# Exploring Sleep Habits in the Wide World of Esports

by

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# Summary

Esports is a form of organised video game competition which has gained significant mainstream traction in recent years. Hence, researchers have begun to investigate the factors that influence the health and performance of competitors, known as esports athletes. The function of sleep may be of particular interest given its central role in supporting human health and performance. However, research in this area is sparce, while the handful of existing studies have methodological limitations.

To investigate the sleep of esports athletes, this thesis proposed three aims. The first aim was to quantify the sleep behaviour of professional esports athletes and, further, how sleep might relate to mood and cognitive performance. The second aim was to identify and begin to understand the factors that influence the sleep of esports athletes. Finally, the third aim was to design and evaluate a sleep intervention for esports athletes. These aims were addressed in a series of studies utilising a range of methodologies.

Overall, this thesis contains seven chapters which comprise five studies. In Chapter 1 we introduced the topic of sleep behaviour in esports. Although quantifying esports athletes' sleep was a key initial focus, we first expanded on the opinion piece by Bonnar et al. (2019) that preceded this thesis. Accordingly, Chapter 2 (Study 1) described additional risk factors for poor sleep in esports and outlined theoretically grounded sleep intervention considerations.

Subsequently, Chapter 3 (Study 2) examined the sleep behaviour and mood of professional esports athletes from several countries. After identifying that some esports athletes experience suboptimal sleep and mood, Chapter 4 (Study 3) implemented a brief sleep intervention aimed at improving the sleep, mood and cognitive performance of esports athletes. However, this intervention only produced modest sleep benefits, with no improvement in mood or cognitive performance.

To develop more effective sleep interventions, Chapter 5 (Study 4) explored the influence and perspective of esports coaches and support staff on the sleep behaviour of esports athletes. Broadley, results revealed that despite overall inadequate sleep knowledge, some participants were trying to implement sleep health support. However, esports athletes' dislike of the process was a barrier. Further, night training and competition timing and load were considered risk factors for poor sleep.

Owing to competitions being a potential risk factor for poor sleep, Chapter 6 (Study 5) evaluated the sleep behaviour, anxiety, mood, and cognitive performance of esports athletes around competition. Results showed deterioration in some aspects of sleep, although total sleep time remained adequate via modification of sleep timing. There was no relationship between anxiety and sleep, nor between total sleep time and next day mood or cognitive performance.

The thesis is concluded in Chapter 7 with a general discussion. Findings are summarised and integrated with the broader literature, methodological and clinical implications are considered, while limitations and avenues for future research are outlined. Importantly, this thesis has made a meaningful contribution to the growing knowledge base regarding the sleep behaviour of esports athletes and provides a foundation for future researchers to build on.

# Glossary of Abbreviations

| | |
|---|---|
| APM | Actions per minute |
| BMI | Body mass index |
| BRUMS | Brunel mood scale |
| CBT-I | Cognitive behaviour therapy for insomnia |
| FPS | First-person shooter |
| ISI | Insomnia severity index |
| LoL | League of Legends |
| MBSR | Mindfulness-based stress reduction |
| MOBA | Multiplayer online battle arena |
| PDSS | Paediatric daytime sleepiness scale |
| PVT | Psychomotor vigilance task |
| RTS | Real-time strategy |
| SBS | Sleep beliefs scale |
| SE | Standard error |
| SOL | Sleep onset latency |
| STAI | State-Trait Anxiety Inventory |
| TST | Total sleep time |
| US | United States |
| WASO | Wake after sleep onset |
| WT | Wake-up time |

# Declaration

I certify that this thesis:

1. does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Name: Daniel Bonnar.

Date: May 24th 2024.

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To my partner Fleur. Your patience, support and tolerance have been incredible. I can't wait for us to get back to simply living. Post-PhD life is just around the corner.

This thesis was edited by Elite Editing, and editorial intervention was restricted to Standards D and E of the Australian Standards for Editing Practice.

Finally, this thesis is dedicated to my parents who have always encouraged my pursuit of education.

# List of Publications in This Thesis

Bonnar, D., Hwu, M., Lee, S., Gradisar, M., Suh, S., & Kahn, M. (2023). The influence of coaches and support staff on the sleep habits of esports athletes competing at professional and semi-professional level. *Journal of Electronic Gaming and Esports*, *1*(1), 1–12. https://doi.org/10.1123/jege.2022-0023

Bonnar, D., Gradisar, M., Kahn, M., & Richardson, C. (2024). The sleep, anxiety, mood, and cognitive performance of Oceanic rocket league esports athletes competing in a multi-day regional event. *Journal of Electronic Gaming and Esports*, *2*(1), 1–12. https://doi.org/10.1123/jege.2023-0036

Bonnar, D., Lee, S., Gradisar, M., & Suh, S. (2019). Risk factors and sleep intervention considerations in esports: A review and practical guide. *Sleep Medicine Research*, *10*(2), 59–66. https://doi.org/10.17241/smr.2019.00479

Bonnar, D., Lee, S., Roane, B. M., Blum, D. J., Kahn, M., Jang, E., Dunican, I. C., Gradisar, M., & Suh, S. (2022). Evaluation of a brief sleep intervention designed to improve the sleep, mood, and cognitive performance of esports athletes. *International Journal of Environmental Research and Public Health*, *19*(7), Article 4146. https://doi.org/10.3390/ijerph19074146

Lee, S., Bonnar, D., Roane, B., Gradisar, M., Dunican, I. C., Lastella, M., Maisey, G., & Suh, S. (2021). Sleep characteristics and mood of professional esports athletes: A multi-national study. *International Journal of Environmental Research and Public Health*, *18*(2), Article 664. https://doi.org/10.3390/ijerph18020664

# List of Additional Publications Completed During Candidature


Hardman, J. R., Rees, C. S., Bonnar, D., & Ree, M. J. (2023). Group cognitive behavioural therapy for insomnia: Impact on psychiatric symptoms and insomnia severity in a psychiatric outpatient setting. *Clinical Psychologist*, *27*(2), 1–11. https://doi.org/10.1080/13284207.2022.2155034

Kuula, L., Gradisar, M., Martinmäki, K., Richardson, C., Bonnar, D., Bartel, K., Lang, C., Leinonen, L., & Pesonen, A. K. (2019). Using big data to explore worldwide trends in objective sleep in the transition to adulthood. *Sleep Medicine*, *62*, 69–76. https://doi.org/10.1016/j.sleep.2019.07.024

Lee, S., Bonnar, D., Kim, Y., Lee, Y., Lee, S., Gradisar, M., & Suh, S. (2020). Sleep characteristics and risk factors of Korean esports athletes: An exploratory study. *Sleep Medicine Research*, *11*(2), 77–87. https://doi.org/10.17241/smr.2020.00773

# Prelude

Prior to commencing the present thesis, I published an opinion piece with some friends regarding the potential importance of sleep in esports. As it was the starting point for the current line of inquiry, the published version of the opinion piece has been included in Appendix A for the reader's convenience. It can be read as desired, either before or after the main content of this thesis or not at all.

# Chapter 1: General Introduction

## 1.1 Chapter Overview

This general introductory chapter provides a background to the novel field of sleep and esports research. The chapter begins with a brief description and characterisation of esports and esports athletes. Subsequently, relevant findings from the wider sleep literature are highlighted to show the potential importance of sleep for esports athletes. The evidence to date regarding the sleep behaviour of esports athletes is then reviewed, followed by an examination of the sleep characteristics of related populations. Next, sleep and performance measures are assessed for their utility and feasibility within esports research. Finally, the chapter concludes with the main aims and outline of the thesis.

## 1.2 Defining Esports

The definition of esports has been refined over time. Wagner (2006) originally defined esports as 'an area of sport activities in which people develop and train mental or physical abilities in the use of information and communication technologies' (p. 3). However, although this definition highlights several important general aspects of esports, it is also nebulous. It has been criticised for failing to include the nature of competition, which has been argued to be a key characteristic upon which the esports industry is built (Jenny et al., 2017).

In response to the criticism of Wagner's definition, there have been subsequent attempts at defining esports. In their paper, Jenny et al. (2017) outlined several key features that define esports, including play (i.e. voluntary, intrinsically motivated activity), organisation (i.e. governed by rules), competition (i.e. have a win or loss outcome), skill (i.e. the outcome is not owing to chance) and a broad following (i.e. not a temporary fad). Some of these features have been echoed by other authors (i.e. Funk et al., 2018; Hallmann & Giel, 2018).

In a bid to synthesise previous research and create an overarching, fine-grained definition, Pedraza-Ramirez et al. (2020) defined esports as:

> The casual or organized competitive activity of playing specific video games that provide professional and/or personal development to the player. This practice is facilitated by electronic systems, either computers, consoles, tablets, or mobile phones, on which teams and individual players practice and compete online and/or in local-area-network tournaments at the professional or amateur level. The games are established by ranking systems and competitions and are regulated by official leagues. This structure provides players a sense of being part of a community and facilitates mastering expertise in fine-coordination and perceptual-cognitive skills, particularly but not exclusively, at higher levels of performance. (p. 322)

As it currently stands, Pedraza-Ramirez et al.'s (2020) definition is the most comprehensive in the literature, which is why it is so frequently cited. However, it should be noted that in time, even this definition of esports will need to be updated because although it specifically details the different types of electronic systems used in esports (e.g. computers, consoles and mobiles), virtual reality devices are omitted. However, as Jenny et al. (2017) speculate in their paper, virtual reality devices will likely form a growing segment of the esports industry. Hence, the definition of esports should be viewed as an evolving concept that will need to change according to developments within the esports industry.

## 1.3 The Evolution of Esports Research

When this thesis commenced in 2019, esports research was in its infancy. At the time, a limited number of studies had been published, and there was no research focusing specifically on the sleep behaviour of esports athletes. However, much like the esports industry, research on esports has experienced significant growth over the last five years, with a rapidly increasing number of journal articles being published each year. Thus, as the esports literature has expanded, the scientific community's understanding of esports has evolved accordingly. For example, in 2019, various terms were being used to describe esports competitors. In an opinion piece by Bonnar et al. (2019) that precipitated the commencement of this thesis, the term 'Eathlete' was used. In contrast, throughout this thesis, the term 'esports athlete' is used, as it has been adopted by many researchers in the field over the last few years (e.g. Poulus et al., 2022a; Smith et al., 2022). However, it should be acknowledged that the term 'Eathlete' and 'player' are still used in some studies (e.g. Leis et al., 2022; Trotter et al., 2021; see Bubna et al., 2023 for a recent discussion of terminology). Another example from Bonnar et al.—and Chapter 2 in the present thesis—is that it is stated that esports is a primarily cognitive-based activity. However, although there is indeed a strong cognitive emphasis in esports (Smithies et al., 2021), recent research has demonstrated that muscular skeletal injuries in esports are common, and there is a need for appropriate physical conditioning and management, which highlights the physical aspects of esports (McGee et al., 2021; Migliore et al., 2021). Consequent to the evolution of esports research, the introductory section of Chapter 1 will take a two-pronged approach. First, the most up-to-date research will be used and referenced to give the reader a contemporary view of esports, including the state of the industry and general esports research. Second, the context of research at the time as it pertains to the sleep behaviour of esports athletes will be described to give the reader a clear understanding of how the current thesis was conceived.

## 1.4 The Wide World of Esports

### 1.4.1 A Brief History

Many people could be forgiven for thinking that esports only occurred in the last decade. On the contrary, the history of esports stretches much further back in time. Taylor (2012) described how the first inception of esports occurred in 1972 at the Stanford University Artificial Intelligence Laboratory, where competitors played Spacewar, a space combat video game, in the grandiosely named Intergalactic Spacewar Olympics. Taylor noted that, in the ensuing years, esports became a niche subculture within the broader video-gaming industry and received minimal attention from key stakeholders such as game developers. Although sporadic attempts to develop esports were made during these early years, success at holding tournaments was limited, and there was no breakthrough interest from the wider community. However, Scholz (2019) noted that from 1997 onwards, esports began a transformation process driven by a confluence of growth factors. Specifically, a combination of faster internet connectivity, more advanced and accessible technology (i.e. computers and consoles), greater game developer involvement, government support, sponsorship (from endemic and non-endemic brands) and the advent of streaming platforms enabling real-time broadcasting, accelerated esports into the mainstream global consciousness.

### 1.4.2 Esports of Today

More recently, evidence indicates that the global esports footprint continues to expand year-on-year. For example, a key market report conducted by Newzoo (2022) showed that in terms of audience, the estimated viewership in 2020 was 435.7 million people, which grew to 489.5 million in 2021 and 532 million in 2022. By 2025, viewership is predicted to reach 640.8 million people, driven by the release of new games and emerging markets, including Southeast Asia, Latin America, the Middle East and Africa. To put these viewership numbers in perspective and highlight the popularity and reach of esports within the community, live streaming in 2022 had more viewers than Netflix and Disney+ subscribers combined (Shewale, 2023a, 2023b). Mirroring the growth in audience, revenue from esports has also steadily increased over time. The Newzoo market report described how revenue estimates in 2020 were US$996 million, which grew to US$1.1 billion in 2021 and US$1.3 billion in 2022. By 2025, revenue is projected to reach US$1.8 billion, demonstrating that esports is not just a cultural phenomenon but also a lucrative industry. According to the Newzoo market report, revenue streams include streaming, merchandise and tickets, publisher fees, digital assets (e.g. non-fungible tokens), media rights and sponsorship. Thus, although there are many differences between esports and traditional sports, there is a growing resemblance in some respects (e.g. viewership and revenue streams). As the esports industry matures, its impact on the global entertainment landscape will grow.

When discussing the growth of esports, it would be remiss to omit the impact of COVID-19. In contrast to the chaos that erupted in the traditional sports landscape, the pandemic appeared to benefit esports overall (Block & Haack, 2021). Like traditional sports, live esports events were disrupted but not completely abandoned. However, unlike traditional sports, the digital characteristics of esports enabled rapid adaptation to online events. For example, the League of Legends (LoL) Championship Series (the primary LoL competition in the United States [US]) switched to an online format within a week (Block & Haack, 2021). Combined with a 'captive' audience stuck at home because of enforced social distancing and lockdown measures, it is easy to see why there was increased demand for esports during this time (Cranmer et al., 2021).

Additionally, esports gained further advantage when some traditional sports transitioned their competitions to an online format. Perhaps the best example is Formula 1, which was forced to cancel or postpone several Grand Prix events. In response, Formula 1 shifted its operations to the pre-existing Formula 1 Esports Series (a simulation racing competition) and held a virtual Grand Prix series with current and former racers participating (Block & Haack, 2021). The sudden entry of major global sporting organisations into esports presumably brought a new segment of viewers and potentially further fuelled interest and interaction with esports content.

It is difficult to estimate the current number of esports leagues and tournaments globally owing to a continually changing esports landscape and varying levels of professionalism. However, some major enduring esports leagues include the League of Legends, DOTA Pro Circuit[1], ESL Pro League[2] and Rocket League Championship Series. These leagues are typically divided by geographical region (e.g. North America, Europe and Oceania) to create separate but related competitions known as domestic leagues. Domestic league seasons occur simultaneously in each region, with teams competing against each other for prize money and points. Depending on the region and the game, esports athletes can play remotely or in person, with viewers able to watch online.

Interspersed throughout the season are international events (termed 'majors') that the top teams from each region attend to compete against each other. Majors have higher stakes than domestic league matches (e.g. points, prestige and prize money) and are often held in stadiums or arenas with vast crowds (see Figure 1.1). The end of the season concludes with a world championship, where, once again, the top teams from each region meet to compete against each other (see the Rocket League Championship Series season structure for an example of how a league functions; Nowakowski, 2022). World championships usually occur across several weeks and can attract massive crowds (in person and online). For example, viewership for the 2023 world championship in arguably the most popular game, LoL, reached a record 6.4 million concurrent viewers for the final, while the overall tournament recorded 146 million hours watched (Desena, 2023).

[1] DOTA (Defense of the Ancients).
[2] ESL (Electronic Sports League).

**Figure 1.1**

*A Rocket League Major in 2023 with Live Spectators at an Arena*


*Note.* For major esports events (termed 'majors') such as the one shown in the image above, esports athletes compete on stage at the arena's centre (or front), with massive viewing screens enabling live spectators to watch the match. In addition, spectators can also view majors online in real time via streaming services such as Twitch or YouTube. This image was used with permission from Beau Melia at Ground Zero Gaming (Perth, Western Australia, Australia).

The ongoing professionalisation of the esports industry has given rise to a variety of ancillary institutions and industries that help sustain the esports ecosystem. For example, given a historical lack of training and education pathways, coaching institutions and academies are now being created to help develop more well-trained coaches (e.g. International Federation of Esports Coaches; ifoec.com). To help esports athletes successfully navigate the industry, agencies based on those in traditional sports are now available to help represent esports athletes, negotiate contracts and sponsorships and manage other business deals (Witkowski & Manning, 2018). Educational institutions (e.g. colleges and universities) have started to offer esports programs that also involve participation in lower-tier esports leagues, providing a training ground for the next generation of professional esports athletes (Sabtan et al., 2022). Esports content creators engage with fans, generate interest and help grow the esports community by creating content such as gameplay videos, tutorials and analysis (Witkowski & Manning, 2018). Production companies produce esports broadcasts, providing streaming services, commentary and analysis to enhance the viewing experience (M. R. Johnson & Woodcock, 2021). Esports organisations now employ health professionals, such as physical therapists and psychologists, to help support the health needs of their esports athletes (e.g. Esports Health and Performance Institute; EHPI.org). Taken together, esports of today are perceived and practised very differently from esports of the past. Indeed, the descriptive phrase 'niche subculture' would no longer appear to reflect the contemporary esports industry.

