz et al., 2015) and below what is suggested as sufficient for athletes (9-10 h) (Bird, 2013; Watson, 2017). Some studies among athletes have shown longer sleep durations (Gupta et al., 2017; Hrozanova et al., 2018), while other studies have detected shorter sleep durations (Leeder et al., 2012; Moen et al., 2020). A recent study in a comparable sport such as chess showed that the esport players in the current research gained more sleep than chess players´ (6:44) in the same age group (Moen, et al., 2020). However, the results in the current study showed that the esport players are fairly dissatisfied with their sleep (mean=3.37, max 5). Thus, both the esport players´ subjective perception of getting enough sleep and the objectively measured sleep indicate that the amount of sleep they obtained only is fairly satisfying. Interestingly, extended sleep beyond the recommendations has been associated with improved athletic performance, such as more significant shooting percentage, faster sprint times, and reaction time (Mah et al., 2011). Moreover, research claims that extended sleep leads to improvements in daytime alertness and mood (Hirshkowitz et al., 2015; Mah et al., 2011). These benefits of extended sleep can be translated to improved performance in esport, and ample sleep might therefore be the difference between success and failure in esport. Thus, there is reason to question whether the amount of sleep detected in the current study is sufficient to ensure optimal preparation of the esport players.

On average, the esport players fell asleep at 02:09 h (SD=02:01) and woke up at 10:10 h (SD=02:32). The sleep onset and offset in the current study showed that sleep started later at night and ended later in the morning compared to what is found among junior athletes in earlier studies (Hrozanova et al., 2018; Moen et al., 2020). An explanation for these findings might be due to the COVID-19 pandemic that took place during sleep monitoring. The esport players had digital home teaching some of the weeks, which consequently may have led to a delay in sleep onset/offset. Especially on weekdays is there reasonable to suggest that the esport players´ normal sleep patterns were altered due to changed routines at school. The digital home teaching might have led to sleep-wake cycles that are comparable with sleep-wake habits at weekends. If this is the case, this is in line with findings showing that both junior athletes (Hrozanova et al., 2018) and youth in general (Saxvig et al., 2012) typically delay their sleep/wake cycles during weekends. However, the school was mainly organized with online digital solutions, and the players were expected to follow ordinary time schedules at school on the digital solutions. Another explanation for the late sleep onset/offset might as well be due to the character of esport, such as gaming across multiple time zones. In esport, the games are played among competitors in every global time zone, and games are therefore played also at night time. Thus, the organizing of esport games might explain why sleep started later at night and ended later in the morning compared to what is found among junior athletes in earlier studies. However, more research is needed before we can draw any conclusions regarding these potential associations.

The sleep efficiency among the esport players was on average 67.7 % (SD=16.0), which is significantly below the recommended levels of ≥ 85 % (Ohayon et al., 2017). The sleep efficiency among the esport players is also lower compared to findings among athletes in earlier studies (Gupta et al., 2017; Hrozanova et al., 2020; Hrozanova et al., 2018; Leeder et al., 2012; Moen et al., 2020). Given that poor sleep efficiency is associated with impaired daytime functioning (Kirmil-Gray et al., 1984), the low sleep efficiency found in the present study is likely to have a determinable effect on the esport players. The sleep onset latency (SOL) showed that the esport players in the current study used 57 minutes (SD=0:54) to fall asleep. The SOL is longer compared to findings among chess players in the same age group (Moen et al., 2020). Interestingly, the relative long SOL can be supported by the esport players´ subjective perception about if they struggle to fall asleep at night (mean=3.15, max 5). Accordingly, these results indicate that the esport players in the current study think they struggle too much to fall asleep at night. Comparable, a systematic review shows that subjective sleep disturbance is common among athletes (Gupta et al., 2017). Interestingly, the sleep efficiency and sleep onset latency found in the current study imply that the esport players both struggled to fall asleep at night and had frequent awakenings from sleep onset to sleep offset. As such, the results revealed a poor sleep quality among the esport players (Ohayon et al., 2017). There might be several explanations for these findings. First of all, there is possible that esport players spend more time on digital devices than other groups of athletes. Indeed, the esport players reported a high amount of time they usually spend on digital screens per day (13h), wherein gaming (4:15), streaming (3:20), and school (2:35) were found to occupy most of their time. Thus, these findings indicate that the esport players in the current study are exposed to a significant amount of light form digital devices each day, which may negatively have influenced their sleep pattern (Chang et al., 2015; Green et al., 2017). Indeed, light exposure from digital screens is associated with a delay of the circadian timing system (Chang et al., 2015). More specifically, this type of light exposure, especially late in the evening, is associated with prolonged sleep onset latency (Chang et al., 2015; Green et al., 2017). Additionally, research claims that digital media negatively impacts adolescents´ sleep efficiency (Fobian et al., 2016). Another potential explanation for the poor sleep quality found in the current study might be the experience of high loads caused by stress. Indeed, stress is considered a common predictor of sleep disturbance (Eliasson & Vernalis, 2011; Morin et al., 2003). Morin et al. (2003) found that higher stress levels during the day were associated with higher cognitive and somatic arousal at bedtime, negatively influencing sleep quality. Earlier findings among athletes have also revealed that sleep onset problems and reduced sleep efficiency are associated with stress (Gupta et al., 2017). Thus, the esport players in the current sample might have appraised their stressors as stressful, which in turn elevated pre-sleep arousal state and subsequent sleep disturbance (Morin et al., 2003).

On average, the esport players´ sleep was disturbed on 55.9 % (SD=7.5) of light sleep, 20.0 % (SD=6.6) of deep sleep, and 24.9 % (SD=6.3) of REM sleep. Thus, the esport players in the current study were in the upper limit of what is recommended of time in light sleep (50-55 %) and REM sleep (20-25 %), and in the lower limit of what is recommended of time in deep sleep (20-25 %). Interestingly, the distribution of time in each sleep stage is roughly the same as what has been found among chess players in the same age group (Moen et al., 2020). Given the importance of deep sleep on learning and memory consolidation, especially declarative memory (Aeschbach et al., 2008; Plihal & Born, 1997; Spencer et al., 2017), deep sleep is a crucial component of learning and development of the cognitive functions that are essential to perform at higher levels in esport. Since the esport players in the current study were in the lower limit of what is recommended of time in deep sleep, one can question whether the amount of deep sleep is sufficient to ensure optimal conditions for adequate recovery and performance progression of the esport players. Thus, there is reason to suggest that the performance development among the esport players could have been optimized with more time in deep sleep and less time in light sleep. However, the distribution of time in each sleep stage doesn’t derivate much from the general recommendations. Additionally, the light sleep stages are also essential for the esport players´ performances, such as memory consolidation and sensory processing of external stimulus (Czisch et al., 2009). Thus, further research is needed before we can conclude whether and how the distribution of time in light/deep sleep impacts the esport players´ future performance development. As opposite, the time the esport players spent in REM sleep was in the upper limit of the recommendations. Thus, one can suggest that the esport players´ conditions were sufficient to take advantage of the benefits of REM sleep, such as emotional recovery and adaptation (Goldstein & Walker, 2014), procedural memory consolidation (Plihal & Born, 1997), and the adaption of fine motoric skills of the controller (Nishida & Walker, 2007; Walker et al., 2005). However, a potential explanation for the relatively high amount of time in REM sleep might be due to exposure to daytime stress arousal that increased the esport players´ need for emotional regulation (Vandekerckhove et al., 2011). Thus, the relatively high amount of REM sleep detected in the current study might be a sign of high loads caused by stress that needed to be processed and regulated during the night. However, we did not collect data on variables such as perceived stress or mental strain. The effects of stress on REM sleep are also limited and somewhat contradictory (Vandekerckhove et al., 2011). Thus, future research should investigate the impact of stress and potential associations with REM sleep. However, later in the discussion, what becomes interesting to discuss is whether and how the esport players´ game performances are associated with their subsequent distribution of time in each sleep stage. Indeed, it is expected that the distribution of time in each sleep stage will differ since the different stages have various tasks in the recovery process and that recovery demands will vary regarding variations in the stress loads that the players are exposed to. Thus, how the esport players perform might explain their subsequent distribution of time in each sleep stage.