### 1.4.3 Esports Athletes

Given the wide spectrum of individuals who partake in some form of gaming, defining what constitutes an esports athlete is important. According to Pedraza-Ramirez et al.'s (2020) definition of esports, anyone who plays casually or competitively within a ranked system or structured competition is considered an esports athlete. However, as Bubna et al. (2023) highlight in their paper, many individuals exist within these esports ecosystems who do not compete for a ranking or within a competition—instead, some play for leisure or for other purposes like content creation and streaming for entertainment. Further adding to the complexity of defining an esports athlete is the fact that there are notable differences (e.g. lifestyle and conditions experienced) between esports athletes who compete in ranked systems and those who compete professionally within structured competitions. Many research studies within the esports literature use samples that are easier to recruit, such as esports athletes who play within a ranked system (e.g. Kraemer et al., 2022; Poulus et al., 2020), which limits the generalisability of findings owing to external validity constraints.

Looking deeper still, within the realm of professional esports athletes who compete within structured competitions, there are varying levels of eliteness (i.e. level of skill, talent and dedication) and competition (i.e. tiered systems). Clearly, the current lack of guidelines for describing participant samples has contributed to confusion within the esports research community and led to the conflation of different esports populations in studies.

In all studies described in this thesis (apart from Chapter 5, which comprised coaches and support staff), samples comprising professional esports athletes competing in structured competitions (i.e. Tier 1 and 2 leagues in their respective regions) were used. In other words, participants were competing at a national or international level. Hence, a strength of this thesis from a sampling perspective is that the presented findings represent esports athletes competing at the top level (or very close to) of their respective games.

### 1.4.4 Esports Genres and Games

Esports encompasses a wide range of game genres, each with its own gameplay style and competitive dynamics. Table 1.1 describes the main esports genres and some notable games within each genre (please note that this is a non-exhaustive list). It is worth highlighting that some of these games have existed within esports for over a decade (e.g. LoL; Hennington, 2020), while others have been released more recently (e.g. Valorant; Farrelly, 2023). Thus, as esports continues to evolve, new games will enter the esports ecosystem, and some may depart.

**Table 1.1**

*A List of Notable Games Within the Main Esports Genres*

| Esports genre | Notable games |
|---|---|
| First-person shooter (FPS) | Counter-Strike: Global Offensive<br>Call of Duty<br>Overwatch<br>Valorant |
| Multiplayer online battle arena (MOBA) | League of Legends<br>Defense of the Ancients 2 |
| Real-time strategy (RTS) | StarCraft II<br>Warcraft III<br>Age of Empires II |
| Battle royale | Fortnite<br>PlayerUnknown's Battlegrounds<br>Apex Legends |
| Sports and racing | FIFA<br>Rocket League<br>Formula 1 Esports Series |
| Fighter | Street Fighter V<br>Super Smash Bros<br>Tekken |

*Note.* This is a non-exhaustive list of games within each esports genre. For example, another less notable esports genre is the Olympics Esports Series, which includes games such as cycling, baseball and rowing.

### 1.4.5 Summary of Esports

In summary, esports rival many aspects of traditional sports. The evolution and professionalisation of esports has not only increased the competition between esports athletes, teams and organisations but has also led to a focus on optimal performance and health. Thus, leveraging factors known to optimise performance and health is important. One of those known and influential factors is sleep.

## 1.5 The Importance of Sleep Health in Competitive Settings

There is an accumulating body of literature regarding the role of sleep in supporting human health and performance. This understanding eventually prompted sports science researchers to consider the potential impact of sleep on athletic performance and mental health (Bonnar et al., 2018). Subsequently, over the last decade, sleep has become a significant focus in sports science (Walsh et al., 2021). This development in the sports science field was one of the key precipitants for the conceptualisation of the current thesis. It stands to reason that if sleep is important for optimal health and performance in traditional athletes, the same may be true for esports athletes. In this section, the consequences of suboptimal sleep on two pertinent domains in esports, namely cognitive functioning and mental health, are outlined and discussed.

### 1.5.1 Sleep and Cognitive Functioning

Esports athletes face many intricate cognitive demands during gameplay (Pedraza-Ramirez et al., 2020). Although the specific cognitive demands likely differ between games, there are broad commonalities. For example, rapid and accurate *visual processing* is critical as esports athletes must continuously process a vast array of information, including positions and movements of opponents and teammates, game objectives and other game-related cues (Grushko et al., 2021). In response to incoming information, esports athletes rely on *visuomotor functioning* (an integration of *visual perception* and *motor control*) to make motor movements and control their on-screen avatars (Bonnar et al., 2019). This action requires *fine motor control*, which is the ability to make precise movements with the small muscles in the hands to manage the keyboard and mouse or console controller. Importantly, these movements need to be fast in addition to being precise. For example, in StarCraft 2, esports athletes have been recorded making up to 600 mouse clicks per minute (K. Wong, 2014), emphasising the crucial role of *reaction time* in the fast-paced world of esports. Furthermore, the ability to *sustain attention* and maintain vigilance is important, as some esports matches can average 40 minutes (Schubert et al., 2016). Likewise, *selective attention* is needed to focus on relevant in-game aspects while simultaneously filtering external distractions (e.g. opponent trash talking; Irwin et al., 2021). *Working memory* and *executive functioning* are taxed as esports athletes must hold and manipulate multiple pieces of information (e.g. strategies) and then evaluate and select optimal actions (which requires *cognitive flexibility*; Bonnar et al., 2019). The high cognitive load imposed on esports athletes highlights the importance of understanding and optimising the factors that influence their cognitive performance.

A substantial volume of research has examined the relationship between sleep and cognitive functioning. Studies in this area of the literature have primarily used sleep loss paradigms to investigate this relationship (Smithies et al., 2021). In this approach, participants are intentionally deprived of sleep to varying degrees and duration, with cognitive performance typically assessed before, during and after the sleep loss period. Some of these studies have employed total sleep deprivation, whereby participants obtain no sleep for a set period. However, as previous authors have noted, total sleep deprivation is uncommon in the general population and other populations, such as traditional athletes, and therefore, findings from these studies have low ecological validity (e.g. Smithies et al., 2021; Walsh et al., 2021).

On the contrary, sleep restriction (i.e. moderately reduced total sleep time [TST] over one or more nights) is much more commonly experienced. It can, therefore, offer greater insight into the effect of typical sleep loss on cognitive functioning (Banks & Dinges, 2007). Currently, no studies have specifically investigated sleep restriction in an esports sample. This situation is likely because of esports being a new field of study, the high costs and time associated with running sleep restriction protocols and the difficulty recruiting esports athletes. However, findings from the wider sleep literature can still provide valuable insights into how esports athletes may be affected by sleep restriction.

Experimental sleep dose-response studies are particularly informative when assessing the effects of sleep restriction on cognitive functioning. Multiple studies have used this study design, including a particularly well-known study by Van Dongen et al. (2003). In this study, participants were allowed different sleep durations each night, ranging from a full sleep (8 hours) to restricted sleep (4 and 6 hours) over a two-week period. Additionally, another group were completely sleep-deprived for three days. Each day during the study period, participants completed cognitive testing and subjective questionnaires. The authors found a clear dose-response relationship between TST and cognitive functioning. As the degree of sleep restriction increased, cognitive functioning, including attention, reaction time and decision-making, significantly declined. Importantly, the study also highlighted the cumulative nature of sleep debt, with cognitive deficits accumulating over each successive night of sleep restriction. Parallel to cognitive functioning, the authors also reported that decreased TST was associated with increased sleepiness and decreased alertness. The Van Dongen et al. (2003) study aligns with findings from other sleep dose-response studies, including Belenky et al. (2003) and Jewett et al. (1999). These studies indicate that adequate and continuous TST is essential for multiple aspects of cognitive functioning and that even mild sleep restriction over several nights can have a notable impact on cognitive functioning.

There have now been numerous systematic reviews and meta-analyses because of the research volume available. In a particularly relevant study for esports, Smithies et al. (2021) conducted a systematic review that examined the impact of sleep restriction on cognitive functioning, specifically in samples of elite cognitive performers (e.g. military personnel and medical professionals). They found that simple cognitive tasks that rely on more rudimentary cognitive abilities (e.g. vigilance, attention and reaction time) were reliably impaired by sleep restriction. This finding is consistent with evidence from the aforementioned sleep dose-response studies and previous systematic reviews and meta-analyses (e.g. de Bruin et al., 2017; Lowe et al., 2017). However, the authors also found that more complex tasks that rely on higher-order executive functioning were less reliably impaired unless cognitive flexibility was required. Cognitive flexibility refers to the ability to adapt to changing task requirements (Ionescu, 2012). It is critical when required to adapt to new situations, learn efficiently, and excel in complex and changing environments (Ionescu, 2012). Taken together, these findings are important, given it is proposed that esports are often fast-paced and require complex decision-making within unpredictable match circumstances (Bonnar et al., 2019). Indeed, Smithies et al. concluded that because esports athletes can be classified as elite cognitive performers, their findings are highly relevant for this population.

### 1.5.2 Sleep and Mental Health

Sleep has a well-documented relationship with mental health. Indeed, sleep is considered one of the key pillars of mental health, alongside other lifestyle factors such as nutrition and physical activity (Firth et al., 2020). Accordingly, the interaction between sleep and mental health conditions has been extensively studied, with depression standing out as one of the most thoroughly researched areas. Depression is a highly prevalent mental health condition and a significant contributor to the overall global disease burden (Yan et al., 2022). Notably, the co-occurrence of sleep disturbances (an encompassing term referring to conditions such as restricted TST, insomnia and poor sleep quality) with depression is high (Fang et al., 2019). However, while sleep disturbances were historically treated as a symptom of depression, accumulating longitudinal evidence now suggests that sleep disturbances often precede depression (Fang et al., 2019). For example, Lovato and Gradisar (2014) conducted a meta-analysis and concluded that sleep disturbance in young people predicted the development of depression, while little support was found for the reverse. Moreover, in their meta-review, Firth et al. (2020) highlighted that multiple meta-analyses have demonstrated a prospective link between sleep disturbance and depression in adults. The effect of sleep on depression can also be seen when considering the findings from sleep intervention studies. For example, gradual sleep extension (as well as sleep hygiene) among chronically sleep-restricted adolescents decreased depression symptoms (Dewald-Kaufmann et al., 2014). Likewise, Firth et al. reported a similar reduction in depression symptoms from meta-analyses assessing randomised controlled trials of sleep interventions based on cognitive behavioural therapy principles. Overall, sleep disturbance appears to play an important role in the onset of depression, while improving sleep can alleviate depression symptoms.

The interaction between sleep and anxiety has also been well researched. Anxiety disorders are the most common mental health problem in the world and can cause distress and disrupt functioning (Chellappa & Aeschbach, 2022). Further, like depression, the co-occurrence of sleep disturbance and anxiety symptoms is high (Cox & Olatunji, 2020), with sleep disturbance being more likely to precede anxiety than the other way around (Gradisar et al., 2022). In one meta-analysis, Short et al. (2020) found that restricted TST in adolescents increased the odds of anxiety by 41%. Similar findings have been observed elsewhere in the literature (e.g. Seo et al., 2021), while converging evidence from neuroimaging studies indicates sleep restriction amplifies activity within the ‘fear network’, including the limbic system. In terms of other sleep complaints, meta-analytic evidence suggests that individuals with pre-existing insomnia are three times more likely to develop an anxiety disorder than those without insomnia (Hertenstein et al., 2018). Furthermore, it has been proposed that poor sleep quality is strongly implicated in the development of anxiety in young adolescents (Jamieson et al., 2021). As with depression, the effect of sleep on anxiety can also be viewed through the lens of sleep improvement. Multiple meta-analyses have found that sleep interventions (often cognitive behavioural therapies in nature) and the subsequent benefits of sleep lead to a reduction in anxiety symptoms (Belleville et al., 2011; Staines et al., 2022). Collectively, it would seem that sleep disturbance exerts an anxiogenic influence, while conversely, improved sleep can reduce anxiety symptoms.

It is also important to consider the intersection between sleep and mental health in esports, given the fact that traditional athletes (a related population) already experience an increased mental health burden. In their meta-analysis, Gouttebarge et al. (2019) found that mental health issues were common in traditional athletes, irrespective of age and professional level. Indeed, the authors reported that 26% of current traditional athletes reported significant stress or distress, 34% reported symptoms of depression and anxiety, and 19% reported alcohol misuse. Although it remains to be determined whether traditional athletes experience more mental health issues than the general population, they may be at an increased risk owing to their unique lifestyle characteristics (e.g. acute stressors, demanding training and competition schedules; Kim et al., 2022). As it currently stands, empirical evidence regarding the mental health of professional esports athletes is scarce. However, esports athletes share many of the same lifestyle characteristics as traditional athletes and may, therefore, also be vulnerable to mental health issues. Thus, it is plausible that suboptimal sleep could add to the mental health burden of esports athletes.

### 1.5.3 Summary of Sleep Health in Competitive Settings

Research involving esports athletes is required to elucidate sleep's role in supporting cognitive functioning and mental health in this population. However, it is possible to make theoretically grounded inferences based on findings from the wider sleep literature. To that end, it can be asserted that sleep health is important for both cognitive functioning and mental health, which may have implications for esports athletes. Sleep restriction can impair a range of cognitive abilities (e.g. attention and cognitive flexibility) that are likely important for peak performance in esports, thereby compromising the likelihood of competitive success. Furthermore, sleep restriction (and, more broadly, sleep disturbances) can also contribute to poorer mental health outcomes such as depression and anxiety, which could add to a possibly already increased mental health burden experienced by esports athletes. Overall, the consequences of suboptimal sleep health for both performance and wellbeing emphasise the importance of investigating the sleep behaviour of esports athletes to understand their sleep health better.

## 1.6 Sleep Behaviour of Esports Athletes

When this thesis commenced in mid-2019, no data on the sleep behaviour of esports athletes was available in the literature, a point highlighted in the opinion piece by Bonnar et al. (2019). However, in the subsequent months, two articles were published, one in late 2019 by Thomas et al. (2019) and another in early 2020 by Rudolf et al. (2020), that investigated the sleep behaviour of esports athletes. In this section, we outline the findings from both studies, examine their methodological integrity and provide directions for future research.

In the first study, Thomas et al. (2019) obtained secondary data on lifestyle habits relative to their primary aim of investigating the impact of energy drink consumption on cognitive performance in esports athletes. In a verbal questionnaire, they asked nine esports athletes to describe how many hours of sleep they achieved each night on average. Results showed that participants slept an average of 8.1 ± 1.2 hours per night, although the standard deviation suggests that at least one participant slept less than 7 hours. Notably, this average is within the recommended 7–9 and 8–10 hours per night recommended for adults and adolescents, respectively (Hirshkowitz et al., 2015).

In the second study, Rudolf et al. (2020) asked 1,066 German casual gamers via an online survey examining lifestyle habits to report their TST and rate their sleep quality on a 4-point categorical rating scale (*very good* to *very poor*). Results from a sub-sample of 14 esports athletes showed that participants slept for 7.8 ± 1.3 hours per night, slightly less than participants in the Thomas et al. (2019) study but still within the recommended 7–9 hours per night for adults (although less than the 8–10 hours for adolescents). Furthermore, the mode subjective sleep quality rating was *quite good*, which accounted for 50% of the sample.

At face value, these findings suggest that esports athletes in both studies were sleeping adequately in terms of sleep duration and quality. However, both studies have several notable methodological shortcomings that limit the extrapolation of their results. First, the methods used to measure sleep duration and quality were assessed via a single-item question that asked for a retrospective estimate with no time frame established (e.g. over the last two weeks). This type of question is prone to recall inaccuracy as bedtime and wake-time information is omitted (Mallinson et al., 2019).

Second, because sleep was not the primary focus of either paper, the scope of sleep variables obtained was limited to TST and sleep quality. Importantly, in isolation, these data provide only partial insight into the overall sleep behaviour of esports athletes. Key aspects of sleep (among others) such as sleep timing (i.e. sleep onset time and wake-up time), sleep onset latency (SOL), wake after sleep onset (WASO), frequency and nature of sleep disruptions during training and competition schedules, how much priority is placed on sleep, influencing factors for sleep in esports, all remain unexplored at this point in time.

Third, the level of esports athletes involved in the Thomas et al. (2019) and Rudolf et al. (2020) studies was not adequately described. In the Thomas et al. study, the authors refer to ‘elite’ LoL players, while Rudolf et al. refer to ‘professional players’. The omission of information about the league and tier played in means it cannot be ascertained whether the samples comprised professional esports athletes and how elite the participants were. Consequently, the samples of these studies may not truly reflect professional esports athletes and the unique conditions under which they train and compete, thereby limiting the external validity of these findings.

### 1.6.1 Summary of Sleep Behaviour of Esports Athletes

Overall, the confluence of methodological shortcomings outlined above, including low-quality sleep measures, the limited scope of sleep information obtained and the unknown professional level of participants, cast doubt on the validity and generalisability of the findings reported by Thomas et al. (2019) and Rudolf et al. (2020). Thus, there is a need to investigate the sleep behaviour of esports athletes using more robust and information-rich sleep measures, with samples comprising true professional esports athletes. These methodological improvements will enable a more comprehensive and accurate understanding of esports athletes' sleep behaviour to be developed.