4.1.2 Individual sleep patterns

The current study results also showed that the individual sleep patterns among the esport players vary within a particular pattern. The intraclass correlations (ICC) and the autoregressive values indicated individual stable variations for some sleep variables. Results showed regular variations in respect to sleep onset, sleep offset, time in bed, sleep efficiency, and NREM RPM. Accordingly, the present study results indicate that the esport players had stable sleep patterns regarding when they fell asleep and woke up, how much time they spent in their beds, and their sleep efficiency. The NREM respiration rates also showed stable within-person variations. Thus, the current results indicate that sleep patterns among the esport players are individual. A recent study among soccer players´ also confirms that sleep patterns are unique (Costa et al., 2019). Interestingly, the current study results did not find sleep onset latency, light sleep, deep sleep, REM sleep, and total sleep time to have the same individual stable variations. Importantly, and as earlier noted, it is expected that the distribution of sleep stages varies since the different sleep stages have various tasks in the recovery process and that recovery demands will vary regarding variations in the stress loads that the players are exposed to. That's the function sleep has for the mind and body. Accordingly, the current study results are interesting and show the importance of analyzing the distribution of time in each sleep stage as well as the total sleep time when investigating sleep among athletes. The sleep hygiene among the esport players seems to be individual and stable since the results showed that they fell asleep, woke up, and stayed in bed in the same routine time pattern. However, the sleep stages seem to have an individual unstable variation. Accordingly, it is essential with longitudinal designs that use measurements with sleep staging accuracy that is reliable and needed to explore associations between physical and psychological loads and recovery in depth. The current study results also highlight the importance of employing a method that permits separation of within-person variations in sleep from the between-person associations.

4.1.3 Sufficient sleep for adequate recovery?

The findings in the present study give valuable insight into sleep characteristics among esport players and lead to questions whether the measured sleep is sufficient for adequate recovery from the loads these athletes are exposed to. Junior sports athletes, such as the esport players in the current study, are exposed to physical and psychological loads from sport, school work, and social hassles (Moen et al., 2016). Performance impairment, injuries, and athlete burnout are likely to occur if these loads are not appropriately balanced (Moen et al., 2015). Accordingly, a balance between psychophysiological stress loads and recovery is essential for their performance development (Kellmann et al., 2018). Because the esport players´ total sleep time detected in the current study was at the minimum level of the recommendations for the general population in this age group (7-9 h) (Hirshkowitz et al., 2015), one can propose that the total sleep time is not sufficient to ensure optimal preparations of the esport players. Also, the esport players´ sleep efficiency was far below what is identified as good sleep quality (Ohayon et al., 2017). Accordingly, the current study results indicate that the esport players potentially could obtain better recovery and adaption with longer total sleep time and improved sleep efficiencies. With optimized sleep patterns, the esport players may improve their cognitive functions and learning potential, reduce their risk of injuries, and thus improve their performance development and overall health and well-being. Hence, the esport players could benefit from adopting and integrating some of the sleep hygiene recommendations (e.g., stress reduction, ensuring sufficient sleep conditions in the bedroom, and avoiding blue light from screens at least 2 h before bed) to optimize their sleep (Vitale et al., 2019). However, the current study results also showed considerable individual differences between the esport players who participated in the study and that sleep patterns were relatively consistent within players. Thus, the results indicate that sleep characteristics are individual. The present study results might reflect individual differences in sleep needed or significant individual differences in the ability to maintaining sufficient sleep (Hirshkowitz et al., 2015). In this regard, what becomes interesting to discuss in the following, is whether and how the esport players´ game performances are associated with their subsequent sleep. How the esport players perform might explain the quality and quantity of sleep recorded in the current study.

4.2 Sleep and associations with game performance

The unstandardized estimates on the within-level showed that the esport players´ weekly game performances significantly predicted their sleep offset in the following week. Further, the standardized estimates on the within-level showed that better game performance predicted subsequently earlier sleep onset, earlier sleep offset, less time in bed, more time in deep sleep, less time in light sleep, and lower NREM RPM. The results from the RDSEM analysis on the between-level showed that those esport players with better game performances also had significantly longer total sleep time and scored lower on NREM RPM than the esport players who didn´t score as well on their game performances. Thus, the current study results give reason to discuss if better esport game performances are predictive of a better sleep pattern.

Athletes in esport and any sport, who are motivated and spend considerable amounts of time practicing in their sport, will typically expect to improve their performances as athletes. Thus, their performances will usually impact their thoughts, feelings, and experience of stress. Indeed, research claims that appraisal, coping, and the emotions they result in are constantly influenced by feedback from how athletes perform (Lazarus, 2000). Results that confirm personal goals and expectations will typically lead to a positive stress response since the players experience accomplishing sport-specific demands they are exposed to in their games (Pedraza-Ramirez et al., 2020). On the other hand, if game demands exceed their capabilities, it might activate a negative stress response. Importantly, in-game communication, criticism, negative evaluations, and lack of confidence are found to be significant stressors for esport players participating in CS: GO (Smith et al., 2019). Interestingly, research claims that the respiratory ventilation of the body will increase when humans are faced with internal or external stressors (Tipton et al., 2017). As such, the current study results indicate that better esport game performances the preceding week leads to less perceived stress, which in turn leads to a lower respiratory rate during sleep. Comparable, a recent study among chess players showed that players with a positive performance development had a significantly lower respiratory rate than players with a negative performance development over four months (Moen et al., 2020). Accordingly, esport players who are experiencing a positive performance development are mediated of less stress, which might lead to less negative underlying thoughts and emotions before bedtime (Morin et al., 2003). Thus, the esport players´ NREM respiration rates are influenced by the players´ positive and negative stress experiences due to their game performances. This potential explanation can be supported by the fact that stress is considered a common predictor of sleep disturbance (Eliasson & Vernalis, 2011; Morin et al., 2003), likely caused by cognitive and emotional reactions to stress (Baglioni et al., 2010). Interestingly, a recent study among junior athletes has shown that worry and perceived stress were associated with sleep quality (Hrozanova et al., 2019). Thus, esport players experiencing a negative performance development may be at risk of disturbed sleep because of cognitive and emotional reactions caused by stress due to their game performances. Accordingly, better esport game performances might be predictive of a more favorable sleep pattern.

These arguments can also be supported by the solid significant correlations between game performance and NREM RPM (-.44) and between game performance and total sleep time (.55) found in the current study. Interestingly, a longitudinal study among university students found that sleep duration decreased in periods with high stress levels and increased in periods with low stress levels (Hicks & Garcia, 1987). Likewise, Vandekerckhove et al. (2011) found that emotional stressors correlated with decreased total sleep time. As such, the results in the present study indicate that in periods when esport players are experiencing a positive performance development, sleep duration is likely to increase because of lower stress levels. Thus, the total sleep time among esport players might be influenced by the players´ cognitive and emotional reactions to stress due to their esport game performances. These arguments can also be supported by the current study results that showed a strong correlation between game performance and NREM RPM. As earlier noted, research claims that the respiratory ventilation of the body will increase when humans are faced with internal or external stressors (Tipton et al., 2017). Interestingly, the RDSEM revealed that better game performances were associated with a lower NREM respiratory rate at both the within-person dynamics and at the between-person associations, which consequently strengthens this connection and potential associations to cognitive and emotional reactions to stress due to the esport players´ game performances.

Because of potential associations to stress, one can suggest that esport players could benefit from improving their abilities to cope with stressors. Coping is an essential component of stress and emotion reactions (Lazarus, 1999), and coping skills might therefore have a moderating role in the relationship between esport game performance and sleep. Accordingly, coping with stressors might protect esport players against the detrimental effect of a negative performance development on sleep. Interestingly, research claims that social resources are crucial in protecting athletes against worsening in sleep quality when experiencing stress or adversity (Hrozanova et al., 2019). Thus, both personal resources (e.g., coping skills) and social resources (e.g., supportive family and coach) might have a moderating role in how the esport players´ game performances influence the players´ subsequent sleep. Accordingly, the findings in the present study show some of the complexity of skill- and performance development among athletes. Thus, there essential to building an understanding of how different mechanisms affect each other and consequently how this collectively affects the development process of the esport players (Henriksen, 2010). Notably, such factors are determining for the esport players´ future performance development and, as suggested by the results in the current study, essential to enhance the players´ sleep. Accordingly, as with sleep and emotions (Kahn et al., 2013), sleep and esport game performances might affect each other in a cycle where the two domains mutually interfere with each other.

The prediction from game performances of the esport players´ NREM respiration variance and potential associations to stress might also explain the sample-specific findings showing that better game performance was predictive for more time in deep sleep, less time in light sleep and in bed, earlier sleep onset, and earlier sleep offset.

When players experience a negative performance development, they are potentially stimulated to activate adverse cognitive and emotional reactions such as worry and rumination (Brosschot et al., 2005). Such mental and emotional activations will typically keep the stress-related content from resolving and cause the body´s stress response systems to remain activated (Brosschot et al., 2005). Thus, both cognitive activations and potential remained stress activity make it difficult to fall asleep earlier at night, as suggested by the results in the current study showing that better game performance predicted earlier sleep onset. Further, the results in the present study showed that better game performance was predictive of more time in deep sleep and less time in light sleep. Accordingly, esport players who perform better might go to bed in a more relaxed state, making it easier for the body to obtain more time in deep sleep and less time in light sleep during the sleep cycles throughout the night. Indeed, the brain waves, the respiratory system, and muscle activity are at their lowest during deep sleep (Dijk, 2009). Due to the restorative function of deep sleep (Dijk, 2009), players with more time in deep sleep might recover better during the night and wake up earlier as a consequence, as suggested by the results in the current study connecting better esport game performances to subsequent earlier sleep offset.

Overall, the results from the RDSEM analysis indicate that better esport game performances are essential to gain optimal sleep. Thus, the current study results give reason to claim that one crucial tool for optimizing sleep among esport players is to optimize their learning of task-specific capabilities to improve their performances continually.

4.3 Conclusion and limitations

The current study results provide valuable insights into sleep characteristics among esport players and lead to questions whether the measured sleep is sufficient to ensure adequate recovery from the loads these athletes are exposed to. The sleep characteristics detected in the current study indicate that esport players potentially could obtain better recovery and adaption with longer total sleep time and improved sleep efficiencies. However, the results also showed considerable individual differences in sleep between the esport players who participated in the current study and that sleep patterns were relatively consistent within the players. Thus, the present study results indicate that sleep characteristics are individual. Further, the results give important insights into how the esport players' game performances are related to their subsequent sleep, suggesting that improved esport game performance might be an essential tool to enhance esport players´ sleep.

The results that are presented in the current study are interesting. However, several limitations should be kept in mind when interpreting the results. First of all, the present results should be interpreted with the COVID-19 pandemic during data collection. The COVID-19 pandemic might have led to more screen time and less activity, potentially altering the esport players´ regular sleep patterns. Secondly, the findings should be considered given the relatively low number of participants and observed values of game performance, which both influence the power to find significant associations in the multilevel statistical analyses (RDSEM) used in the current study. Additionally, the number of observed values of the game performance was weekly (8) per participant (27) and not daily as was the case for the sleep variables (56), which also possibly influence the power in the RDSEM analyses. Indeed, the majority of the significant results at the within-level were found at the standardized estimates. Thus, future research should investigate the associations found in the current study with a research design that includes more participants and several values on esport game performances than what was the case in the present study. Thirdly, although the sleep monitor applied in the current research has shown great validity against PSG, the derived sleep parameters of the Somnofy are not perfect (Toften et al., 2020). Thus, some measurement errors regarding the sleep variables detected in the present study should be acknowledged. Also, 18 % of all potential data was lost mainly because of difficulties with the local wi-fi network, especially when the esport players stayed at different locations outside their homes. Finally, it is crucial to keep in mind that the current study results could potentially be affected due to other variables that were not included in the present study. Such variables might be training loads, daily stress loads, and coping styles. A better understanding of such variables should be essential due to the verities of processes that potentially can interfere with athletes´ sleep over time (Fullagar et al., 2015). The current study did neither control for sleep during daytime and napping frequency (Petit et al., 2014). Thus, future research should include data on several variables a longitudinal design to control for their effects. Accordingly, still much research remains to fully understand the associations between sleep and esport game performance, including the causal role of performance on sleep and vice versa. Potential interpretations of the current study results must therefore consider these limitations.

References

Aeschbach, D., Cutler, A. J., & Ronda, J. M. (2008). A role for non-rapid-eye-movement sleep homeostasis in perceptual learning. *J Neurosci*, *28*(11), 2766-2772. https://doi.org/10.1523/jneurosci.5548-07.2008

Alhola, P., & Polo-Kantola, P. (2007). Sleep deprivation: Impact on cognitive performance. *Neuropsychiatric disease and treatment*, *3*(5), 553-567. https://pubmed.ncbi.nlm.nih.gov/19300585

Asparouhov, T., Hamaker, E. L., & Muthén, B. (2018). Dynamic Structural Equation Models. *Structural Equation Modeling: A Multidisciplinary Journal*, *25*(3), 359-388. https://doi.org/10.1080/10705511.2017.1406803

Asparouhov, T., & Muthén, B. (2019). Latent Variable Centering of Predictors and Mediators in Multilevel and Time-Series Models. *Structural Equation Modeling: A Multidisciplinary Journal*, *26*(1), 119-142. https://doi.org/10.1080/10705511.2018.1511375

Baglioni, C., Spiegelhalder, K., Lombardo, C., & Riemann, D. (2010). Sleep and emotions: A focus on insomnia. *Sleep Medicine Reviews*, *14*(4), 227-238. https://doi.org/10.1016/j.smrv.2009.10.007

Bird, S. P. (2013). Sleep, recovery, and athletic performance: a brief review and recommendations. *Strength & Conditioning Journal*, *35*(5), 43-47. https://doi.org/10.1519/SSC.0b013e3182a62e2f

Bjorvatn, B. (2016, 2020). *Søvnregistrering og søvnstadier*. https://helse-bergen.no/nasjonal-kompetansetjeneste-for-sovnsykdommer-sovno/sovnregistrering-og-sovnstadier

Bonnar, D., Castine, B., Kakoschke, N., & Sharp, G. (2019). Sleep and performance in Eathletes: for the win! *Sleep health*, *5*(6), 647-650.