## 1.7 Potential Pressures on the Sleep of Esports Athletes

While evidence regarding the sleep behaviour of esports athletes is currently lacking, insights may be gleaned by examining related populations. Notable related populations include traditional athletes, young people and casual gamers. This section describes the sleep characteristics of these populations and the various factors that influence these characteristics.

### 1.7.1 Traditional Athletes

Although there is an ongoing debate within the esports research community about whether esports athletes are 'real' athletes (e.g. see Formosa et al., 2022), there are demonstrable similarities between the two populations. For example, traditional and esports athletes have coaches and support staff, train for long hours, compete in front of large audiences for prize money and engage with fans (Bubna et al., 2023; Reitman et al., 2020). These parallels (among others) are important as it is well documented that the unique training, travel and competition conditions experienced by traditional athletes can interfere with their sleep patterns (Bonnar et al., 2018). Consequently, it is plausible that esports athletes may encounter similar risk factors for poor sleep.

Evidence suggests that traditional athletes across a range of different sports experience suboptimal sleep outcomes. In a recent consensus statement, Walsh et al. (2021) stated that traditional athletes tend to obtain short TST (< 7 hours), have un-refreshing sleep, experience a long SOL around competitions, and show high levels of daytime sleepiness and fatigue. The authors also noted that studies regarding sleep quality have found that 50–78% of traditional athletes report sleep disturbance. Likewise, another systematic review that assessed the impact of sports participation observed that insomnia symptoms (e.g. long SOL, high WASO and fatigue) were prevalent in traditional athletes (Gupta et al., 2017). These findings clearly illustrate that traditional athletes are at high risk of experiencing suboptimal sleep outcomes.

Traditional athletes' sleep patterns are influenced by two primary types of factors—societal factors and sport-specific factors. Walsh et al. (2021) describe how societal factors are common to both traditional athletes and non-athletes and encompass aspects such as individual characteristics (e.g. sex), social demands (e.g. friends) and family commitments (e.g. children). In contrast, the authors note that sport-specific factors are intricately tied to training, travel and competition, making them unique to traditional athletes.

Competition can affect the sleep of traditional athletes in several different ways. First, the pressure of performing in competition can lead to anxiety (Ehrlenspiel et al., 2018). Cognitive models propose that sleep is affected by anxiety owing to activation of the sympathetic nervous system and corresponding physiological arousal, which makes it difficult to relax and initiate sleep (Harvey, 2002). However, while not all studies have found an effect of the nights preceding a competition (Roberts et al., 2019), several have (e.g. Erlacher et al., 2011). In a seminal study, Erlacher et al. (2011) evaluated the sleep patterns of 632 German athletes before an important competition. They found that 62.3% of participants reported a sleep disturbance in the night(s) preceding the competition. Difficulty initiating sleep was the most common sleep complaint, while the main cause of anxiety was thoughts about the competition. A subsequent study by Juliff et al. (2015) corroborated these findings in a sample of 283 elite Australian athletes. Thus, the impact of pre-competition anxiety may be a concern, potentially affecting many traditional athletes and often leading to sleep disturbances.

The timing of competition can also influence the sleep of traditional athletes. Although traditional athletes generally tend to sleep less on competition nights (Roberts et al., 2019), night competitions may be particularly impactful (Walsh et al., 2021). For example, Fullagar et al. (2016) assessed the sleep of 16 top-division European football players across day and night matches. They found that participants' TST was significantly reduced following night matches compared with day matches (i.e. there was a mean 157- minute difference between day and night matches). Similar findings have been reported in another sample of football players (Nédélec et al., 2019) in addition to several other sports, including Australian rules football (Sargent & Roach, 2016) and rugby union (Shearer et al., 2015). Furthermore, Miles et al. (2019) found indirect evidence supporting these findings in a sample of 86 coaches and support staff. In their study, results showed that most participants (86%) reported that night matches negatively affected the sleep of traditional athletes. In summary, numerous studies across various sports and from both direct and indirect sources have consistently highlighted the detrimental impact of night competitions on the sleep of traditional athletes.

Like competition, training can affect the sleep of traditional athletes in several different ways. First, early morning training (at or before 7:00 am) has been found to result in reduced TST and sleep efficiency (Roberts et al., 2019). In one study involving Olympic swimmers, Sargent et al. (2014) found that time in bed and TST were significantly shorter on nights preceding training days versus nights preceding rest days. This shorter TST occurred despite participants attempting to offset the impact of the earlier training time by going to bed and trying to sleep earlier, highlighting the difficulty of preventing reductions in TST. Second, increased training load can reduce TST and sleep efficiency via increased cortisol levels and pain experiences such as muscle soreness (Roberts et al., 2019). Reductions are typically modest (i.e. TST = < 30 minutes; sleep efficiency = < 5%; Walsh et al., 2021), while large increases in training load are more consistently linked with worse sleep than small increases (Roberts et al., 2019). In conclusion, the impact of training on the sleep of traditional athletes is multifaceted, with both training timing and intensity playing key roles.

Travel is another prominent sport-specific factor found to have a detrimental effect on the sleep of traditional athletes (Roberts et al., 2019). Sleep opportunities can be curtailed because of late-night or early-morning departure times, leading to reduced TST (Fowler et al., 2015). For traditional athletes travelling by air, jet lag can arise when travelling across time zones owing to the circadian misalignment between the internal circadian system and the time at the new destination (Janse van Rensburg et al., 2021). Jet lag symptoms include sleep disturbances (e.g. SOL, WASO and early morning awakening), reduced TST and daytime impairments such as fatigue (Walsh et al., 2021). Symptom severity and duration vary based on factors such as the time zone differential, direction of travel and individual differences in circadian rhythm timing (Janse van Rensburg et al., 2021). At the end of travel, unfamiliar sleep environments can also contribute to poor sleep. Pitchford et al. (2017) found in a group of Australian rules football athletes that unfamiliar sleep environments contributed to increased WASO and decreased sleep efficiency. Taken together, all stages of the travel process can create sleep challenges for traditional athletes.

### 1.7.2 Young People (Adolescents and Young Adults)

The average age of professional esports athletes is generally around the early 20s (e.g. Poulus et al., 2023; Poulus et al., 2022b). However, there are younger esports athletes as well, with some leagues (e.g. the North American League of Legends Championship Series, and the Rocket League Championship Series) setting the minimum competitive age below 18 years of age (LCS & LACS, 2020; Watson, 2016). Hence, many young people (i.e.

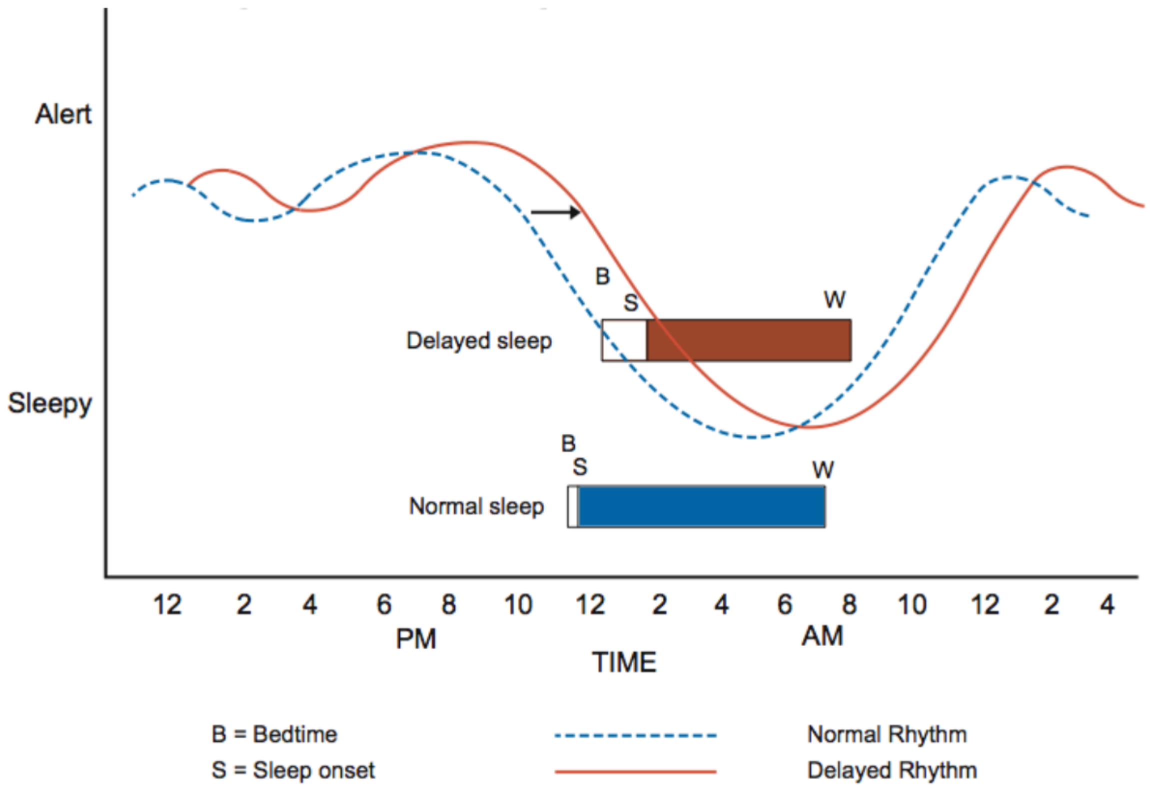
adolescents and young adults) compete in esports. Importantly, it is well known that adolescence and the transition to adulthood is a time of great change, during which significant social, cognitive and emotional development occurs (Casey et al., 2019; Kilford et al., 2016; Pfeifer & Blakemore, 2012). For example, young people learn to drive, obtain employment, prefer to spend time with friends rather than family, have greater academic demands placed on them and engage in more risk-taking behaviour, such as substance use (Laursen & Hartl, 2013; Spear, 2000). Sleep is not impervious to these changes and is influenced by a complex interplay of biological and psychosocial factors (Carskadon, 2002).

From a biological perspective, the circadian system (known as Process C) determines the timing of sleep. It is one of the primary driving forces behind changes in young people's sleep (Carskadon, 2002). The circadian system generates circadian rhythms, which are near 24-hour hormonal and behavioural cycles regulated by the suprachiasmatic nucleus (SCN), a small structure located in the anterior hypothalamus (Lack & Wright, 2007). The SCN requires daily adjustment to the external 24-hour world, with entrainment achieved through environmental time cues (known as zeitgebers or 'time givers'; Roenneberg & Merrow, 2007). There are several zeitgebers (e.g. eating and physical activity), but the most prominent is the light/dark cycle (Lack & Wright, 2007). More specifically, light/dark information received by photoreceptors in the retina is transmitted to the SCN via the optic nerve (Duffy et al., 2021). The SCN responds to this information by influencing a range of physiologic functions, including melatonin and core body temperature, which have a reciprocal and stable phase relationship (i.e. they are coupled) and affect sleep propensity (Lack & Wright, 2007). Melatonin—a hormone produced by the pineal gland—increases in dim light in the evening and decreases in bright light (Zaki et al., 2020). In healthy samples with normal sleep/wake schedules, melatonin excretion begins approximately 2 hours before sleep onset, is highest just after the sleep midpoint and decreases to barely detectable levels within about 2 hours of waking (Shanahan & Czeisler, 1991). Inversely, as melatonin increases, core body temperature decreases (Lack & Wright, 2007). Core body temperature is typically highest in the early evening before decreasing to a nadir (i.e. core temperature minimum) slightly after the melatonin peak and approximately 2 hours before natural wake-up time (Lack & Wright, 2007). For normally entrained individuals, optimal melatonin and core body temperature conditions are at night, which allows the major sleep period to occur during the hours of darkness (Kubota et al., 2002). Thus, adequate TST can be obtained without conflict between the major sleep period and daytime obligations.

In contrast to typical entrainment (i.e. when sleep occurs at night), young people are naturally predisposed to a phase delay in their circadian rhythm, as shown in Figure 1.2 (Carskadon, 2002). Beginning in puberty, a shift in circadian timing results in later sleep onset and wake-up times as sleep propensity delays (Duffy et al., 2021). Normative data from around the world shows that this shift in circadian timing occurs across adolescence and well into early adulthood before stabilising near age 30 (Kuula et al., 2019). Furthermore, there are clear sex differences, with males showing a bigger delay in their circadian timing than females (Kuula et al., 2019). Problematically, delayed circadian timing can result in a misalignment between an individual's biological and social clocks since the major sleep period begins to conflict with daytime tasks and activities (Lack et al., 2009). There are two main consequences of this conflict. First, if individuals are required to wake earlier than their natural wake time, they will operate near the circadian nadir of core body temperature (Lack et al., 2009). Research investigating intra-daily variation in performance has found that traditional athletes who perform close to this circadian nadir experience decreased performance (Brager et al., 2022). Second, sleep opportunity is curtailed if required to wake earlier (Lack et al., 2009). Consequently, normative data show that as circadian timing delays, TST declines, particularly in males (Kuula et al., 2019). Thus, as mentioned earlier, chronic sleep restriction is common during adolescence and young adulthood (Owens et al., 2014).

**Figure 1.2**

*An Example of a Delayed and 'Normally Entrained' Circadian Rhythm*




*Note.* The blue dotted line represents an individual with a 'normally entrained' circadian rhythm, whereby sleep and wake times are consistent with social obligations. The red line represents an individual with a delayed circadian rhythm, whereby sleep and wake times conflict with social obligations. Horizontal bars reflect the sleep period for each respective individual, while the transparent parts of the bar reflect the time between bedtime and sleep onset. This image was used with permission from Professor Michael Gradisar at WINK Sleep.

Adding further biological pressure on young people's sleep are changes in the homeostatic sleep drive (known as Process S), which works in conjunction with the circadian system to regulate the sleep-wake cycle (Lack & Wright, 2007). After waking, sleep pressure increases throughout the day. Notably, the specific homeostatic sleep drive regulatory processes are still being elucidated (Gradisar et al., 2022). For example, evidence indicates that the increase in sleep pressure is partly attributable to the accumulation of the neuromodulator adenosine in wake-promoting areas of the brain (e.g. basal forebrain; Huang et al., 2011). Once sleep is initiated, adenosine levels gradually decrease across the sleep period, which contributes to the restoration of wakefulness upon waking (Huang et al., 2011).

Additionally, recent research has focused on the role of brain maturation and the implications for sleep propensity (Reynolds et al., 2023). During pubertal development, there is an increase in sleep propensity until the age of 14.3 years, after which the accumulation of sleep pressure plateaus and sleep propensity remains stable into adulthood (Campbell et al., 2024). These changes are associated with developmental changes in brain maturation (e.g. synaptic pruning) and alterations in brain activity (i.e. a decline in slow-wave sleep; Campbell et al., 2024). Consequently, sleep signals occur later in the evening, compounding the inclination for later bedtimes and sleep onset times (Crowley et al., 2007; Reynolds et al., 2023).

In addition to biological changes, psychosocial factors can also influence young people's sleep. Meta-analytic evidence from Bartel et al. (2015) suggests that internet use, exposure to evening light before bed, computer use, mobile phone use, video gaming and negative family environment were all associated with later bedtimes. The authors also found that a negative family environment was associated with a longer SOL. In contrast, tobacco use, computer use, evening light, negative family environment and caffeine consumption were associated with decreased TST. Another prominent psychosocial factor that has been found to influence young people's sleep is increased autonomy (Carskadon, 2011). Older adolescents transitioning into adulthood have fewer parental restrictions, including set bedtimes (Carskadon, 2011; Khor et al., 2021; Short et al., 2013). Thus, this freedom to stay up longer typically results in later bedtimes (Short et al., 2013). However, if young people cannot wake up later because of morning commitments such as school or work, sleep opportunity and TST are curtailed (Carskadon, 2011).

### 1.7.3 Casual Gamers

Casual gamers and esports athletes share an obvious commonality—they both play video games. Casual gamers play video games for entertainment and leisure rather than pursuing serious competitive goals (Bubna et al., 2023). However, casual gamers play the same games as esports athletes despite the differences in how they interact with video games (e.g. different goals and motivations). Further, they can both play video games for long periods. Importantly, over the years, a growing awareness has developed regarding the adverse health risks caused by excessive video game play (Holden et al., 2018), including an impact on sleep.

Most cross-sectional research has linked playing video games with worse sleep outcomes. For example, Exelmans and Van den Bulck (2015) recruited 844 participants and assessed a range of sleep outcomes. Results showed that greater levels of video game play were associated with delayed sleep timing (i.e. later sleep onset and wake-up times) and increased insomnia symptoms. Moreover, these effects were greater when video game play exceeded 60 minutes. Other studies have echoed these findings in different ways. In their study, De Rosa et al. (2023) recruited 402 adults who identified as either habitual or non-habitual gamers. They found that habitual gamers had delayed circadian timing compared with non-habitual gamers, with hours of video game play per week predicting delayed circadian timing. However, the authors did not find any impact on sleep quality. Emphasising the impact of longer video game play, Twenge et al. (2019) observed that video game play increased the odds of short TST in a big data study comprising 43,755 US adolescents, with hours of video game play correlated with < 7 hours of sleep per night. While these cross-sectional studies provide valuable insight into the relationship between video game play and sleep, they cannot establish a cause-and-effect relationship. Hence, experimental research is necessary to determine whether video game usage directly causes sleep disturbances and to explore the mechanisms behind these effects.