Brosschot, J. F., Pieper, S., & Thayer, J. F. (2005). Expanding stress theory: prolonged activation and perseverative cognition. *Psychoneuroendocrinology*, *30*(10), 1043-1049. https://doi.org/10.1016/j.psyneuen.2005.04.008

Brown, F. C., Buboltz, W., Jr., & Soper, B. (2002). Relationship of sleep hygiene awareness, sleep hygiene practices, and sleep quality in university students. *Behavioral Medicine*, *28*(1), 33-38. https://doi.org/10.1080/08964280209596396

Carley, D. W., & Farabi, S. S. (2016). Physiology of Sleep. *Diabetes Spectr*, *29*(1), 5-9. https://doi.org/10.2337/diaspect.29.1.5

Chang, A. M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proc Natl Acad Sci U S A*, *112*(4), 1232-1237. https://doi.org/10.1073/pnas.1418490112

Costa, J., Figueiredo, P., Nakamura, F., Rago, V., Rebelo, A., & Brito, J. (2019). Intra-individual variability of sleep and nocturnal cardiac autonomic activity in elite female soccer players during an international tournament. *PLOS one*, *14*(9), e0218635. https://doi.org/10.1371/journal.pone.0218635

Curran, P. J., & Bauer, D. J. (2011). The disaggregation of within-person and between-person effects in longitudinal models of change. *Annu Rev Psychol*, *62*, 583-619. https://doi.org/10.1146/annurev.psych.093008.100356

Czisch, M., Wehrle, R., Stiegler, A., Peters, H., Andrade, K., Holsboer, F., & Sämann, P. G. (2009). Acoustic oddball during NREM sleep: a combined EEG/fMRI study. *PLOS one*, *4*(8), e6749. https://doi.org/10.1371/journal.pone.0006749

Dijk, D.-J. (2009). Regulation and functional correlates of slow wave sleep. *Journal of Clinical Sleep Medicine*, *5*(2 suppl), S6-S15.

Edwards, B., & Waterhouse, J. (2009). Effects of One Night of Partial Sleep Deprivation upon Diurnal Rhythms of Accuracy and Consistency in Throwing Darts. *Chronobiology international*, *26*, 756-768. https://doi.org/10.1080/07420520902929037

Eliasson, A., & Vernalis, M. (2011). Perceived stress correlates with disturbed sleep: A link connecting stress and cardiovascular disease. *Stress (Amsterdam, Netherlands)*, *15*, 45-51. https://doi.org/10.3109/10253890.2011.578266

Fletcher, D., Hanton, S., & Mellalieu, S. (2006). An organisational stress review: Conceptual and theoretical issues in competitive sport. In S. Hanton & S. Mellalieu (Eds.), *Litterature Reviews in Sport Psychology* (pp. 321-374). Nova Science Publishers.

Fobian, A. D., Avis, K., & Schwebel, D. C. (2016). Impact of Media Use on Adolescent Sleep Efficiency. *J Dev Behav Pediatr*, *37*(1), 9-14. https://doi.org/10.1097/DBP.0000000000000239

Fullagar, H. H., Skorski, S., Duffield, R., Hammes, D., Coutts, A. J., & Meyer, T. (2015). Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports medicine*, *45*(2), 161-186. https://doi.org/10.1007/s40279-014-0260-0

Furley, P., & Memmert, D. (2013). "Whom Should I Pass To?" The More Options the More Attentional Guidance from Working Memory. *PLOS one*, *8*(5), e62278. https://doi.org/10.1371/journal.pone.0062278

Genzel, L., Kroes, M. C. W., Dresler, M., & Battaglia, F. P. (2014). Light sleep versus slow wave sleep in memory consolidation: a question of global versus local processes? *Trends in Neurosciences*, *37*(1), 10-19. https://doi.org/doi.org/10.1016/j.tins.2013.10.002

Glickman, M. E. (2012). Example of the Glicko-2 system. *Boston University*, 1-6.

Goldstein, A. N., & Walker, M. P. (2014). The Role of Sleep in Emotional Brain Function. *Annual Review of Clinical Psychology*, *10*(1), 679-708. https://doi.org/10.1146/annurev-clinpsy-032813-153716

Green, A., Cohen-Zion, M., Haim, A., & Dagan, Y. (2017). Evening light exposure to computer screens disrupts human sleep, biological rhythms, and attention abilities. *Chronobiology international*, *34*(7), 855-865. https://doi.org/10.1080/07420528.2017.1324878

Gross, J. (1998). The emerging field of emotion regulation: An integrative review. *Review of general psychology*, *2*(3), 271-299.

Gross, J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*(3), 281-291. https://doi.org/10.1017/S0048577201393198

Gupta, L., Morgan, K., & Gilchrist, S. (2017). Does elite sport degrade sleep quality? A systematic review. *Sports medicine*, *47*(7), 1317-1333. https://doi.org/10.1007/s40279-016-0650-6

Hanton, S., Fletcher, D., & Coughlan, G. (2005). Stress in elite sport performers: A comparative study of competitive and organizational stressors. *Journal of sports sciences*, *23*, 1129-1141. https://doi.org/10.1080/02640410500131480

Henriksen, K. (2010). The ecology of talent development in sport: A multiple case study of successful athletic talent development environments in Scandinavia.

Hicks, R. A., & Garcia, E. R. (1987). Level of Stress and Sleep Duration. *Perceptual and Motor Skills*, *64*(1), 44-46. https://doi.org/10.2466/pms.1987.64.1.44

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., Hazen, N., Herman, J., Adams Hillard, P. J., Katz, E. S., Kheirandish-Gozal, L., Neubauer, D. N., O'Donnell, A. E., Ohayon, M., Peever, J., Rawding, R., Sachdeva, R. C., Setters, B., Vitiello, M. V., & Ware, J. C. (2015). National Sleep Foundation's updated sleep duration recommendations: final report. *Sleep health*, *1*(4), 233-243. https://doi.org/10.1016/j.sleh.2015.10.004

Hobson, J. (2005). Sleep is of the brain, by the brain and for the brain. *Nature*, *437*, 1254-1256. https://doi.org/10.1038/nature04283

Hrozanova, M., Klöckner, C. A., Sandbakk, Ø., Pallesen, S., & Moen, F. (2020). Reciprocal Associations Between Sleep, Mental Strain, and Training Load in Junior Endurance Athletes and the Role of Poor Subjective Sleep Quality [Original Research]. *Frontiers in Psychology*, *11*(2498). https://doi.org/10.3389/fpsyg.2020.545581

Hrozanova, M., Moen, F., Myhre, K., Klöckner, C., & Pallesen, S. (2018). Habitual sleep patterns of junior elite athletes in cross-country skiing and biathlon: A descriptive study. *Cogent Medicine*, *5*(1). https://doi.org/10.1080/2331205X.2018.1548549

Hrozanova, M., Moen, F., & Pallesen, S. (2019). Unique Predictors of Sleep Quality in Junior Athletes: The Protective Function of Mental Resilience, and the Detrimental Impact of Sex, Worry and Perceived Stress [Original Research]. *Frontiers in Psychology*, *10*(1256). https://doi.org/10.3389/fpsyg.2019.01256

Jarraya, S., Jarraya, M., Chtourou, H., & Souissi, N. (2014). Effect of time of day and partial sleep deprivation on the reaction time and the attentional capacities of the handball goalkeeper. *Biological Rhythm Research*, *45*(2), 183-191. https://doi.org/10.1080/09291016.2013.787685

Jenny, S. E., Manning, R. D., Keiper, M. C., & Olrich, T. W. (2017). Virtual(ly) Athletes: Where eSports Fit Within the Definition of "Sport". *Quest (00336297)*, *69*(1), 1-18. https://doi.org/10.1080/00336297.2016.1144517

Jonasson, K., & Thiborg, J. (2010). Electronic sport and its impact on future sport. *Sport in Society*, *13*(2), 287-299. https://doi.org/10.1080/17430430903522996

Kahn, M., Sheppes, G., & Sadeh, A. (2013). Sleep and emotions: bidirectional links and underlying mechanisms. *Int J Psychophysiol*, *89*(2), 218-228. https://doi.org/10.1016/j.ijpsycho.2013.05.010

Keen, S., & Hirshkowitz, M. (2011). Monitoring and staging human sleep. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), *Principles and practice of sleep medicine* (pp. 1602-1609). Elsevier Saunders.

Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts, A. J., Duffield, R., Erlacher, D., Halson, S. L., Hecksteden, A., Heidari, J., Kallus, K. W., Meeusen, R., Mujika, I., Robazza, C., Skorski, S., Venter, R., & Beckmann, J. (2018). Recovery and Performance in Sport: Consensus Statement. *International Journal of Sports Physiology and Performance*, *13*(2), 240-245. https://doi.org/10.1123/ijspp.2017-0759

Kirmil-Gray, K., Eagleston, J. R., Gibson, E., & Thoresen, C. E. (1984). Sleep disturbance in adolescents: Sleep quality, sleep habits, beliefs

about sleep, and daytime functioning. *Journal of Youth and Adolescence*, *13*(5), 375-384. https://doi.org/10.1007/BF02088636
Lazarus, R. S. (1999). *Stress and emotion: a new synthesis*. Springer Publishing Company, Inc.
Lazarus, R. S. (2000). How emotions influence performance in competitive sports. *The Sport Psychologist*, *14*(3), 229-252.
Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., & Pedlar, C. (2012). Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *J Sports Sci*, *30*(6), 541-545. https://doi.org/10.1080/02640414.2012.660188
Mah, C. D., Mah, K. E., Kezirian, E. J., & Dement, W. C. (2011). The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*, *34*(7), 943-950. https://doi.org/10.5665/SLEEP.1132
Makarov, I., Savostyanov, D., Litvyakov, B., & Ignatov, D. I. (2018). Predicting winning team and probabilistic ratings in "Dota 2" and "Counter-Strike: Global Offensive" video games. *International Conference on Analysis of Images, Social Networks and Texts*, 183-196. https://doi.org/10.1007/978-3-319-73013-4_17
Martin-Niedecken, A. L., & Schättin, A. (2020). Let the Body'n'Brain Games Begin: Toward Innovative Training Approaches in eSports Athletes. *Front Psychol*, *11*, 138. https://doi.org/10.3389/fpsyg.2020.00138
Mauss, I. B., Troy, A. S., & LeBourgeois, M. K. (2013). Poorer sleep quality is associated with lower emotion-regulation ability in a laboratory paradigm. *Cognition & emotion*, *27*(3), 567-576. https://doi.org/10.1080/02699931.2012.727783
McNeish, D., & Hamaker, E. L. (2020). A primer on two-level dynamic structural equation models for intensive longitudinal data in Mplus. *Psychol Methods*, *25*(5), 610-635. https://doi.org/10.1037/met0000250
Mellalieu, S., Neil, R., Hanton, S., & Fletcher, D. (2009). Competition stress in sport performers: Stressors experienced in the competition environment. *Journal of sports sciences*, *27*, 729-744. https://doi.org/10.1080/02640410902889834
Moen, F., Federici, R. A., & Abrahamsen, F. (2015). Examining Possible Relationships between Self-Determination and Burnout among Junior Athletes in Sport. *International Journal of Coaching Science*, *9*(2), 43-58.

Moen, F., Myhre, K., & Sandbakk, O. (2016). Psychological Determinants of Burnout, Illness and Injury among Elite Junior Athletes. *The Sport Journal*.
Moen, F., Olsen, M., & Hrozanova, M. (2020). Associations between sleep patterns and performance development among Norwegian chess players. *Frontiers in Psychology*, *11*, 1855. https://doi.org/10.3389/fpsyg.2020.01855
Morin, C. M., Rodrigue, S., & Ivers, H. (2003). Role of Stress, Arousal, and Coping Skills in Primary Insomnia. *Psychosomatic Medicine*, *65*(2), 259-267. https://doi.org/10.1097/01.Psy.0000030391.09558.A3
Mukherjee, S., Patel, S. R., Kales, S. N., Ayas, N. T., Strohl, K. P., Gozal, D., & Malhotra, A. (2015). An Official American Thoracic Society Statement: The Importance of Healthy Sleep. Recommendations and Future Priorities. *American Journal of Respiratory and Critical Care Medicine*, *191*(12), 1450-1458. https://doi.org/10.1164/rccm.201504-0767ST
Muthén, B., & Asparouhov, T. (2012). Bayesian Structural Equation Modeling: A More Flexible Representation of Substantive Theory. *Psychol Methods*, *17*(3), 313-335. https://doi.org/10.1037/a0026802
Muthén, L. K., & Muthén, B. (2017). *Mplus User's Guide*. Muthén & Muthén.
Nédélec, M., Halson, S., Abaidia, A.-E., Ahmaidi, S., & Dupont, G. (2015). Stress, Sleep and Recovery in Elite Soccer: A Critical Review of the Literature. *Sports medicine*, *45*(10), 1387-1400. https://doi.org/10.1007/s40279-015-0358-z
Newzoo. (2020). *Global Esports Market Report*. Newzoo. https://newzoo.com/insights/trend-reports/newzoo-global-esports-market-report-2020-light-version/
Nishida, M., & Walker, M. (2007). Daytime Naps, Motor Memory Consolidation and Regionally Specific Sleep Spindles. *PLOS one*, *2*, e341. https://doi.org/10.1371/journal.pone.0000341
O'Donnell, S., Beaven, C. M., & Driller, M. W. (2018). From pillow to podium: a review on understanding sleep for elite athletes. *Nature and science of sleep*, *10*, 243. https://doi.org/10.2147/NSS.S158598
Ohayon, M., Wickwire, E. M., Hirshkowitz, M., Albert, S. M., Avidan, A., Daly, F. J., Dauvilliers, Y., Ferri, R., Fung, C., Gozal, D., Hazen, N., Krystal, A., Lichstein, K., Mallampalli, M., Plazzi, G., Rawding, R., Scheer, F. A., Somers, V., & Vitiello, M. V. (2017). National Sleep

Foundation's sleep quality recommendations: first report. *Sleep health*, *3*(1), 6-19. https://doi.org/10.1016/j.sleh.2016.11.006

Pallesen, S., Grønli, J., Myhre, K., Moen, F., Bjorvatn, B., Hanssen, I., & Heglum, H. (2018). A Pilot Study of Impulse Radio Ultra Wideband Radar Technology as a New Tool for Sleep Assessment. *Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine*, *14*. https://doi.org/10.5664/jcsm.7236

Palmer, C. A., & Alfano, C. A. (2017). Sleep and emotion regulation: An organizing, integrative review. *Sleep Med Rev*, *31*, 6-16. https://doi.org/10.1016/j.smrv.2015.12.006

Paquet, J., Kawinska, A., & Carrier, J. (2007). Wake detection capacity of actigraphy during sleep. *Sleep*, *30*(10), 1362-1369. https://doi.org/10.1093/sleep/30.10.1362

Pedraza-Ramirez, I., Musculus, L., Raab, M., & Laborde, S. (2020). Setting the scientific stage for esports psychology: A systematic review. *International Review of Sport and Exercise Psychology*, 1-34. https://doi.org/10.1080/1750984X.2020.1723122

Petit, E., Mougin, F., Bourdin, H., Tio, G., & Haffen, E. (2014). A 20-min nap in athletes changes subsequent sleep architecture but does not alter physical performances after normal sleep or 5-h phase-advance conditions. *Eur J Appl Physiol*, *114*(2), 305-315. https://doi.org/10.1007/s00421-013-2776-7

Plihal, W., & Born, J. (1997). Effects of early and late nocturnal sleep on declarative and procedural memory. *J Cogn Neurosci*, *9*(4), 534-547. https://doi.org/10.1162/jocn.1997.9.4.534