Fortunately, experimental study designs have also been used to explore the impact of video gaming on sleep. For example, Dworak et al. (2007) recruited a sample of 11 adolescents who played a video game for 60 minutes between 6:00 pm and 7:00 pm. They found that compared with a control condition, SOL increased by 21 minutes for participants who played the video game. Likewise, Weaver et al. (2010) recruited a sample of 13 adolescents who played a video game for 50 minutes, stopping just before their regular bedtime. Results showed that relative to the control condition, participants who played the video game had increased SOL of 4.5 minutes, which was not considered clinically remarkable. Noting that previous studies typically capped video game play at smaller doses (e.g. 50–60 minutes), King et al. (2013) examined the impact of a bigger dose of video gaming (i.e. 150 minutes v. 50 minutes) in a sample of 17 adolescent males. They reported that compared with a 50-minute dose, participants in the prolonged play condition experienced increased subjective SOL (but not objective), shorter objective TST and decreased objective sleep efficiency. The finding that bigger doses of video game play have a more detrimental effect on sleep is also supported by cross-sectional research (Exelmans & Van den Bulck, 2015; Twenge et al., 2019).

Expanding on the findings from King et al., some evidence suggests that the effects of prolonged gaming on sleep may differ based on participants' expertise. Ivarsson et al. (2013) recruited a sample of 30 adolescents with a gaming history of low exposure (≤ 1 hour per day) or high exposure (≥ 3 hours per day). They had them play either a violent or non-violent video game for 120 minutes. The findings revealed that sleep quality was more negatively influenced after the violent game in the low-exposure compared with high-exposure participants. The authors concluded that video game play may have a de-sensitising effect on sleep in casual gamers who play for longer and more regularly. Overall, a range of factors (e.g. gaming content, duration and prior participant experiences) appear to influence the impact of video game play on sleep, making it a complex area of study.

Several mechanisms explaining the impact of video games on sleep have been proposed and investigated. First, increased physiological arousal (typically measured via heart rate) has been suggested to affect SOL. Although Weaver et al. (2010) and King et al. (2013) found no effect of video games on pre-sleep heart rate and sleep, other studies have (e.g. Ivarsson et al., 2009, 2013). In their review of the literature, Peracchia and Curcio (2018) concluded that it is likely that playing video games influences pre-sleep heart rate and, by extension, subsequent sleep. It has been asserted that some games (e.g. faster-paced games) may induce a stronger effect on arousal owing to greater cognitive load (Kemp et al., 2021), yet this hypothesis remains to be tested.

Second, increased pre-sleep cognitive alertness has also been proposed as a potential mechanism, but only a handful of studies have investigated this link. For example, one study using alpha power (measured by electroencephalogram) and another using functional magnetic resonance imaging demonstrated that playing a video game led to heightened cognitive alertness (Mathiak & Weber, 2006; Weaver et al., 2010). Once again, many questions (e.g. game type and duration) regarding the potential role cognitive alertness plays in disrupting the sleep of casual gamers are yet to be answered.

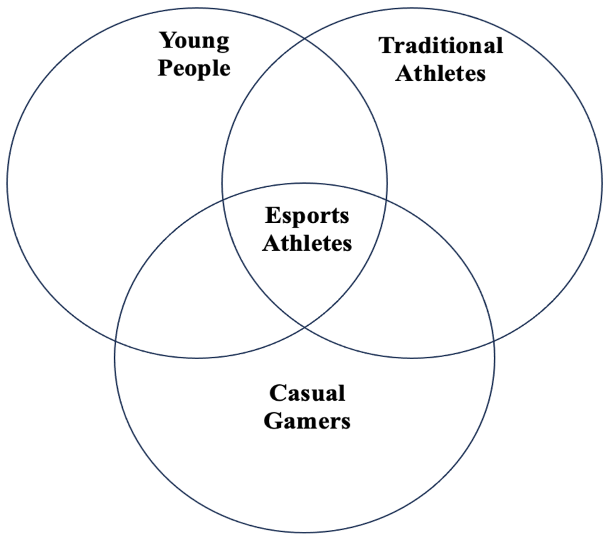
Third, exposure to bright light via screens (and associated melatonin suppression) is an often-cited mechanism by many authors in the literature (e.g. Kemp et al., 2021). However, despite significant academic and media attention, findings regarding the link between evening screen light exposure and disturbed sleep are equivocal (N. A. Wong & Bahmani, 2022). Overall, the current body of evidence is lacking and conflicting, highlighting the need for further research to fully elucidate the mechanistic relationship between playing video games and sleep disruptions.

### 1.7.4 Summary of Potential Pressures on the Sleep of Esports Athletes

Esports athletes sit at the nexus of three related populations—traditional athletes, young people and casual gamers (see Figure 1.3). Evidence clearly shows that each of these populations is at risk of suboptimal sleep outcomes (e.g. long SOL, sleep disturbances, short TST and insomnia symptoms) owing to a range of factors. Traditional athletes are susceptible to the effects of training, travel and competition. Young people are vulnerable to biological and psychosocial changes that accompany their development. At the same time, casual gamers appear to be affected by the use of video games themselves (although the mechanistic relationship is poorly understood). Consequently, esports athletes' sleep patterns may be adversely affected owing to a confluence of risk for poor sleep.

**Figure 1.3**

*Venn Diagram Showing Esports Athletes at the Nexus of Three Related Populations*




*Note.* Esports athletes are exposed to a confluence of risk factors for poor sleep, which may adversely affect their sleep patterns.

## 1.8 Measuring Sleep

In line with a broader societal trend toward greater monitoring and recording of health data (Bunn et al., 2018), there is an ever-expanding range of sleep measurement tools available to researchers and clinicians (Walsh et al., 2021). Measures can be categorised as objective or subjective but differ based on the technology or process used to capture sleep data. The more commonly reported sleep variables recorded by these measures include TST, SOL, sleep onset time, WASO, wake-up time, sleep efficiency and sleep architecture.

### 1.8.1 Objective Measures

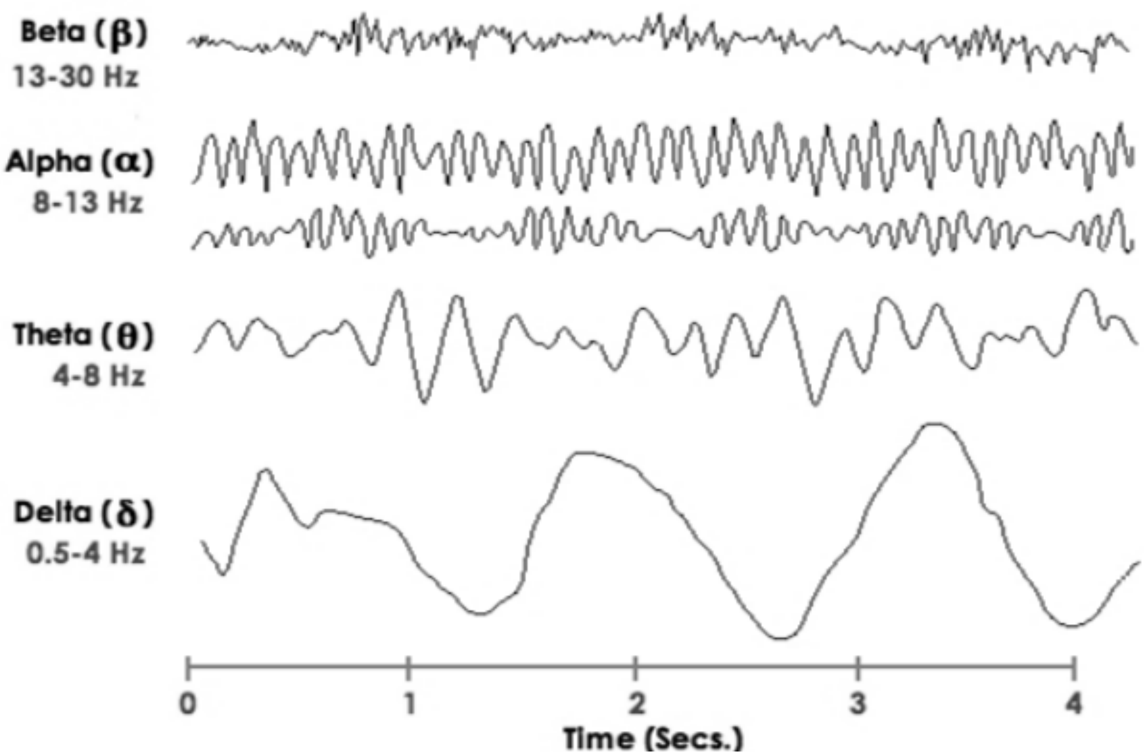
Objective sleep measures play a crucial role in providing accurate and impartial information about an individual's sleep that is free of bias (Martin & Hakim, 2011). However, objective sleep measures cannot capture information about perceptions of sleep, the daytime effects of sleep (e.g. fatigue and sleepiness) or other sleep-related behaviours (e.g. caffeine use).

### *1.8.1.1 Polysomnography*

In the field of sleep medicine, polysomnography (PSG) is considered the 'gold standard' for measuring, monitoring and assessing sleep in humans (Berry et al., 2012). PSG can precisely differentiate sleep and wake states and sleep architecture (i.e. the structural organisation of sleep cycles and stages; see Figure 1.4) by simultaneously recording and triangulating multiple physiologic parameters related to sleep (Jafari & Mohsenin, 2010). More specifically, electrodes are applied to the head and face to measure electrical brain activity (electroencephalogram), eye movements (electrooculography) and muscle tone (electromyography; Jafari & Mohsenin, 2010).

**Figure 1.4**

*PSG Output*




*Note.* An example of brain activity during different stages of sleep as measured by PSG. This image was used with permission from Dr Kate Bartel.

Despite being the gold standard in sleep measurement, the use and application of PSG in normal living conditions outside of sleep laboratory settings is extremely limited (Dunican et al., 2018), even with advancements in home-based PSG (Punjabi et al., 2022). Not only is there a high participant burden, but equipment is also expensive, and technicians require intensive training owing to the administration and scoring complexity of PSG (Walsh et al., 2021). Hence, PSG is typically used in single-night sleep studies for diagnostic purposes and research with brief protocols rather than in field-based research in which multiple participants are monitored concurrently over successive nights (Dunican et al., 2018). Accordingly, PSG was deemed unsuitable for use in the present thesis.

#### *1.8.1.2 Wrist Activity Monitors*

Wrist activity monitors are another objective sleep measure commonly used for clinical and research purposes (Grandner & Rosenberger, 2019). Wrist activity monitors are wearable devices that were originally based on the principles of actigraphy, whereby gross motor movement recorded using an accelerometer is used to determine sleep-wake states (i.e. essentially, no movement is sleep and movement is wake; Fekedulegn et al., 2020). However, although accelerometers remain the cornerstone of wrist activity monitor technology, many devices now incorporate other physiological sensors (e.g. heart rate and temperature) to improve their accuracy (Rentz et al., 2021). Collectively, these data are analysed using either semi-automated or fully automated scoring algorithms.

Wrist activity monitors are often used as an alternative to PSG as they are less invasive, cheaper and more deployable (Walsh et al., 2021). Importantly, they continuously track data on the sleep-wake behaviour of individuals under normal living conditions in the home for extended periods, promoting high ecological validity (e.g. measuring sleep patterns across weekdays and weekends; Wright et al., 2017). Whereas data from older wrist activity monitor models needed to be manually extracted, modern wrist activity monitors integrate remote monitoring and recording capability, allowing near-real-time data processing (Wright et al., 2017). Thus, for these reasons, wrist activity monitors offer the high operational flexibility required for field-based research (Van De Water et al., 2011).

In recent years there has been a proliferation of commercial wrist activity monitors. Unlike traditional research-grade wrist activity monitors (e.g. Actiwatch), commercial devices use entirely automated algorithms and usually do not require an input of time-in-bed data (Chinoy et al., 2021). Moreover, although the mathematical modelling that underpins the algorithms of traditional research-grade wrist activity monitors is open source, the algorithms in commercial devices are proprietary and, therefore, unknown (Rentz et al., 2021). Thus, some authors have raised concerns about the validity and utility of commercial wrist activity monitors being used as an alternative to traditional research-grade wrist activity monitors in sleep research (Chinoy et al., 2021; Rentz et al., 2021).

**Figure 1.5**

*An Example of Wrist Activity Monitor Output*


*Note.* This output is from a Readiband device developed by Fatigue Science, which was used in Chapters 3 and 4. Light grey horizontal bars represent sleep (white gaps in these bars represent wake). Dark grey spiky lines represent movement. White horizontal background represents wakefulness. Red lines with no dark grey spiky lines indicate when the device was not being worn. The green line represents an alertness score based on an individual's sleep data, an additional feature of the Readiband device that can be switched on to provide biofeedback to the user (which is featured in Chapter 4). This anonymised output is from a participant who permitted their data to be used as an image.

In response to the concerns regarding commercial wrist activity monitors, researchers have conducted validation studies (i.e. 'performance evaluation'; de Zambotti et al., 2022). For example, Chinoy et al. (2021) compared four commercial wrist activity monitors (i.e.

Fitbit Alta HR, Readiband, Garmin Fenix and Garmin Vivosmart) to PSG and Actiwatch. Results revealed that the Readiband (see Figure 1.5) and two Garmin devices performed equivalent to the Actiwatch on many variables, while the Fitbit Alta HR performed better on most. Thus, the authors concluded that appropriately validated commercial wrist activity monitors can be used for research purposes. Further to this point, Walsh et al. (2021) posited that wrist activity monitors should be classified as either research grade (validated against PSG) or commercially available (not validated against PSG).

Wrist activity monitors have many advantages, but they are not without limitations. Acknowledging inter-device variability, wrist activity monitors generally have high sensitivity (i.e. ability to detect sleep), while specificity (i.e. ability to detect wake) is relatively poor (Chinoy et al., 2021; Sadeh, 2011). That is, although wrist activity monitors can correctly identify periods of sleep, periods of wake may be misidentified as sleep. Hence, relative to PSG, there is a bias to overestimate TST, amplified when individuals spend longer in bed awake but are immobile (known as 'quiet wakefulness'; Grandner & Rosenberger, 2019). Conversely, there is also a bias for wrist activity monitors to underestimate WASO and SOL, although these discrepancies are typically modest for many devices (Chinoy et al., 2021).

It is also worth noting that wrist activity monitors tend to perform poorly in sleep-disturbed populations compared with healthy sleepers (Sadeh, 2011). For example, poor correspondence between wrist activity monitors and PSG has been found in adolescents and adults with sleep-disordered breathing (N. L. Johnson et al., 2007; Morgenthaler et al., 2007) and adults with hypersomnolence (Cook et al., 2018) and insomnia (Kahawage et al., 2020; Kang et al., 2017). To mitigate the risk of wrist activity monitor data accuracy being compromised, it is recommended that multiple nights of sleep data should be obtained, even for healthy sleepers (Sadeh, 2011). Aggregating data this way enables a more stable and representative measure of sleep to be gained (Fekedulegn et al., 2020).

A final limitation for wrist activity monitors is that despite the fact they are more feasible for larger scale studies than PSG, there are still considerations regarding dissemination that need to be considered. That is, they are not always realistic for studies with many participants or where participants are spread out geographically (Gradisar et al., 2011). This second point is particularly pertinent for esports as many domestic competitions are online, meaning esports athletes can play from a remote location to the esports league headquarters and separate from their teammates. For example, in Australia, most esports athletes tend to reside on the East Coast of Australia and can, therefore, play for the same team but be in any one of five separate states or territories. Altogether, wrist activity monitors have utility in esports research and were used in the present thesis where feasible.

#### *1.8.1.3 Nearables*

An emerging area of sleep monitoring that comes under the objective sleep measure umbrella is the use of aptly named nearables. Nearables are non-contact sleep trackers embedded in the sleep environment (Yoon & Choi, 2023). There are three main types of nearable technology: film-based systems placed under the bed or mattress and radar or microphone-based systems placed close to an individual (Yoon & Choi, 2023). Similar to wrist activity monitors, the different nearable technologies employ a range of physiological sensors and can detect and monitor signals such as an individual's body movement, heart rate, and breathing (Bianchi, 2018). Data are then analysed using automated scoring algorithms (once again proprietary and therefore unknown) and typically presented to the user via a mobile phone application (Yoon & Choi, 2023).

The main advantage of nearables over other objective sleep measures is that they are not required to be worn to obtain information about an individual's sleep. Hence, they are unobtrusive and may be less prone to compliance issues compared with wrist activity monitors (e.g. Tudor-Locke et al., 2011), which can be uncomfortable for some users or forgotten to be worn. However, despite these advantages, nearables are vulnerable to ‘noise’, whereby signal quality is impaired by unintended information picked up by the device. Furthermore, some nearables have the same deployability issues as wrist activity monitors (i.e. dissemination challenges), while validation studies are lacking (Walsh et al., 2021). Overall, evidence supporting nearables is still developing; hence, their use in clinical and research settings is cautioned (Walsh et al., 2021). In light of these facts, nearables were not considered for the present thesis.

### 1.8.2 Subjective Measures

Subjective sleep measures provide valuable insight into an individual’s sleep habits, daytime functioning and sleep-related behaviour based on their own perception and experience (Carney et al., 2012). They are cheap, easy to administer (Walsh et al., 2021), and useful for large-scale studies or when participants are geographically scattered (Mallinson et al., 2019). However, they are vulnerable to response biases, such as recall bias, whereby an individual may have an inaccurate memory or perception of their own sleep (Martin & Hakim, 2011). The following sections summarise the characteristics of two broad types of self-report measures: sleep diaries and questionnaires.