Poulus, D., Coulter, T. J., Trotter, M. G., & Polman, R. (2020). Stress and coping in esports and the influence of mental toughness. *Frontiers in Psychology*, *11*, 628. https://doi.org/10.3389/fpsyg.2020.00628

Reyner, L. A., & Horne, J. A. (2013). Sleep restriction and serving accuracy in performance tennis players, and effects of caffeine. *Physiol Behav*, *120*, 93-96. https://doi.org/10.1016/j.physbeh.2013.07.002

Sainz, I., Collado-Mateo, D., & Coso, J. D. (2020). Effect of acute caffeine intake on hit accuracy and reaction time in professional e-sports players. *Physiol Behav*, *224*, 113031. https://doi.org/10.1016/j.physbeh.2020.113031

Sassin, J. F., Parker, D. C., Mace, J. W., Gotlin, R. W., Johnson, L. C., & Rossman, L. G. (1969). Human Growth Hormone Release: Relation to Slow-Wave Sleep and Sleep-Waking Cycles. *Science (American Association for the Advancement of Science)*, *165*(3892), 513-515. https://doi.org/10.1126/science.165.3892.513

Saxvig, I. W., Pallesen, S., Wilhelmsen-Langeland, A., Molde, H., & Bjorvatn, B. (2012). Prevalence and correlates of delayed sleep phase in high school students. *Sleep Medicine*, *13*(2), 193-199. https://doi.org/10.1016/j.sleep.2011.10.024

Schmidt, S. C., Gnam, J.-P., Kopf, M., Rathgeber, T., & Woll, A. (2020). The influence of cortisol, flow, and anxiety on performance in e-sports: A field study. *BioMed research international*, *2020*. https://doi.org/10.1155/2020/9651245

Schuurman, N., Ferrer, E., Boer-Sonnenschein, M., & Hamaker, E. (2016). How to Compare Cross-Lagged Associations in a Multilevel Autoregressive Model. *Psychological Methods*, *21*. https://doi.org/10.1037/met0000062

Selye, H. (2013). *Stress in health and disease*. Butterworth-Heinemann.

Shapiro, C. M. (1981). Sleep and the athlete. *Br J Sports Med*, *15*(1), 51-55. https://doi.org/10.1136/bjsm.15.1.51

Siegel, J. M. (2005). Clues to the functions of mammalian sleep. *Nature*, *437*(7063), 1264-1271. https://doi.org/10.1038/nature04285

Smith, M. J., Birch, P. D. J., & Bright, D. (2019). Identifying Stressors and Coping Strategies of Elite Esports Competitors. *International Journal of Gaming and Computer-Mediated Simulations*, *11*(2), 22-39. https://doi.org/10.4018/ijgcms.2019040102

Spencer, R. M. C., Walker, M. P., & Stickgold, R. (2017). Sleep and Memory Consolidation. In S. Chokroverty (Ed.), *Sleep Disorders Medicine* (pp. 205-223). Springer. https://doi.org/10.1007/978-1-4939-6578-6_13

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature*, *437*(7063), 1272-1278. https://doi.org/10.1038/nature04286

Taylor, T. L. (2012). *Raising the stakes: E-sports and the professionalization of computer gaming*. Mit Press.

Tipton, M. J., Harper, A., Paton, J. F. R., & Costello, J. T. (2017). The human ventilatory response to stress: rate or depth? *The Journal of Physiology*, *595*(17), 5729-5752. https://doi.org/doi.org/10.1113/JP274596

Toften, S., Pallesen, S., Hrozanova, M., Moen, F., & Grønli, J. (2020). Validation of sleep stage classification using non-contact radar technology and machine learning (Somnofy®). *Sleep Medicine*, *75*. https://doi.org/10.1016/j.sleep.2020.02.022

Utdanningsdirektoratet. (2006). *Læreplan i toppidrett- valgfrie programfag i utdanningsprogram for idrettsdag*. https://www.udir.no/kl06/IDR5-01

Vandekerckhove, M., Weiss, R., Schotte, C., Exadaktylos, V., Haex, B., Verbraecken, J., & Cluydts, R. (2011). The role of presleep negative emotion in sleep physiology. *Psychophysiology*, *48*(12), 1738-1744. https://doi.org/10.1111/j.1469-8986.2011.01281.x

Vaz, C. (2019, 27. March). *CS:GO - Ranks guide (How to rank up in Competitive matchmaking)*. https://www.metabomb.net/csgo/gameplay-guides/csgo-ranks-guide-how-to-rank-up-in-competitive-matchmaking

Venter, R. (2012). Role of sleep in performance and recovery of athletes: A review article. *South African Journal for Research in Sport, Physical Education and Recreation*, *34*, 167-184.

Vitale, K. C., Owens, R., Hopkins, S. R., & Malhotra, A. (2019). Sleep Hygiene for Optimizing Recovery in Athletes: Review and Recommendations. *Int J Sports Med*, *40*(8), 535-543. https://doi.org/10.1055/a-0905-3103

Vlahoyiannis, A., Sakkas, G. K., Manconi, M., Aphamis, G., & Giannaki, C. D. (2020). A critical review on sleep assessment methodologies in athletic populations: factors to be considered. *Sleep Medicine*, *74*, 211-223. https://doi.org/10.1016/j.sleep.2020.07.029

Wagner, M. G. (2006). On the Scientific Relevance of eSports. International conference on internet computing,

Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with Sleep Makes Perfect: Sleep-Dependent Motor Skill Learning. *Neuron*, *35*(1), 205-211. https://doi.org/10.1016/S0896-6273(02)00746-8

Walker, M. P., Stickgold, R., Alsop, D., Gaab, N., & Schlaug, G. (2005). Sleep-dependent motor memory plasticity in the human brain. *Neuroscience*, *133*(4), 911-917. https://doi.org/10.1016/j.neuroscience.2005.04.007

Watson, A. M. (2017). Sleep and athletic performance. *Current sports medicine reports*, *16*(6), 413-418. https://doi.org/10.1249/JSR.0000000000000418

Appendix

Appendix 1: Information form

NTNU
Senter for
toppidrettsforskning

NORGE
Olympiatoppen
Midt-Norge

Forespørsel om deltakelse i forskningsprosjektet

Søvn og Prestasjoner i e-sport
Dette er et spørsmål til deg om å delta i et forskningsprosjekt for å undersøke mulige sammenhenger mellom søvn, opplevd stress/belastning og prestasjon i e-sport. Du er valgt ut til dette studiet, fordi du er en del av et idrettsmiljø innenfor e-sport som vi har valgt å følge over en periode på ca. åtte uker. NTNU ved Senter for Toppidrettsforskning i samarbeid med Olympiatoppen Midt-Norge er ansvarlig for studien.

Hva innebærer PROSJEKTET?
Du vil i en periode på ca. åtte uker bli bedt om å plassere en radar (Somnofy) på nattbordet ved sengen din. Denne radaren registrerer din søvn ved hjelp av avanserte algoritmer som benytter bevegelsesdata fra radaren. Du vil kunne få en oversikt over din søvn hver morgen via en mobil applikasjon om du skulle ønske dette. Skal du ut å reise under prosjektperioden lar du radaren stå igjen på nattbordet ved sengen din, søvnregistreringen vil gjenopptas når du er tilbake igjen. I tillegg til søvnregistrering innebærer deltakelse i prosjektet at du fyller ut et ukentlig spørreskjema. Spørreskjemaet inneholder spørsmål om blant annet belastning, stress, subjektiv opplevelse av søvn og skjermbruk. Frivillig deltakelse og mulighet for å trekke sitt samtykke. Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte:

Marte Vatn: Mobil: 91 70 00 44, Mail: vamarte@online.no
Eller Frode Moen: Mobil: 93 24 87 50, Mail: frode.moen@ntnu.no

Hva skjer med informasjonen om deg?
Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Anonymiserte data vil i tillegg bli benyttet til å videreutvikle algoritmer knyttet til søvnanalyser. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert. Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger gjennom en navneliste. Prosjektleder har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Informasjon om deg vil bli anonymisert eller slettet senest fem år etter prosjektslutt.

Godkjenning
Prosjektet er godkjent av Regional komite for medisinsk og helsefaglig forskningsetikk, saksnr. hos REK (2017/ 2072).

Samtykke til deltakelse i PROSJEKTET

Jeg er villig til å delta i prosjektet

Sted og dato	Deltakers signatur
	Deltakers navn med trykte bokstaver

Appendix 2: Agreement for use of the equipment

NTNU
Senter for toppidrettsforskning

NORGE
Olympiatoppen Midt-Norge

Avtale for bruk av utstyret i forskningsprosjektet Søvn i relasjon til prestasjoner og belastning i e-sport

Dette er en avtale for bruk av utstyret i forskningsprosjektet du deltar på. Utstyret er levert av NTNU / OLTMN for å gjennomføre datainnsamling i forskningsprosjektet. I løpet av prosjektperioden får du benytte deg av dette utstyret:

Somnofy søvnmonitor basert på radarteknologi
Kabel til Somnofy
Strømforsyning
Modem med simkort og kabel som kun skal benyttes til dataoverføring fra Somnofy

Dine forpliktelser i dette prosjektet

Ved å signere denne avtalen…

… Jeg forplikter meg å bruke alt av utstyret i hele perioden av datainnsamling (8 sammenhengende uker).

… Jeg forplikter meg for å ta vare på alt utstyret.

… Jeg forplikter meg til å kontakte Frode Moen (93248750, Mail: frode.moen@ntnu.no) eller Marte Vatn (91700044, vamarte@online.no) umiddelbart, dersom noe skulle skje med utstyret.

… Jeg forplikter meg å levere alt av utstyret tilbake etter datainnsamling, i samme stand jeg fikk det.

Samtykke

Sted og dato Deltakers signatur

Deltakers navn med trykte bokstaver

Appendix 3: REC application

Prosjektsøknad Skjema for søknad om godkjenning av forskningsprosjekt i de regionale komiteer for medisinsk og helsefaglig forskningsetikk (REK)

Dokument-id: 725589

Søvn og stress i toppidrett

1. Generelle opplysninger

1.1 Prosjektleder

Navn:	FRODE MOEN
Akademisk grad:	PHD
Stilling:	AMANUENSIS
Hovedarbeidssted:	NTNU
Arbeidsadresse:	Pedagogisk institutt
Postnummer:	7020
Sted:	Trondheim
Telefon:	93248750
E-post adresse:	frode.moen@ntnu.no

1.2 Prosjekttittel

Norsk tittel	Søvn og stress i toppidrett
Vitenskapelig tittel	Sleep and stress in elite sport

1.3 Forskningsansvarlig

Institusjon	Kontaktperson	Stilling	E-post adresse
1. Norges teknisk-naturvitenskapelige universitet	Frode Moen	Amanuensis	frode.moen@ntnu.no

1.4 Initiativtaker

Hvem er initiativtaker til prosjektet?	Prosjektleder og/eller

	forskningsansvarlig institusjon (bidragsforskning)

1.5 Utdanningsprosjekt

Er prosjektet del av en utdanning eller doktorgrad?	Nei

1.6 Prosjektmedarbeidere

Navn	Stilling	Institusjon	Akademisk rolle	Prosjektrolle
1. Hrozanova	Vitenskapelig assistent	NTNU	MA	Medarbeider

1.7 Tidsramme for prosjektet

Prosjektstart dato	01.01.2018
Prosjektslutt dato	31.12.2020

1.8 Offentlig innsyn

Søkes det om unntak fra offentlig innsyn i søknad eller vedlegg?	Nei

1.9 Samarbeid med utlandet

Har prosjektet noen form for samarbeid med utlandet?	Nei

1.10 Annet prosjekt med betydning for vurderingen

Er det noe annet prosjekt som kan ha betydning for vurderingen av det aktuelle prosjektet?	Nei

2. Prosjektopplysninger

2.1 Oppsummering av forskningsprosjektet

Prosjektbeskrivelse

Det er allment akseptert at søvn har viktige gjenoppbyggende kvaliteter som er nødvendig for å opprettholde optimalt fysiologisk- og mentalt funksjonsnivå. Historisk sett er hovedutfordringen med forskning på søvn mangelen på presist og brukervennlig utstyr. Vital Things (VT) har utviklet en avansert sensor (Somnofy) som registrerer søvn, både mengde og kvalitet, og viktige miljø variabler (luftkvalitet, lysforhold, støy osv.), basert på radar teknologi. Somnofy rapporterer disse viktige variablene relatert til søvn til brukeren på daglig basis gjennom en mobil applikasjon. Somnofy er validert mot PSG (Polysomnografi) og denne studien er under fagfellevurdering. I motsetning til PSG vil ikke brukeren ha behov for å være i direkte kontakt med sensoren (utstyret). Hovedformålet med dette prosjektet er å teste sensoren (Somnofy) som vil bli plassert i soverommet for å studere potensielle signaturer i søvnmønstre og korrelere disse til stress blant ulike grupper eliteutøvere.

2.2 Legemiddelutprøving

Legemiddelutprøving	Nei

2.3 Forskningsdata

2.3.1 Tidligere registrerte opplysninger	Nei
2.3.2 Nye helseopplysninger	Ja

Spesifiser hvilke typer helseopplysninger

Det skal innhentes hår prøver for å analysere kortisolnivå (objektiv markør av stress) i hår de siste 3 måneder.

Det skal hentes inn opplysninger om antall sykedager og hvilken type sykdom.

2.3.3 Humant biologisk materiale	Ja
Nytt humant biologisk materiale	Hår og negler
Materialet skal destrueres innen to måneder etter prøvetaking	Ja
Skal det gjøres genetiske undersøkelser av biologisk materiale?	Nei

2.4 Studiepopulasjon

2.4.1 Antall forskningsdeltakere og styrkeberegning

50 toppidrettsutøvere tilknyttet Olympiatoppen.

2.4.2 Beskrivelse av forskningsdeltakere/utvalg

Andre personer

Spesifiser hvilke personer

Toppidrettsutøvere som trener for å prestere på nivå med de beste i verden i sin idrett.

Begrunn hvorfor disse personene skal inkluderes

Studiet skal undersøke hvordan søvn påvirker prestasjon til utøvere som er avhengig av å prestere på høyeste nivå.

Studiet skal undersøke hvordan stress påvirker søvn til utøvere som er avhengig av å prestere på høyeste nivå.

2.5 Forskningsmetode

2.5.1 Metode for analysering av data

Statistiske (kvantitative) analysemetoder

2.5.2 Metode for innhenting av data

Annen type intervensjon

Spesifiser

Nyutviklet radarteknologi som registrerer søvnmengde og søvnkvalitet uten at utstyr er festet til forsøkspersonens kropp.

Analyse av 120 stk hårprøver (3 cm). Utføres av Biomarker Analysis Lab ved Anglia Ruskin University (England).

Bruk av app for innhenting av opplysninger om antall sykedager og hvilken type sykdom.

2.6 Begrunnelse for valg av data og metode

Redegjør for den faglige og vitenskapelige begrunnelsen for valg av data og metode

Sammenhengen mellom søvn og prestasjon i idrett er svært interessant, ettersom hvile og restitusjon er avgjørende for å oppnå ønskede adapsjoner i kroppen etter trening. Tidligere studier på dette området har i stor grad fokusert på egenrapportert søvnkvantitet og bruk av aktigrafi, og betydningen av kvaliteten på søvn for adapsjon og prestasjon er derfor lite kjent. Det er også lite kjent hvordan stress påvirker søvn i et utvalg av toppidrettsutøvere.