#### *1.8.2.1 Sleep Diaries*

Sleep diaries are considered the gold standard of subjective sleep measures and involve the daily recording of information about sleep and daytime behaviour over a specified period, such as two weeks (Carney et al., 2012). The information collected by sleep diaries includes many of the same variables captured by objective sleep measures like PSG and wrist activity monitors (e.g. SOL, WASO and TST). However, it can also include others like bedtime and lights out time, which are behavioural measures of sleep (Carney et al., 2012). Information about behaviours that can influence sleep, such as sleep medication, caffeine and alcohol use, can also be obtained, as can information regarding consequences of sleep, such as daytime alertness (Carney et al., 2012).

In terms of the agreement between sleep diaries and PSG and wrist activity monitors, the relationship profile is mostly comparable. Relative to PSG, evidence suggests that sleep diaries yield higher estimates of TST (Lehrer et al., 2022; Matthews et al., 2018). In line with this finding, sleep diaries underestimate SOL and WASO (Lehrer et al., 2022). A similar pattern is observed for sleep diaries compared with wrist activity monitors. That is, relative to wrist activity monitors, sleep diaries generally overestimate TST and underestimate WASO but overestimate SOL (Walsh et al., 2021). Interestingly, sleep diary estimates of sleep timing are consistent with PSG and wrist activity monitors (Dietch & Taylor, 2021). Furthermore, agreement between sleep diaries and PSG and wrist activity monitors tends to decrease in sleep-disordered populations (e.g. Lehrer et al., 2022).

With respect to reliability (i.e. the number of sleep diary entries required to estimate sleep accurately), evidence varies between studies. For example, Short et al. (2017) assessed the number of sleep diary entries required to estimate sleep in a multi-national sample comprising Australian, American, British and Qatari adolescents. The authors found that conservatively speaking, a minimum of five nights were needed for a reliable estimate of bedtime, SOL and TST on school nights. However, a reliable estimate could be obtained with fewer nights depending on the country and sleep variable measured. In another study involving young adults, reliability values increased with more days of data collected. However, the authors concluded that only seven nights were required for an adequate and reliable estimate of TST (Borba et al., 2020).

Sleep diaries are generally considered more accurate than questionnaires for sleep pattern assessment owing to daily recording instead of a once-off estimation (Mallinson et al., 2019; Miller et al., 2015). A good example of the difference in precision between the two measures can be seen with TST, where there is a trend for questionnaires to result in rounding to the nearest half-hour. This phenomenon is not present in sleep diaries (Mallinson et al., 2019). However, some studies have found moderate-to-strong correlations between sleep diaries and questionnaires, suggesting some level of agreement (e.g. Matricciani, 2013). Another benefit of sleep diaries over questionnaires is that sleep diaries allow analysis of night-to-night variability in sleep variables. This ability may be useful for some researchers, whereas questionnaires only provide a single data point (Ibáñez et al., 2018).

Among the variety of sleep diaries available to researchers and clinicians, the Consensus Sleep Diary is widely recognised and utilised (Carney et al., 2012). The Consensus Sleep Diary was jointly developed by a panel of sleep experts and then refined by other sleep experts in addition to good and poor sleepers through focus groups and a drafting process (Carney et al., 2012). The culmination was a consensus-based standardised sleep diary supported by researchers, clinicians and users. Research suggests no differences between online and paper versions of the Consensus Sleep Diary, but online versions may have other benefits (e.g. superior daily recording compliance and reduced time burden) compared with sleep diaries and are thus recommended (Tonetti et al., 2016). Overall, online sleep diaries appear well suited to esports research and were used in the present thesis where appropriate.

#### *1.8.2.2 Sleep Questionnaires*

The other subjective measure frequently used in the literature is once-off questionnaires (Ibáñez et al., 2018). These questionnaires typically take the form of structured surveys and are designed to assess various aspects of an individual's sleep patterns (e.g. TST), daytime functioning (e.g. sleepiness), potential sleep disorders (e.g. insomnia) and other sleep-related behaviour such as bedtime procrastination (Walsh et al., 2021).

Questionnaires are typically brief, convenient and even less onerous than sleep diaries for participants to complete (Gradisar et al., 2011; Martin & Hakim, 2011). Additionally, they are highly versatile and can be used for a range of different purposes, such as screening (e.g. for symptoms of insomnia), clinical assessment (e.g. diagnosing sleep disorders) and research (e.g. monitoring treatment outcomes; Ibáñez et al., 2018; Walsh et al., 2021).

Although the validity and reliability of questionnaires can vary, the psychometric properties of the more widely used questionnaires in the literature are well established. For example, the insomnia severity index (ISI) used to assess the presence and severity of insomnia symptoms has been validated in multiple countries with different populations (e.g. Bastien et al., 2001; Cho et al., 2014). Further, in line with its broad evidence base, the ISI has excellent sensitivity and specificity (Morin et al., 2011). However, it should be noted that no sleep-related questionnaires have specifically been validated in an esports population. Of course, that does not preclude sleep questionnaires from being used in research with esports athletes, but it does mean caution is required when interpreting and generalising results.

Although questionnaires have many advantages, there are drawbacks as well. As with sleep diaries, questionnaires are vulnerable to response biases (Walsh et al., 2021). For example, recall bias can lead to inaccurate answers, while social desirability bias can contribute to the overestimation or underestimation of sleep-related issues. Additionally, participants may interpret questionnaire items differently based on factors such as event definition, context and timeframe, leading to response variability (Robbins et al., 2021). Furthermore, questionnaires may not capture all relevant information related to an individual's sleep experience (Ibáñez et al., 2018). Researchers can mitigate against these drawbacks and improve the quality of data collected by doing things such as including objective measures where possible, standardising administration and openly addressing response biases with participants. In summary, like sleep diaries, sleep questionnaires were considered useful in the current thesis.

### 1.8.3 Summary of Measuring Sleep

All sleep assessment methods have advantages and disadvantages. PSG is the gold standard of sleep assessment but is typically not feasible for field-based research. Wrist activity monitors are more suitable for field-based research but are difficult to disseminate to geographically scattered participants. Nearables are an emerging and interesting technology but require further validation. Sleep diaries and questionnaires are cheap and easy to administer for large-scale, geographically challenged studies but are vulnerable to response biases and other issues. Ultimately, sleep assessment measures should be combined where possible and adapted to the individual needs of a study. To this end, the series of studies in the present thesis investigated various aspects of esports athletes' sleep behaviour. These studies were conducted at a multi-national or national level, meaning participants were spread out. Hence, sleep diaries and questionnaires were used, and despite dissemination difficulties, wrist activity monitors were also used when deemed feasible.

### 1.8.4 Measuring Performance

Although esports research has expanded in recent years, there are no standardised or recommended best practices for measuring performance in esports at this current time. However, as described earlier, there is shared common ground between traditional and esports athletes. Hence, the sleep domain of the sports science literature may offer some useful insights into the types of performance measures that could be used with esports athletes.

Performance measures used in the sports science and sleep literature can generally be categorised into universal measures and sport-specific measures (Mah et al., 2011). Universal measures are metrics that can be applied across various sports. These measures are generalisable and not specific to any particular sport. For example, reaction time measured via the psychomotor vigilance task (PVT) can be obtained from athletes competing in many sports (e.g. handball and swimmers; Jarraya et al., 2014; Rosa et al., 2018). In contrast, sport-specific measures are metrics tailored to a specific sport or even a position within a sport. These measures are designed to assess skills and abilities directly related to the requirements of that sport. For example, serving accuracy for tennis players (e.g. Schwartz & Simon, 2015) or free throw accuracy for basketball players (e.g. Mah et al., 2011). As with any measure, there are advantages and disadvantages for both types. In general, universal measures appear to have been used more frequently in the literature, possibly because (a) they allow comparative analysis between studies and (b) data are relatively easy to collect. Conversely, sport-specific measures may be particularly meaningful and relevant as they provide insights within the context of a sport (Mah et al., 2011). Measure selection depends on research objectives, available resources and pragmatic considerations.

Determining the suitability of universal and sport-specific measures for esports research requires consideration of several factors. For example, unlike traditional sports, in esports, there are a multitude of sport-specific measures that data can be collected for and analysed relatively easily because esports athletes compete on computers (an example of a sports-specific measure in an esports context is kills/deaths/assists ratio in Counter-Strike: Global Offensive; Pluss et al., 2019). However, data ownership restrictions (game developers often own esports athletes' data; Karhulahti, 2017) and team concerns around confidentiality and giving opponents insight into their performance create significant data access barriers. Hence, the ease with which data for sport-specific measures can be captured in esports is offset by the challenges of accessing the data.

Another consideration when selecting universal or sport-specific performance measures in sleep and esports research is whether a measure has adequate sleep sensitivity.

For example, it is well established that the PVT (which generates metrics such as reaction time) has a high sleep sensitivity, which is why it is used so often in the sleep literature (Basner et al., 2011). In contrast, it may be harder to isolate the effect of sleep on other less sleep-sensitive measures or for which there are multiple determinants (Smithies et al., 2021). Furthermore, researchers are yet to establish which sport-specific measures (across the vast range of games played in esports) in esports are sleep-sensitive. Essentially, there is a lack of evidence in the literature to make theoretically grounded decisions about which sport-specific measures in esports are sleep-sensitive. Given the limitations mentioned above, sport-specific measures were deemed unfeasible for the present thesis.

Among universal measures, the PVT is perhaps the most widely used measure in the sleep domain of the sports science literature, given its high sleep sensitivity (Basner et al., 2011; Hudson et al., 2020). Modern versions of the PVT are typically presented on a computer or device (e.g. tablet or phone) in a quiet, distraction-free environment (e.g. Antler et al., 2022; Jones et al., 2018). A stimulus is presented on the screen randomly over a specified period (e.g. 5 minutes), and participants must touch the screen as quickly as possible (Jones et al., 2018). As noted earlier, the PVT generates a range of metrics. However, reaction time and number of response errors (e.g. touching the screen before the stimulus is presented) are the two most widely reported (Basner et al., 2011). Remote assessment using the PVT has been used in seminal research (Mah et al., 2011). Furthermore, it has no learning curve (i.e. no practice effects), which makes it suited to studies using repeated measures (Hudson et al., 2020). Thus, the PVT was selected for the present thesis as it struck the correct balance between our research objectives and the pragmatic constraints of conducting esports research.

#### *1.8.4.1 Summary of Measuring Performance*

Although sport-specific measures are considered more meaningful than universal measures, barriers to accessibility and not knowing which measures are sleep-sensitive make data collection very difficult. As esports research grows and these barriers are resolved, sports-specific measures may become more feasible. However, as it currently stands, universal measures appear to be a more viable option and offer the benefit of comparative analysis across studies. This situation will prove useful in the future if other researchers want to compare esports athletes across different games. Consequently, in the present thesis, the PVT (delivered in person for one study and remotely for another) was used in relevant studies when performance measures were included.

## 1.9 Chapter Summary

The esports industry has experienced remarkable growth over the last decade and has gone global. Consequent to the increasing professionalisation of esports, the health of esports athletes has come into focus. Sleep is one such area, given its critical role in supporting human health and performance. Of specific relevance to esports athletes, evidence from the wider sleep literature shows that suboptimal sleep has a deleterious effect on cognitive functioning and mental health. These findings highlight the need to understand the sleep health of esports athletes. However, the limited existing evidence regarding the sleep behaviour of esports athletes, which suggests they sleep adequately, is prone to several methodological shortcomings, casting doubt on the validity and generalisability of these findings. Indeed, esports athletes sit at the nexus of three related populations: traditional athletes, young people and casual gamers, all of whom experience a high risk for poor sleep outcomes. In light of this confluence of risk for poor sleep, esports athletes may also be vulnerable to suboptimal sleep. Overall, further research using more robust and rigorous methodologies will enable a more comprehensive understanding of esports athletes' sleep to be developed. Based on the characteristics and nature of the esports population, the most viable sleep measures are likely sleep diaries and questionnaires (although wrist activity monitors will be used where possible). In contrast, the most feasible performance measures are universal measures (i.e. PVT).

## 1.10 Thesis Aims and Outline

The aims of the current thesis were threefold. **Aim 1** was to quantify the sleep behaviour of professional esports athletes and, further, how sleep behaviour might relate to mood and cognitive performance. **Aim 2** was to identify and begin to understand the factors that influence the sleep behaviour of esports athletes. Finally, **Aim 3** was to design and evaluate a sleep intervention for esports athletes.

While the three aims are presented chronologically to maintain theoretical coherence, the thesis chapters that comprise studies diverge from this sequence. This divergence is attributed to the complexities inherent in collaborating with the esports industry, similar to what would be observed in top traditional sporting teams. That is, esports organisations and their teams have their own unique needs, schedules, ideas and priorities, all of which need to be carefully navigated to ensure the viability and successful implementation of a research study. Consequently, the order of chapters is based on our ability to navigate these challenges. Importantly, despite the misalignment between our stated aims and the order of chapters, the aims have been met.

Although quantifying esports athletes' sleep behaviour was a key initial focus, we felt it was necessary to first expand on the opinion piece by Bonnar et al. (2019) that preceded this thesis. Accordingly, **Chapter 2** presents Study 1, which describes additional risk factors for poor sleep in esports and outlines theoretically grounded sleep intervention considerations. Subsequently, **Chapter 3** presents Study 2 which examined the sleep behaviour and mood of professional esports athletes from South Korea, the US and Australia.

Once it became evident that esports athletes were sleeping poorly and some were also experiencing poor mood, we sought to improve these outcomes. Thus, **Chapter 4** presents Study 3, which involved implementing a brief sleep intervention designed to benefit professional esports athletes' sleep, mood and cognitive performance. As the brief sleep intervention only achieved modest sleep benefits, it was determined that further research was required to develop more effective sleep interventions. We were specifically interested in the influence and perspective of esports coaches and support staff on the sleep habits of esports athletes. To this end, **Chapter 5** presents Study 4, which investigated the sleep knowledge and sleep practices used by esports coaches and support staff, barriers to sleep practices and the risk factors they perceive for poor sleep in esports. At this point, because the impact of competition was emerging as a more prominent potential risk factor for poor sleep, we decided to explore this aspect further. Consequently, **Chapter 6** presents Study 5 which evaluated the sleep behaviour, anxiety, mood and cognitive performance of esports athletes leading up to competition, across a competition period and post-competition. To conclude, **Chapter 7** presents an integrated overall discussion of findings generated by the thesis.

All chapters comprising studies have been published (i.e. Chapters 2, 3, 4, 5 and 6). Each chapter was originally written in accordance with the specific journal's formatting requirements; however, some changes have been made to ensure consistency in their presentation within this thesis and its formatting, including the addition of numbered headings and the thesis-wide use of abbreviations (and their definitions). Hence, although the slight variability in formatting between chapters may reflect these different requirements, all chapters are formatted using APA 7th Edition referencing. Please note that small, non-substantive changes have been made throughout the thesis for consistency (i.e. all chapters have been changed to British/Australian English).

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# Chapter 2: Risk Factors and Sleep Intervention Considerations in Esports: A Review and Practical Guide

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## 2.1 Abstract

Esports is a booming global industry and has been officially included in the lead-up to the 2020 Olympics in Tokyo. Given that esports is a cognitive-based activity and sleep is well known to be critical for optimal cognitive functioning, our research group recently proposed that sleep might be an important determinant of esports performance. The focus of the current review was to expand our limited understanding regarding the role of sleep in esports by exploring risk factors for suboptimal sleep and developing an associated intervention framework. More specifically, we aimed to (1) examine how gaming culture and game genre might negatively influence sleep behaviour, (2) describe a conceptual model to explain how suboptimal sleep occurs in esports and (3) outline sleep intervention considerations that specifically meet the needs of esports athletes. We conclude that gaming culture and game genre could affect the sleep behaviour of esports athletes via cognitive and behavioural mechanisms. Furthermore, adapting Spielman's three-factor model to esports may provide a useful and easy-to-understand conceptualisation for suboptimal sleep in esports. Lastly, sleep interventions for traditional athletes can be suitably modified for esports but must be comprehensive and extend from a theoretically grounded conceptual model.

**Keywords:** sleep, esports, risk factors, intervention, performance.

# Risk Factors and Sleep Intervention Considerations in Esports: A Review and Practical Guide

## 2.2 Introduction

Esports, a form of organised video game competition (Witkowski, 2012), has developed from relative obscurity into a billion-dollar global industry. In 2018, there were an estimated 380 million spectators worldwide (Newzoo, 2018), while in 2019, the Fortnite World Cup champion won more prize money than Novak Djokovic and Simona Halep received for winning Wimbledon (ATP Tour, 2019; The Fortnite Team, 2019). More recently, it has been announced that esports will officially be included in the lead-up to the 2020 Olympics (Hayward, 2019). Together, these developments clearly demonstrate the esports industry's accelerating growth, popularity and increasing professionalisation (Newzoo, 2018). Yet, despite the transformation esports is currently undertaking, there is limited performance-based research available to support the needs of the competitors themselves. Thus, for esports athletes to reach their peak potential, research is required to address this gap in the literature.

Esports is a cognitive-based activity (Himmelstein et al., 2017), and sleep is critical for optimal cognitive functioning (e.g. processing speed, working memory and executive functioning; Goel, 2017; Lowe et al., 2017). Hence, our research group has recently proposed that adequate sleep likely plays a key role in esports performance (Bonnar et al., 2019). Importantly, despite the apparent need for sleep, esports athletes may be exposed to a range of risk factors for suboptimal sleep, similar to traditional athletes. In our previous paper (Bonnar et al., 2019), we outlined several universal risk factors (e.g. caffeine use, pre-competition anxiety and travel) experienced by all athletes regardless of the sport played. However, other potential risk factors for suboptimal sleep inherent to esports also warrant attention, namely, gaming culture and game genre. Neither of these factors has been examined in relation to sleep, although both may have the capacity to be sleep disrupting. Additionally, as an increasing number of risk factors are identified, it will prove useful to have a conceptual model outlining how they contribute to the development and maintenance of sleep disturbances in esports.

Furthermore, given the unique conditions and experiences that characterise esports, there is a need to consider how sleep interventions should be designed and delivered to esports athletes. Over recent years, there has been rapid development in sleep management strategies specifically designed to address the idiosyncratic needs of athletes in traditional sports, with a general push toward intervention ‘packages’ over isolated strategies (Bonnar et al., 2018). Although many strategies used within traditional sports may be generally appropriate (e.g. sleep education and relaxation techniques) in esports as well, the specific content, aims, style and mode of delivery, technology, resources and evaluation tools used should be devised based on the sleep needs of esports athletes.

To the best of the authors’ knowledge, no previous paper has attempted to explore this topic. The focus of this review is to expand the available scientific knowledge on risk factors for poor sleep in esports and inform ‘on the ground’ practices regarding the sleep management of esports athletes. Our aims are to (1) explore how gaming culture and game genre may negatively affect sleep, (2) describe a conceptual model that outlines the development and maintenance of suboptimal sleep in esports and (3) outline considerations for sleep interventions tailored specifically to the needs of esports athletes.

## 2.3 Risk Factors for Poor Sleep in Esports

In the following section we focus on two potential risk factors for poor sleep unique to esports, namely, gaming culture and game genre. More specifically, we draw from the broader sleep, sporting and gaming literature to describe the potential mechanism by which these factors may affect sleep in esports.

### 2.3.1 Gaming Culture

Culture (defined as the shared attitudes, values and customs of a particular group; Merriam-Webster, n.d.) has been found to have a role in shaping beliefs, which, in turn, influence behaviour, including sleep (Arslan et al., 2015). In their review of traditional sports, Burgess and Naughton (2010) outlined how junior athletes who show potential are selected for talent development pathways to help propel them to elite levels. During this development phase, they are often afforded organisational support in the form of education while performance-enhancing behaviour, such as adopting adequate nutrition and obtaining sufficient sleep (Charles & Alexander, 2019), is promoted. Essentially, from a young age, traditional athletes are immersed in a culture in which performance-enhancing behaviour, informed by a strong foundation of sports science research, is prioritised to increase the likelihood of competitive success (Burgess & Naughton). Hence, athletes may be more likely to engage in behaviour consistent with this type of culture and the evidence-based beliefs that develop in response. For example, an individual who has a belief that they need to keep a regular sleep-wake schedule to obtain adequate sleep may be less likely to stay up late watching Netflix and instead keep a consistent bedtime and wake-up time.

In comparison, the pathway to professional esports is far less institutionalised and is predominantly unregulated and unstructured (Taylor, 2012). Taylor (2012) notes that because junior leagues are uncommon, many esports athletes start out as amateur gamers (i.e. individual, casual players of video games) and spend their formative years playing online or possibly at LAN (i.e. local area network) events face-to-face against other amateur gamers. In other words, they exist in an environment that generally lacks the organisational oversight, support and educational privileges received by traditional athletes. Furthermore, they often belong to or play with a particular group (sometimes known as a clan or guild), which can take on its own subculture and group norms. The collective consequence is that unhelpful and dysfunctional beliefs can develop from this subculture. For example, the gaming community often promotes ‘grinding’ (i.e. excessive practice, up to 13 hours per day) over other health considerations such as nutrition, physical activity and sleep, presumably owing to perceived performance benefits such as skill mastery (Lewis et al., 2011). Although the benefits of grinding have not been empirically tested, literature on the diminishing returns of sleep loss relating to cognitive performance (Van Dongen et al., 2003) would suggest this strategy is unhelpful.

It should be noted that the esports athlete development landscape is making positive progress, albeit slowly. For example, academies and minor leagues are being implemented at a college/university and high school level. Moreover, although performance-based research is still in its infancy, this, too, is beginning to change. However, there is still a long way to go before esports athlete development reaches a level of professionalisation similar to that seen in traditional sports.

Unhelpful and dysfunctional beliefs about sleep among gamers may also be reinforced by other segments of the wider gaming community, such as gaming ‘streamers’ (i.e. individuals who broadcast their gaming activity live to online viewers; Johnson & Woodcock, 2019). Richard Blevins (known as ‘Ninja’), one of the most popular streamers in the world who had a total of 478 million views while on Twitch (a popular streaming platform), streamed on average for 8.8 hours at a time and usually started at 2:50 pm (with a finish time of approx. 11:39 pm; TwitchTracker, 2019). Furthermore, in April 2019, a streamer named ‘Edison Park’ streamed content for approximately 17 hours per day over 30 days for a total of 541 hours (Goodling, 2019). Social learning theory (Lelchook & de Luque, 2015) would suggest that this type of ‘play till you drop’ behaviour modelled by popular and influential streamers could serve to devalue the importance of sleep in the eyes of viewers, which includes future professional esports athletes.

Consequently, it is plausible that in the absence of intervention, unhelpful and dysfunctional beliefs about sleep shaped by gaming culture during the formative years in amateur gaming environments could be carried unmodified into professional esports. Hence, at elite levels, when optimal performance is paramount for competitive success, some esports athletes may be predisposed toward unhelpful wake behaviours that compromise sleep and, in turn, their performance. Furthermore, if an esports athlete plays in a team with others who hold similar beliefs, this would also perpetuate poor sleep behaviour. In sum, gaming culture would appear to have the capacity to negatively influence sleep, although empirical research is required to determine the exact nature and extent of this influence.

### 2.3.2 Game Genre

Similar to traditional sports, there are several genres in esports. The most popular genres are RTS, MOBA, FPS and sports games. RTS is a strategy game genre where the goal is to win a battle by competing with opponents, securing resources, and producing and operating units (Zagała & Strzelecki, 2019). The most popular game in the RTS genre is StarCraft II. FPS is a game genre where the player runs through a three-dimensional space and attacks the enemy by firing a weapon such as a gun (Deleuze et al., 2017). The most popular games of the FPS genre are Counter-Strike: Global Offensive and Overwatch. MOBA developed from the RTS genre (Mora-Cantallops & Sicilia, 2018) and combines a match and a siege (a game genre aimed at attacking a building of a partner). There are many different MOBA games, but LoL and Defense of the Ancients 2 are the most popular (Baltezarević & Baltezarević, 2018). The sports genre in esports refers to games that simulate the sporting experience, including sports such as soccer, baseball, golf and basketball. FPS and MOBA genres are team esports, and RTS and sports genres are mainly individual esports (Zagała & Strzelecki, 2019).

The sleep of esports athletes may be affected by the type of genre in which an individual specialises. There is currently little empirical evidence to support that some genres have more influence on sleep compared with others. However, the idea of specific sports genres having differential effects on sleep has been examined in traditional elite athletes.

Nédélec et al. (2018) proposed that the sleep of elite athletes is affected by multiple sport-specific and societal factors. The research in traditional sports has been classified in two ways: one is by the team format (individual v. group), and the other is by the characteristics of the sport. The literature focusing on team size reported that the TST of athletes from individual sports was 30 minutes less than those who engaged in team sports, even though they went to bed earlier and woke up earlier (Lastella et al., 2015). This result suggests that individual sports athletes may take more naps during the daytime compared with those who engage in team sports to compensate for shorter night-time sleep durations. Similarly, it is possible that these results are reflected in esports, where esports athletes engaging in individual genres who do not have teammates and train individually at home (e.g. esports athletes playing FIFA online) can take a nap when they want to and have more freedom in deciding their sleep schedule.

When it comes to a type (or genre) of traditional sports classified by characteristics, sleep disorders are more common in some specific sports than others (Dunican & Eastwood, 2017). For example, sleep problems such as difficulty falling asleep, night-time awakenings and daytime sleepiness are more prevalent in aesthetic sports (i.e. gymnastics, synchronised swimming and figure skating), while athletes in high-risk sports (i.e. sliding, aerial and motor sports) report significantly fewer sleep issues than the others (Schaal et al., 2011). Obstructive sleep apnoea seems to be much more prevalent among strength-power athletes (e.g. rugby) than other athletes, owing to a high body mass index (BMI) score (Emsellem & Murtagh, 2005). There are many studies that have reported on the correlation between game play time and obesity (Ballard et al., 2009; Stettler et al., 2004; Tremblay & Willms, 2003). Ballard et al. (2009) reported that the duration of gaming was positively associated with BMI in a study including 116 male participants. In a study comprising 10,984 participants, Dunton et al. (2009) reported a positive association between gaming and BMI. Considering that esports players spend more time playing games than regular gamers, it is possible that some esports players have a high BMI.

Suppiah et al. (2015) also reported differences in sleep patterns between high-intensity athletes and low-intensity athletes. High-intensity athletes displayed significantly greater amounts of slow-wave sleep, less light sleep and better sleep continuity. It is difficult to ascertain which genre in esports is more intensive than others because esports does not require a lot of physical movement, and esports athletes are sedentary even when they are in the middle of the most challenging competitions. Nevertheless, similar to various shooting disciplines, the physical skills required for esports rely on fine, rather than gross, motor movements. These movements are measured as actions per minute (APM), which is the measure of how many clicks and key presses a player can perform in 60 seconds. These require manual dexterity to perform and are significantly and positively correlated with performance in esports (Lewis et al., 2011). Some esports genres may require high levels of APM compared with others. For example, in StarCraft II (RTS), in which fine control with fast hand speed is critical to win, elite esports athletes showed APMs up to 500, while other MOBA games, such as LoL, do not require APMs that are as high (Wong, 2014). While APM is different from the intensity of traditional sports, future research on the amount and density of fine motor skills used in specific esports genres and the differential effects on sleep should be measured and analysed.

In summary, sleep interventions for esports athletes can vary based on genre, depending on team size and game characteristics. Particularly, in the case of team esports, it may be necessary to design sleep interventions that take into account the whole team, the overall schedule, the characteristics of the individual teammates and the sleep environment.

## 2.4 Consideration for Sleep Interventions in Esports

In the following section, we initially adapt Spielman's three-factor model (3-P model) to conceptualise how suboptimal sleep occurs in esports, and then, based on this model, we outline considerations for sleep interventions that address the specific sleep needs of esports athletes.

### 2.4.1 Using the Cognitive Behaviour Therapy for Insomnia Framework for Esports Athletes

Cognitive behaviour therapy for insomnia (CBT-I) is a non-pharmacological treatment for insomnia patients and is recommended as the first line of treatment for insomnia (Qaseem et al., 2016). CBT-I is usually delivered as a multi-component treatment package consisting of behavioural and cognitive components delivered over 4 to 8 weekly sessions. The components consist of sleep hygiene, stimulus control, sleep restriction therapy, cognitive therapy and relaxation training (Siebern et al., 2012). For a detailed review of each treatment component, see Siebern et al. (2012). While not all esports athletes will have insomnia symptoms (e.g. difficulty falling asleep or difficulty staying asleep despite being given ample opportunity), using the CBT-I framework to approach sleep disturbance in these players may be helpful in both preventing and treating future occurrences of sleep disturbance.

CBT-I is based on the 3-P model by Spielman et al. (Spielman et al., 1987) and proposes that three factors are involved in the development and maintenance of insomnia: predisposing factors, precipitating factors and perpetuating factors. Predisposing factors are vulnerabilities that an individual possesses that increase the likelihood of developing insomnia, such as genetic predisposition to sleep disturbance, being at high risk for psychopathology or circadian misalignment (i.e. being an extreme morning or evening type). For esports athletes, this may be a strong tendency toward eveningness. Additionally, most esports athletes are younger, which may developmentally predispose them to have strong eveningness tendencies during the height of their career (Carskadon, 1990; Roenneberg et al., 2004). Precipitating factors are usually stressful events that typically result in acute sleep disturbance, such as an exam, loss of a family member or a break-up (Robinson et al., 2009). Instead of exams, esports athletes may experience sleep disturbance before a competition, similar to traditional elite athletes (Roberts et al., 2018). Additionally, unlike traditional athletes, esports training (known as 'scrims') and matches may take place late in the evening hours, which may delay sleep timing, as is seen with young people's part-time work (Crowley et al., 2007). Frequent travel for matches and adjusting to several time zones in short periods of time may also be a precipitating factor for this population.

While short-term sleep disturbance may be a natural stress response, some individuals may begin to engage in behavioural changes to battle the sleep disturbance that end up maintaining sleep problems. Perpetuating facts are maladaptive thoughts and behaviours that are usually initiated in an attempt to battle sleep disturbance but end up contributing to the maintenance of sleep disturbance. For example, esports athletes may consume excessive amounts of caffeine to maximise game performance and also battle sleepiness. Additionally, late-night training and matches may leave little time for esports athletes to wind down before bed after periods of high stress and excitability. In addition to changes in sleep-related behaviours, sleep-related cognitions can also perpetuate sleep disturbance. An esports athlete who is on a losing streak may believe that sacrificing sleep to train longer hours may curtail sleep duration, creating a vicious cycle of sleep deprivation and poor game performance. The 3-P model suggests that sleep disturbance is a combination of all three factors and designing sleep interventions for esports athletes will also need to take a comprehensive approach and consider all factors (see Table 2.1).

**Table 2.1**

*Potential 3-P Factors for Esports Athletes*

| Factors | Esports example |
|---|---|
| Predisposing factor | • Strong eveningness tendencies<br>• Gaming culture |
| Precipitating factor | • Late game and training sessions<br>• Peak training workloads<br>• Frequent travel (e.g. jet lag, hotel bed, noise)<br>• Participating in team esports<br>• Competition |
| Perpetuating factor | • Drinking excessive amounts of caffeine to enhance performance and battle sleepiness<br>• Lack of wind-down time<br>• Sleep-interfering activities (e.g. using smartphones in bed)<br>• Irregular sleep-wake schedule<br>• Dysfunctional beliefs about sleep (e.g. '*I need to stay up longer to perform better*') |

### 2.4.2 Current Guidelines for Sleep in Traditional Athletes

Previous studies have investigated sleep interventions in traditional athletes to enhance physical and cognitive abilities. A review by Bonnar et al. (2018) categorised sleep interventions for traditional athletes into three subtypes: (1) sleep extension and napping interventions, (2) interventions to promote sleep hygiene, and (3) post-exercise recovery strategies.

Sleep extension interventions target chronic sleep deprivation in this population, recommending that athletes spend 9–10 hours in bed per day, including naps. Two studies investigating sleep extension and napping interventions found an increase in total sleep duration and a corresponding increase in sports performance (Mah et al., 2011; Schwartz & Simon, 2015). Similarly, napping interventions ask athletes to take daytime naps that are placed within the optimal circadian window (e.g. midday naps for swimmers; Bonnar et al., 2018).

Interventions that promote sleep hygiene are typically behaviours that promote sleep, such as tending to the temperature and light of the bedroom environment or avoiding alcohol or strenuous exercise before sleep (Irish et al., 2015). While sleep hygiene is usually not recommended as a standalone treatment, studies have shown that a sleep hygiene intervention can be beneficial for increasing sleep duration for athletes (Irish et al., 2015).

Studies that have investigated post-exercise recovery interventions involve introducing procedures such as whole-body cryostimulation (Schaal et al., 2015) and red light irradiation (Zhao et al., 2012) with the goal of indirectly improving nocturnal sleep through these procedures. While the results of these studies look promising in improving sleep, more studies are needed to understand the relationship between these interventions, sleep and performance (Bonnar et al., 2018).

The literature on sleep interventions for traditional athletes is far from comprehensive and further research is needed to incorporate specific characteristics of the athlete lifestyle. Specifically, studies investigating the characteristics of esports athletes and their idiosyncratic sleep needs are necessary for tailoring sleep interventions for this population. In their study, Baltezarević and Baltezarević (2018) noted that the typical age of esports athletes is between 17–25 years, an age that is particularly prone to strong evening tendencies (Roenneberg et al., 2004). Professional team members from countries such as South Korea and the US typically live together to improve training efficiency, which may make it challenging to have a sleep environment that is sleep-conducive. Thus, coaches and managers of esports teams who usually make important decisions about the athletes' lifestyle and training schedules should be incorporated into the planning of sleep interventions for these athletes. This participation would improve their knowledge of sleep and also monitoring of their own sleep, which is important in promoting a top-down healthy sleep culture (Farahnak et al., 2020; Miles et al., 2019).

### 2.4.3 Treatment Guidelines for Sleep Disturbance in Esports Athletes

Based on the principles of traditional sleep interventions, guidelines can be adapted to fit the lifestyle of esports athletes. Compared with the traditional approach for sleep interventions, which usually consists of psychoeducation or several weekly sessions, a flexible approach is necessary to accommodate training schedules and important matches.

#### *2.4.3.1 Managing Game Genre-Related Effects*

Issues that come up in treatment may vary depending on whether the game genre is team or individual-player-based. MOBA games such as LoL are team-based, and training times (and sleeping times) usually occur similarly for all team members. Thus, group interventions may be necessary for team-based game genres as the team players cannot train alone. Additionally, game performance hinges on good teamwork strategies and communication between members, and sleep disturbance or sleep deprivation resulting in poor emotional regulation may be detrimental to working together as a team (Talbot et al., 2010). In contrast, individual-player games can benefit both from individual or group formats.