Etablerte metoder for kvalitetsmessige målinger av søvnkvalitet er i dag begrenset av behovet for omfattende utstyr som må festes på forsøkspersonen (PSG). Dette gjør testmetoden kostbar og tidkrevende i bruk, og målinger over tid lar seg av den grunn vanskelig gjøre. Det eksiterer også en del målere i markedet som registrerer søvnkvalitet og -kvantitet, men validiteten og reliabiliteten til disse målerne er i liten grad dokumentert.
Somnofy radar er utviklet for å måle søvn på en pålitelig måte og uten utstyr festet på forsøkspersonens kropp, og vil med dette være et enkelt metodisk redskap for å registrere søvnkvalitet og -kvantitet.

Toppidrettsutøvere lever under et sterkt press for å prestere. Gjennom å følge denne gruppen over tid vil det være mulig å undersøke hvordan søvn påvirker prestasjon (fungerende utøver vs ikke fungerende utøver), og hvordan stress påvirker søvn.

Ved hjelp av håranalyser er det mulig å studere hvordan stress (kortisol) har påvirket søvn de siste 3 måneder. Langvarig analyse av kortisol er ikke mulig ved bruk av blodprøver eller spyttprøver - disse metodene tester kun for akutt stress. I tillegg er håranalyser valgt fordi det ville vært vanskelig å gjennomføre spyttprøver eller blodprøver fra dag til dag over tid i denne gruppen.

3. Informasjon, samtykke og personvern

3.1 Samtykke vil bli innhentet

Samtykke vil bli innhentet	Ja

For hvilke deltakere, opplysninger og evt. prøver vil samtykke bli innhentet?

Alle deltakerne vil bli gitt samtykke skjema for å benytte søvnradaren som redskap for å kartlegge søvnmønster.

Hvordan vil deltakerne bli identifisert, kontaktet og rekruttert? Beskriv rekrutteringsprosedyre og begrunn evt. avvik fra skriftelig samtykke

Deltakerne vil bli rekruttert fra Olympiatoppen sitt nettverk, og kontaktes skriftlig per e-post og samtidig per telefon med informasjon om prosjektet. Det vil også bli gjennomført informasjonsmøter med alle forsøkspersonene.

Beskriv inklusjonskriterier

Forsøkspersoner skal være kategorisert som toppidrettsutøvere i Olympiatoppen og tilhøre Olympiatoppen sitt nettverk. Det vil tilstrebes likevekt mellom kjønnene.

Beskriv eksklusjonskriterier

Personer som ikke faller inn under inklusjonskriteriene er ikke aktuelle som deltakere.

3.2 Samtykke er allerede innhentet

Samtykke er allerede innhentet	Nei

3.3 Det søkes om fritak fra kravet om å innhente samtykke

Det søkes om fritak fra kravet om å innhente samtykke	Nei

4. Avveining av nytte og risiko ved prosjektet

4.1 Fordeler

Angi fysisk, psykisk, sosial og/eller praktisk fordel/nytte/gagn nå eller i fremtida for den enkelte *pasient/deltaker, grupper av personer, samfunnet og/eller vitenskapen .*

Deltakerne i prosjektet vil få svært omfattende innsikt i eget søvnmønster og dets betydning for deres prestasjoner.

4.2 Ulemper

Angi fysisk, psykisk, sosial og/eller praktisk risiko/skade/ubehag/belastning/uleilighet nå eller i fremtida for den enkelte pasient/deltaker, grupper av personer, samfunn og/eller miljø .

Ingen spesielle ulemper identifisert, utover innsatsen forsøkspersonene må gjøre for å ta med søvn radar når de er på reise.

4.3 Tiltak

Redegjør for eventuelle særlige tiltak for å ivareta og beskytte pasientene/deltakerne i forskningsprosjektet og for å begrense mulig risiko/ulempe

Prosjektmedarbeiderne vil stå fult tilgjengelighet for forsøkspersonene før, under og etter datainnsamlingsperioden.

4.4 Forsvarlighet

Hvorfor er det forsvarlig å gjennomføre prosjektet? Gi en begrunnet avveining av fordelene og ulempene ved forskningsprosjektet.

Radaren som detekterer søvn utgjør ingen forstyrrelse for deltakerne i prosjektet og det er svært lite logistikk ved å gjennomføre hårprøvene. Denne gruppen har et ønske og et behov for å se på kvalitative mål på restitusjon (søvn), og er således svært interessert i å delta i dette prosjektet. Samarbeidet mellom Olympiatoppen og NTNU gjør at dette er fordelaktig for alle parter.

5. Sikkerhet, interesser og publisering

5.1 Personidentifiserbare opplysninger

I hvilken form skal personidentifiserbare opplysninger og prøver brukes i prosjektet?

Avidentifisert med koblingsnøkkel

Gi informasjon om hvordan koblingsnøkkelen oppbevares og hvem som har tilgang til denne

Koblingsnøkkel oppbevares på PC uten nett-tilknytning, innelåst på prosjektleders kontor.

5.2 Internkontroll og sikkerhet

5.2.1 Hvordan skal personidentifiserbare opplysninger og prøver oppbevares?

Innelåst oppbevaring

Redegjør nærmere for oppbevaringsmåte, låse- og adgangsrutiner mv

PC uten nett-tilknytning på prosjektleders kontor. PC'en oppbevares innelåst i skap når prosjektleder ikke er tilstede, og det er kun prosjektleder som har nøkkel til dette skapet. Kontoret er låst med nøkkelkort når prosjektleder ikke er tilstede.

PC uten tilknytning til internett

5.3 Forsikring for forskningsdeltakere

Forsikring anses unødvendig

Begrunn hvorfor det anses unødvendig med forsikring for forskningsdeltakerne

Det er ingen fare for å kunne ta skade av å delta i studiet.

5.4 Vurdering av andre instanser

Prosjektet har blitt vurdert/skal vurderes av:

Egen institusjon

5.5 Interesser

Finansieringskilder

Prosjektet finansieres av NTNU og Olympiatopppen Midt-Norge.

Godtgjøring til institusjon

Ingen godtgjøring til institusjon.

Honorar prosjektleder/-medarbeidere

Ingen honorar til prosjektleder/-medarbeidere utover alminnelig lønn.

Kompensasjon for forskningsdeltakere

Ingen kompensasjon til pasienter/deltakere.

Eventuelle interessekonflikter for prosjektleder/-medarbeidere

Ingen interessekonflikter for prosjektleder/-medarbeidere.

5.6 Publisering

Er det restriksjoner med hensyn til offentliggjøring og publisering av resultatene fra prosjektet?	Nei

Redegjør for hvordan resultatene skal gjøres offentlig tilgjengelig

Studiene skal publiseres i relevante vitenskapelige tidsskrifter.

5.7 Håndtering av data etter prosjektslutt

Hvordan skal personopplysninger håndteres etter prosjektslutt?

Data makuleres etter prosjektslutt.

6. Vedlegg

#	Type	Filnavn	Lagt inn dato
1.	CV for prosjektleder	CV Frode Moen_2017.pdf	30.10.17
2.	Forespørsel om deltakelse	Samtykkeskjema_2017_final.pdf	30.10.17
3.	Forskningsprotokoll	Research Protocol_rek.pdf	30.10.17

7. Ansvarserklæring

Jeg erklærer at prosjektet vil bli gjennomført

- i henhold til gjeldende lover, forskrifter og retningslinjer
- i samsvar med opplysninger gitt i denne søknaden
- i samsvar med eventuelle vilkår for godkjenning gitt av REK eller andre instanser

NTNU

Kunnskap for en bedre verden