#### *2.4.3.2 Unconventional Training Times*

Esports athletes often train late at night. This may be owing to training matches (‘scrims’) with teams that are in different time zones and also the delayed sleep tendencies of these young esports athletes. Designing interventions to work within these time parameters is imperative to a successful intervention with this population. Additionally, training times may not end until early morning (e.g. 1:00 am), and esports athletes may not retire to their sleep quarters until after sunrise. Thus, practising sleep guidelines similar to shift workers, such as incorporating eyeglasses that block blue light after training, may help improve sleep disturbance (Sasseville et al., 2009).

#### *2.4.3.3 Cognitive Therapy Specific to Esports Athletes*

Many esports athletes may believe that sacrificing sleep to train excessively will enhance their performance or that sleeping less will make them perform better. Additionally, esports athletes may worry about the consequences of not getting enough sleep before an important match and put too much pressure on themselves trying to sleep. Psychoeducation based on the science of sleep highlighting sleep deprivation studies that have found reduced response speed (that can correspond to slower mouse-click speed) may be helpful to players in making the connection between sleep and game performance (Dinges et al., 1997; Van Dongen et al., 2003). Additionally, traditional cognitive behavioural therapy techniques, such as Socratic reasoning, cost-benefit analysis and behavioural experiments, may be helpful in replacing dysfunctional and unhelpful thoughts about sleep. For example, asking esports athletes to perform a behavioural experiment where they extend their sleep duration and compare their game performance to days when they have sacrificed their sleep can help challenge their beliefs about sacrificing sleep.

One downside of traditional cognitive therapy is that there is a considerable amount of time investment required from esports athletes. Based on the adolescent sleep intervention literature, one of the most common and accepted forms of cognitive therapy is mindfulness-based stress reduction (MBSR; Bartel et al., 2018; Blake et al., 2017; Bootzin & Stevens, 2005). MBSR introduces simple techniques such as the body scan that requires little time to teach and learn (1–2 minutes) and implement (15 minutes per night). Thus, mindfulness-based techniques that have more convenient delivery may be an alternative to traditional cognitive restructuring that can be more conducive to the schedules of esports athletes.

#### *2.4.3.4 Importance of Wind-Down Time*

Training and participating in in-game matches for esports athletes requires a high level of attention and concentration and can cause stress that results in hyperarousal.

Hyperarousal interferes with sleep and can cause insomnia (Bonnet & Arand, 2010; Riemann et al., 2010), so incorporating a wind-down time to de-arouse in preparation for sleep is important for esports athletes. Traditional relaxation techniques such as progressive muscle relaxation, breathing retraining, meditation and imagery rehearsal can be incorporated into treatment before bedtime, as well as including the mindfulness body scan technique.

#### *2.4.3.5 Adjusting to Jet Lag*

Being an esports athlete entails frequent travelling across multiple time zones (Bonnar et al., 2019), so sleep interventions should incorporate education on behavioural methods that can be implemented before, during and after travel to mitigate the effects of jet lag (i.e. circadian misalignment) and travel fatigue. To summarise, current recommendations (Roach & Sargent, 2019) for traditional athletes suggest a combination of appropriately timed light exposure and exogenous melatonin that accounts for the timing of an individual's circadian rhythm and the direction of travel (eastward v. westward travel). There may be some benefit to phase shifting prior to departure and during travel, but this needs to be managed carefully to prevent unintended consequences (e.g. sleep loss).

#### *2.4.3.6 Motivational Strategies*

Motivation is critical for behavioural change yet it has been neglected as a treatment component in sleep interventions for traditional athletes (Bonnar et al., 2018; Halson & Lastella, 2017). In esports, motivation to make sleep-related behavioural change may be a particularly important consideration because the majority of esports athletes are young, and young people are typically apathetic (and sometimes resistant) to this type of change (Cain et al., 2011; Moseley & Gradisar, 2009). A recent study by Micic et al. (2019) that evaluated the readiness-to-change model (Amrhein et al., 2003) for adolescent sleep behaviour found that 'desire' (i.e. how much an individual wants or wishes to change), 'ability' (i.e. self-perception of capability to create change) and 'commitment' (i.e. intention or obligation to change) were the best predictive motivational components of sleep treatment compliance. Hence, incorporating motivational content may enhance sleep and performance outcomes.

#### *2.4.3.7 Early Intervention*

As noted in the Gaming Culture section, gaming culture may shape dysfunctional sleep-related beliefs from a young age. Hence, early intervention in player development via sleep health education may be one way in which to combat the influence of gaming culture, by fostering more helpful sleep-related beliefs and behaviour. Anecdotally, the University of Queensland in Australia has developed a program for high school students aspiring to become professional esports athletes. In their program, they included material that aimed to (1) highlight the consequences of insufficient sleep, (2) encourage better sleep habits, and (3) promote a healthy balance between esports and sleep. Although this program has not been formally evaluated, there is some evidence that suggests early sleep intervention for children and adolescents can produce sleep benefits (Bonnar et al., 2015; Gruber et al., 2016). Additionally, evidence suggests that parental regulation of bedtime (Short et al., 2011) and media (Smith et al., 2017) can help to protect adolescent sleep; therefore, including parents in early intervention programs may also have added utility.

## 2.5 Conclusion

The function of sleep in esports has received minimal attention, yet research from our group and others is starting to provide critical insight on this matter. We have previously identified universal risk factors for suboptimal sleep in esports, such as caffeine, travel and pre-competition anxiety. Additionally, in the current review, we propose that gaming culture and game genre may also play a role in negatively influencing sleep via cognitive and behavioural pathways. Conceptually, adapting Spielman's 3-P model to esports is one way to formulate how these risk factors contribute to the development and maintenance of suboptimal sleep. Moreover, from an intervention perspective, we propose that contemporary athlete sleep interventions can be suitably modified for use in esports but must comprehensively take into account all 3-P factors (i.e. predisposing, precipitating and perpetuating). Importantly, an esports sleep intervention needs to be flexible, address the practical and developmental needs of esports athletes and include key team decision-makers such as coaches and managers.

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# Chapter 3: Sleep Characteristics and Mood of Professional Esports Athletes: A Multi-National Study

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## 3.1 Abstract

Esports is becoming increasingly professionalised, yet research on performance management is remarkably lacking. The present study aimed to investigate the sleep and mood of professional esports athletes. Participants were 17 professional esports athletes from South Korea ($N = 8$), Australia ($N = 4$), and the US ($N = 5$) who played FPS games (mean age 20 ± 3.5 years, 100% male). All participants wore a wrist activity monitor for 7–14 days and completed subjective sleep and mood questionnaires. Participants had a median TST of 6.8 hours and a sleep efficiency of 86.4% per night. All participants had significantly delayed sleep patterns (median sleep onset 3:43 am and wake time 11:24 am). Participants had a median SOL of 20.4 minutes and prolonged WASO of 47.9 minutes. Korean players had significantly higher depression scores compared with the other groups ($p < .01$) and trained longer per day than the Australian or US teams (13.4 v. 4.8 v. 6.1 hours, respectively). Depression scores were strongly correlated with number of awakenings, WASO, and daily training time ($p < .05$). As the first pilot sleep study in the esports field, this study indicates that esports athletes show delayed sleep patterns and have prolonged WASO. These sleep patterns may be associated with mood (depression) and training time. Sleep interventions designed specifically for esports athletes appear warranted.

**Keywords:** esports, sleep, mood, performance, eveningness, depression.

## Sleep Characteristics and Mood of Professional Esports Athletes: A Multi-National Study

### 3.2 Introduction

Esports (electronic sports) is a form of organised video game competition that has become a global phenomenon over the last decade (Bonnar, Castine et al., 2019). Recent estimates indicate that there were 443 million viewers and 885 major events in 2019 (Newzoo, 2020), with prize money in some major tournaments exceeding those of Wimbledon and the US Masters (The Fortnite Team, 2019). As the esports industry has grown and become more competitive, esports athletes have been increasingly required to attempt to gain performance advantages over opponents (Polman et al., 2018). However, a consequence of esports' rapid growth is that performance-based research has not kept pace with its sharp rise in popularity. Thus, limited data exists on the factors that influence performance in esports, restricting the ability of esports athletes to make evidence-based decisions about performance management.

Owing to similarities between traditional athletes and esports athletes (e.g. regular training/competition schedules and travel), the sports science literature offers some useful insights into the importance of sleep for health and performance in competitive settings. The current body of evidence suggests that optimal sleep is important for several elements (but not all) of physical performance (e.g. anaerobic power), many aspects of cognitive performance (e.g. attention; Bonnar et al., 2018) and recovery (e.g. growth and repair of cells; Czeisler & Klerman, 1999). However, despite the need for sleep, esports athletes and traditional athletes are both exposed to unique conditions (e.g. congested training/competition schedules) that may compromise their ability to achieve optimal sleep, potentially placing them at risk of sleep restriction and the associated consequences (Bonnar, Castine et al., 2019).

In contrast to many traditional sports, esports is a predominantly cognitive-based activity (Himmelstein et al., 2017), and sleep is considered critical for optimal cognitive performance (Fullagar et al., 2015). In a landmark study, Van Dongen et al. (2003) investigated the cumulative effect of chronic sleep restriction on cognitive performance. They found that relative to a group who slept 8 hours per day, participants who obtained 4 or 6 hours of sleep per day over a two-week period performed progressively worse on a test of reaction time and attentional lapses. In addition, recent meta-analytic evidence demonstrated that sleep restriction reliably worsens executive functioning, working memory, and sustained attention (Lowe et al., 2017). Taken together, the broad-spectrum impact of sleep restriction on cognitive performance may have important implications for performance in esports.

Parallel to the link between sleep and cognitive performance, there is a well-known relationship between disturbed sleep and affective states (e.g. Dinges et al., 1997; Ferrara & De Gennaro, 2001; Zohar et al., 2005). For example, Dinges et al. (1997) observed that participants who slept 5 hours per night over a seven-day period had elevated subscale scores for fatigue, confusion, tension and total mood disturbance on the Profile of Mood States. Accumulating evidence suggests that the restricted sleep of adolescents, as well as prolonged wakefulness in bed, is predictive of depressive symptoms and anxiety (Babson et al., 2010), a particularly pertinent finding given the young age of many esports athletes (Bonnar, Lee et al., 2019). These findings are important given the proposed effect of mood on athletic performance (Beedie et al., 2000) and reports of high burnout rates in esports (Smithies et al., 2020).

Preliminary evidence from two recent studies (Rudolf et al., 2020; Thomas et al., 2019) suggests that esports athletes from the US ($N$ = 9) and Germany ($N$ = 14) obtain the recommended 7–9 hours of sleep per night for adults (8–10 hours for teens) and ensure good sleep quality. However, because sleep was not the primary focus of either study, only basic single-item retrospective questions were used to measure these outcomes. While easy to utilise, they are prone to inaccuracy (Mallinson et al., 2019). Furthermore, no other data about participants' sleep behaviour (e.g. sleep timing) were collected. Notably, these findings of adequate sleep contrast with evidence demonstrating the opposite, that is, circadian timing delaying and TST shortening across adolescence and into early adulthood, with many young people obtaining insufficient TST, particularly males (Kuula et al., 2019). These findings differ between regions, with individuals from Asia reporting the shortest TST and more delayed sleep patterns than their European, North American or Oceania peers. Hence, it is possible that there may also be regional differences in the sleep behaviour of esports athletes, especially from Asian countries where esports are popular.

Considering the evidence in the literature showing the negative impact of suboptimal sleep on cognitive performance and mood, it follows that sleep could be an important determinant of performance in esports. However, there are no published objective data on the sleep behaviour of professional esports athletes. Thus, two primary aims were proposed to address this lack of empirical evidence. The first was to investigate sleep and wake behaviours of esports athletes (e.g. training times and caffeine use) in countries within several global regions (i.e. Asia, Oceania and North America) that also map onto established esports regions. The second was to examine how the sleep behaviour of esports athletes in these regions (i.e. South Korea, Australia and the US) relates to affect, specifically, measures of anxiety and depression. As the first exploratory study to specifically investigate sleep and mood, our findings will provide much-needed insight into a potentially vital aspect of performance management in arguably the fastest-growing industry in the world—esports.

## 3.3 Method

This was a cross-sectional, observational study and complied with the STROBE (The Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for reporting observational studies.

### 3.3.1 Participants

The 17 participants were South Korean ($N = 8$), Australian ($N = 4$) and US ($N = 5$) elite esports athletes competing in FPS games (Bonnar, Lee et al., 2019) within a professional league. Ethics approval was obtained in all three countries from relevant university ethics boards (Flinders University Social and Behavioural Research Ethics Committee, Sungshin Women's University Review Board and the University of North Texas Institutional Review Board). All participants provided written informed consent.

#### *3.3.1.1 Inclusion/Exclusion Criteria*

Participants were eligible for inclusion if they competed as part of a professional team within an official esports league. Participants were excluded if they did not complete the entire protocol, withdrew consent or did not regularly wear the wrist activity monitor, resulting in unreliable sleep data.

### 3.3.2 Measures

#### *3.3.2.1 Demographic/General Information*

A self-report questionnaire measured demographic and general information (see Appendix B), including self-reported anthropometric data (i.e. height and weight), esports background (e.g. number of years playing professionally), sleep history (e.g. sleep disturbance prior to competition) and level of exposure to risk factors known to affect the sleep of athletes (e.g. caffeine use and training time).

#### *3.3.2.2 Sleep Measures*

**Objective Sleep.** Wrist activity monitors (Readiband V5; Fatigue Science, Inc., Vancouver, BC, Canada) were used as an objective measure of esports athletes' sleep. The Readiband uses a proprietary algorithm to generate sleep data derived from raw acceleration signals. The Readiband has been validated against the gold standard in sleep monitoring—polysomnography—and compared against similar consumer sleep devices (Chinoy et al., 2021). This device is approved by the U.S. Food and Drug Administration, Center for Drug Evaluation (2011) for measures of physical activity and sleep and has been used in performance-related sleep research, such as in the military (Hursh et al., 2004), in the aviation industry (Roma et al., 2012) and with elite athletes (e.g. Dunican et al., 2017, 2019). Generated sleep data included SOL, time of sleep onset, number of awakenings, WASO, sleep efficiency, wake-up time, TST and time in bed. Further, accelerometer data were used to obtain a proxy measure of circadian timing (i.e. sleep onset and wake-up time; Ancoli-Israel et al., 2003) and chronotype, in lieu of self-reports (i.e. Munich Chronotype Questionnaire) or other objective markers (e.g. dim light melatonin onset).

**Insomnia Severity Index.** The ISI (Morin et al., 2011) is a 7-item questionnaire that was used to assess the severity of insomnia in esports athletes. Items (e.g. 'How satisfied/dissatisfied are you with your current sleep pattern?') are rated on a 5-point Likert scale ranging from 0 (*very satisfied*) to 4 (*very dissatisfied*). A total score (ranging from 0 to 28) is calculated by summing individual item scores, with higher scores indicating greater insomnia severity. Morin et al. (2011) demonstrated that the ISI has excellent internal consistency ($\alpha = .90$) and sound convergent validity. A cut-off score of 10 was shown to have 86.1% sensitivity and 87.7% specificity for detecting insomnia cases in community samples (Morin et al.).

**Paediatric Daytime Sleepiness Scale.** The Paediatric Daytime Sleepiness Scale (PDSS; Drake et al., 2003) is an 8-item measure of daytime sleepiness. The PDSS was chosen over other popular sleepiness scales (e.g. the Epworth Sleepiness Scale; Walker et al., 2020) owing to its items showing greater face validity (i.e. questions aimed at morning sleepiness v. situations in the Epworth Sleepiness Scale). The wording of Items 1 and 2 were altered to increase relevance for esports athletes, as the original items were school-related and no participants were attending school. Items (e.g. 'How often do you fall back to sleep after being woken in the morning?') are rated on a 5-point Likert scale from 0 (*never*) to 4 (*always*). Item 3 ('Are you usually alert during the day?') is reverse-scored. Total scores range from 0 to 32 by summing item scores, with higher scores indicating greater daytime sleepiness. The PDSS has good internal consistency (α = .80) and is correlated with reduced sleep duration (Drake et al., 2003). The PDSS has been used in young adults (i.e. participants up to 24 years; Richardson et al., 2018). A cut-off score of 15 points has been proposed to identify excessive daytime sleepiness (Meyer et al., 2018).

***3.3.2.3 Mood Measures***

**Centre for Epidemiological Studies-Depression.** The Centre for Epidemiological Studies-Depression (CES-D; Radloff, 1977) is a 20-item self-report instrument used to assess symptoms of depression. Items (e.g. 'I felt depressed') are rated on a 4-point Likert scale from 0 (*rarely or none of the time*) to 3 (*most or all of the time*). Items 4, 8, 12 and 16 are reverse-scored. A total score (ranging from 0 to 60) is calculated by summing individual item scores, with higher scores indicating greater levels of depressive symptoms. A score of ≥ 16 is used as an indicator of depression. The CES-D has excellent internal consistency (α = .90) and sound construct validity (Cosco et al., 2017).

**State-Trait Anxiety Inventory-Y.** The State-Trait Anxiety Inventory (STAI-Y; Spielberger et al., 1983) is a 20-item measure of state anxiety. Items (e.g. 'I feel calm') are rated on a 4-point Likert scale from 1 (*not at all*) to 4 (*most of the time*). Items 1, 2, 5, 8, 10, 11, 15, 16, 19 and 20 are reverse-scored. A total score (ranging from 20 to 80) is calculated by summing individual item scores, with higher scores indicating greater levels of state anxiety. The STAI-Y has good internal consistency ($\alpha$ = .86–.95), test-retest reliability (Spielberger et al., 1983) and adequate construct and convergent validity (Spielberger, 1989).

### 3.3.3 Procedure

The study protocol took place when all teams were actively practising and competing in their regular seasons. The Australian and South Korean teams completed 14 days of data collection, while the US team completed seven days owing to time constraints with a major upcoming tournament. Participants wore the wrist activity monitor continuously on their non-dominant wrist for the entire observation period, except when practically unable (e.g. showering). They were instructed to maintain typical sleep-wake behaviour during this time. Participants also completed a battery of self-report questionnaires within the first week of the observation period. The data were collected between 29 July and 2 November 2019.

### 3.3.4 Data Analysis

Data were cleaned by checking for completeness and range of values. Descriptive statistics, including frequencies, means and standard deviations, were used to summarise variables. Differences among the group were analysed using the Kruskal–Wallis H test, followed by Dunn's test. Relationships between study variables (e.g. TST and depression) were tested using Spearman's rank correlation coefficients for continuous data. All study data were analysed using SPSS 25, and $p$-values < .05 were considered statistically significant.

## 3.4 Results

Eighteen participants initially commenced the study. However, one participant from Australia was excluded because they left the team part way through the study. Thus, a total of 17 participants were included in the final analysis.

### 3.4.1 Demographic and Anthropometric Information

The demographic and self-reported anthropometric characteristics of participants by group are presented in Table 3.1. All participants were male, with the mean age being 20 (*SD* = 3.5 years; age range = 15–27 years). There were no differences in age, height, weight and BMI between groups.

**Table 3.1**

*Characteristics of the Study Participants*

| Measure | Total ($N$ = 17) | South Korea ($N$ = 8) | Australia ($N$ = 4) | United States ($N$ = 5) | $p$ |
|---|---|---|---|---|---|
| Age[a] | 20.0 ± 3.5 | 19.0 ± 3.3 | 19.4 ± 2.9 | 22.1 ± 3.8 | .284 |
| % of male[b] | 100.0% | 100.0% | 100.0% | 100.0% | |
| BMI[a] | 24.7 ± 16.8 | 25.2 ± 16.8 | 24.6 ± 15.8 | 23.9 ± 23.3 | .742 |
| Years as a professional esports athlete[a] | 2.44 ± 1.32 | 1.74 ± 1.06 | 2.50 ± 1.00 | 3.50 ± 1.41 | .052 |
| Training hours per day[a] | 9.21 ± 4.36 | 13.38 ± 2.00 | 4.75 ± 0.96 | 6.10 ± 1.34 | .002** |
| Sleep disturbance before competition[b] | 9 (52.9%) | 4 (50.0%) | 3 (75.0%) | 2 (40.0%) | .564 |
| Attempts to improve sleep (*n*)[b] | 4 (23.5%) | 2 (25.0%) | 1 (25.0%) | 1 (20.0%) | .976 |
| Caffeine dose (mg)[a,c] | 114.7 ± 118.3 | 150 ± 162.6 | 100 ± 57.7 | 70 ± 44.7 | .648 |
| Sleep medication use (*n*) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | |

*Note.* [a]Data are expressed as mean ± standard deviation and analysed by Kruskal–Wallis test. [b]Data are expressed as number of analysis of $\chi 2$-test for categorical variables. [c]The median of each multiple-choice presented response was used to calculate the caffeine dose.

** indicates correlations significant at $p < .01$ levels (2-tailed).

### 3.4.2 Characteristics of Esports Athletes

The participants' esports backgrounds are presented in Table 3.1. All participants played FPS games for their profession; the Korean team played Overwatch, the Australian team played Counter-Strike: Global Offensive and the US team played Paladins. Participants' career as a professional esports athlete ranged from 1.5 to 5 years.

Korean participants, on average, trained longer than US participants by 7.3 hours and Australian participants by 8.6 hours, totalling 13.4 hours per day. The Korean team trained, on average, from 1:07 pm to 4:45 am. In comparison, the Australian team trained, on average, from 5:30 pm to 10:15 pm, while the US team generally started their training earlier, starting at 11:48 am and finishing at 6:12 pm.

### 3.4.3 Sleep Characteristics

Table 3.2 shows the median and interquartile range of objective sleep measurements obtained from participants. Participants' median TST was 408.4 minutes (i.e. 6.8 hours) per night, while sleep efficiency was 86.4%. Participants had prolonged WASO of 47.9 minutes, which was longer than the recommended 30 minutes (Lichstein et al., 2003). Korean participants showed a median sleep efficiency of 87.5%, followed by Australian (86.3%) and US participants (86.2%; see Table 3.2). There was no significant difference between groups for SOL, the number of awakenings, WASO or time in bed.

All participants had significantly delayed sleep patterns, but US participants slept earlier when compared with the other groups. Using the Kruskal–Wallis method for non-parametric test, participants from the US fell asleep significantly earlier and woke up earlier compared with the other two groups.

Over half (52.9%; $N = 9$) of the participants reported experiencing sleep disturbance, such as early morning awakenings or difficulty initiating sleep before professional competitions, and four participants reported they had attempted to improve their sleep by seeking professional help (see Table 3.1).

**Table 3.2**

*Difference Between Groups in Objective Sleep Data*

| Measure | Group | | | | *p*-value |
|---|---|---|---|---|---|
| | Total | South Korea | Australia | United States | |
| TST (min) | 408.4 (386.4–444.1) | 410.4 (400.1–444.6) | 413.6 (382.3–422.9) | 404.3(345.0–454.2) | .975 |
| SOL (min) | 20.4 (13.5–31.9) | 16.3 (12.5–35.7) | 21.4 (13.4–27.6) | 26.6 (15.9–46.3) | .573 |
| NWAK (n) | 4.4 (3.4–6.4) | 5.1 (3.3–6.8) | 3.6 (3.2–5.8) | 5.1 (2.9–7.8) | .663 |
| WASO (min) | 47.9 (27.6–65.3) | 50.5 (26.9–67.2) | 31.8 (26.2–68.7) | 55.0 (30.0–90.0) | .770 |
| TIB (min) | 505.5 (480.4–542.1) | 513.2 (476.9–552.2) | 493.9 (477.9–509.4) | 510.0 (480.0–553.8) | .594 |
| SE (%) | 86.4 (86.3–87.5) | 87.5 (86.7–87.9) | 86.3 (86.1–86.8) | 86.0% (86.0–86.7) | .019* |
| SO (hh:mm) | 03:43 (02:28–05:06) | 04:50 (03:58–05:18) | 03:40 (03:23–05:06) | 02:00 (01:09–02:28) | .005** |
| WT (hh:mm) | 11:24 (10:19–12:14) | 12:08 (11:56–12:29) | 10:51 (10:31–12:38) | 09:51 (08:29–10:19) | .004** |

*Note.* Data are expressed as median and interquartile range and analysed by Kruskal–Wallis test. Abbreviations: TST, total sleep time; SOL, sleep onset latency; NWAK, number of awakenings; WASO, wake after sleep onset; TIB, time in bed; SE, sleep efficiency; SO, sleep onset; and WT, wake-up time.

*Indicates correlations significant at $p < .05$ levels (2-tailed). **Indicates correlations significant at $p < .01$ levels (2-tailed).

### 3.4.4 Self-Report Measures

Descriptive statistics for self-report questionnaires (STAI, ISI, CES-D and PDSS) are summarised in Table 3.3. Notably, 47.1% ($N = 8$) of all participants exceeded the clinical cut-off for insomnia (ISI scores > 10). In addition, 41.2% ($N = 7$) of participants met the criteria for excessive daytime sleepiness (PDSS scores > 15).

All Korean participants exceeded the clinical cut-off of for depression (CES-D scores ≥ 16) with a significantly higher median score compared with the other groups ($p = .006$). Anxiety (STAI), insomnia severity (ISI) and daytime sleepiness (PDSS) did not differ between groups (see Table 3.3).

**Table 3.3**

*Difference Between Groups in Psychological Measures*

| Group | Group | | | | *p*-value | Post-hoc |
|---|---|---|---|---|---|---|
| | Total | South Korea | Australia | United States | | |
| CES-D | 22.0 (12.5–27.5) | 27.5 (24.5–34.8) | 10.5 (6.5–19.0) | 13.0 (11.0–23.5) | .006** | 1 > 2, 3 |
| STAI | 39.0 (35.5–42.5) | 39.0 (34.5–40.0) | 37.5 (30.3–44.8) | 39.0 (36.5–52.0) | .443 | |
| ISI | 10.0 (6.0–15.0) | 10.5 (7.3–15.5) | 10.5 (3.0–14.3) | 9.0 (3.5–16.5) | .866 | |
| PDSS | 15.0 (10.5–17.5) | 16.5 (11.3–21.0) | 14.5 (9.3–17.5) | 13.0 (10.5–15.0) | .109 | |

*Note.* Data are expressed as median and interquartile range and analysed by Kruskal–Wallis test. Abbreviations: CES-D, Centre for Epidemiological Studies-Depression; STAI, State-Trait Anxiety Inventory; ISI, Insomnia Severity Index; PDSS, Paediatric Daytime Sleepiness Scale. **Indicates correlations significant at $p < .01$ levels (2-tailed).

### 3.4.5 Associations Between Measures

Because the data were not normally distributed, we used Spearman's rho to calculate associations between variables (see Table 3.4). There was a strong correlation between CES-D and the training time (hours) of the players ($\rho = .656$, $p < .01$). Similarly, we found that CES-D scores were strongly correlated with the number of awakenings, WASO, time in bed and wake-up time. There were no significant correlations between CES-D scores and TST.

**Table 3.4**

*Non-Parametric Correlations Between Variables Measured*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1.ISI | | | | | | | | | |
| 2.CES-D | 0.58* | | | | | | | | |
| 3.STAI | 0.48 | 0.32 | | | | | | | |
| 4.PDSS | 0.54* | 0.67** | 0.15 | | | | | | |
| 5.SOL | −0.07 | 0.02 | 0.19 | −0.26 | | | | | |
| 6.WASO | 0.79** | 0.52* | 0.46 | 0.42 | 0.12 | | | | |
| 7.TST | −0.21 | 0.01 | −0.12 | 0.17 | −0.20 | −0.30 | | | |
| 8.SO | −0.10 | 0.27 | −0.14 | 0.43 | −0.24 | −0.26 | −0.01 | | |
| 9.WT | 0.21 | 0.47* | −0.04 | 0.679** | −0.39 | −0.01 | 0.23 | 0.85** | |
| 10.Training Time | 0.16 | 0.66** | 0.09 | 0.29 | −0.23 | −0.02 | −0.15 | 0.50* | 0.46 |

*Note.* The correlation is presented as $r_s$. Abbreviations: CES-D, Centre for Epidemiological Studies-Depression; STAI, State-Trait Anxiety Inventory; PDSS, Paediatric Daytime Sleepiness Scale. SOL, sleep onset latency; WASO, wake after sleep onset; TST, total sleep time; SO, sleep onset; and WT, wake-up time. Correlations between CES-D scores and number of awakenings (0.53, $p < .05$) and time in bed (0.52, $p < .05$) were accidentally not included in the published version of this table.

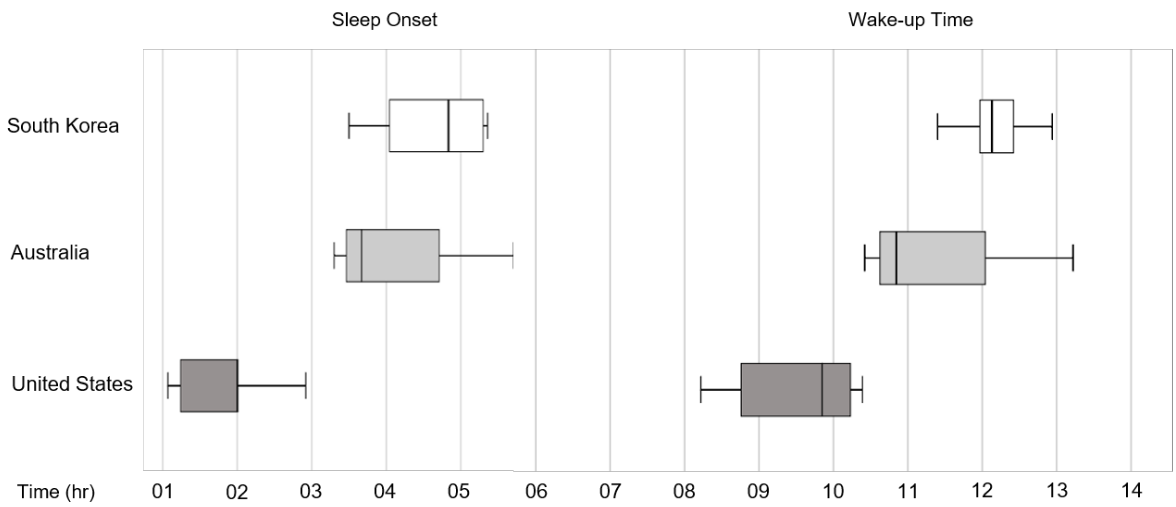
*Indicates correlations significant at $p < .05$ levels (2-tailed) and ** indicates correlations significant at $p < .01$ levels (2-tailed).

## 3.5 Discussion

The present study's aims were to investigate sleep behaviour and the related effect of sleep in an untapped group—esports athletes. Unlike two previous studies in this area (in the US and Germany; Rudolf et al., 2020; Thomas et al., 2019), our study found that participants in all three countries (South Korea, Australia and the US) had a median TST < 7 hours, with prolonged WASO. Although the median sleep latency was under the clinical cut-off of 30 minutes (Lichstein et al., 2003), approximately half of the participants exceeded the clinical cut-off for insomnia and had excessive daytime sleepiness. A striking finding was that esports athletes reported significantly delayed sleep timing, with a median sleep onset time of 3:43 am and wake time of 11:24 am (see Figure 3.1).

**Figure 3.1**

*Differences in Sleep Onset and Wake-up Time*




### *3.5.1* Contributing Factors to Esports Players' Sleep

Many factors may contribute to a young person's delayed sleep onset. In our study, one of the contributing factors appeared to be that esports athletes' training schedules displaced their sleep opportunity. The Korean players provided the best evidence for this, with their longer training hours ranging from early afternoon to the middle of the night. It is clear that the end time of training schedules may strongly influence how late these athletes go to bed. Previous research has noted that the highest risk factors for sleep problems for esports players may be delayed sleep schedules, prolonged exposure to blue light (especially just before bedtime), and stress from competition (Bonnar, Castine et al., 2019; Bonnar, Lee et al., 2019). There is no direct comparison group in this study. However, if we consider the results of a prior study that found exposure to blue light before sleep delayed circadian timing (Chang et al., 2015), we cannot rule out the possibility that the long training time of Korean esports athletes contributed to the delay in sleep onset. Conversely, training times for US participants were much earlier, ranging from lunchtime to the early evening. Hence, their sleep opportunity was not displaced to the same degree as participants from the other countries (although their circadian timing was still delayed).

Once asleep, the esports athletes experienced significant wakefulness during the night (median = 47.9 minutes). Given that the median ISI score for the whole sample was equal to the clinical cut-off, the prolonged wakefulness could be explained by insomnia symptoms. Preliminary evidence suggests that esports athletes (particularly FPS competitors, which comprised our sample) can experience high stress levels (Poulus et al., 2020; Sousa et al., 2020), which is a common precipitant for insomnia symptoms (Drake et al., 2014). However, further research using more thorough diagnostic procedures (e.g. structured clinical interviews) is necessary to determine insomnia prevalence rates in esports populations.

Alternatively, as the average BMI was in the overweight range for South Korean participants and approaching the overweight range for Australian and US participants, and daytime sleepiness was also high within our sample, we speculate the possibility of sleep-disordered breathing disrupting sleep. The nature of sedentary activity associated with esports may put esports athletes at higher risk for sleep disorders and merits further investigation.

The combination of delayed bedtimes and prolonged WASO resulted in most esports athletes obtaining less than 7 hours of sleep. This finding is consistent with the literature in traditional sports, where many athletes do not achieve the 7–9 hours of sleep per night recommended for adults (Sargent et al., 2014), have poor sleep quality (Leeder et al., 2012; Shearer et al., 2015) and are prone to sleep disturbances around competitions (Juliff et al., 2015; Lastella et al., 2014). For instance, one study reported an average sleep duration of 6.6 hours in collegiate basketball players during a competitive season (Mah et al., 2011), and Sargent et al. (2014) reported an average sleep duration of just 6.2 hours in Olympic swimmers during a period of intensive training. Considering the well-known link between sleep and cognitive performance, the short TST esports athletes appear to experience may have performance implications for individuals whose sleep need is consistently restricted. However, it should be noted that not all individuals (adults or teens) need the recommended sleep duration for their age group (Hertenstein et al., 2018), and therefore, the performance of natural short sleepers may be differentially affected as a result. Overall, further empirical investigation examining this link in esports is deemed critical in light of this new evidence.

### 3.5.2 Mood and Sleep in Esports Athletes

South Korean participants showed significantly higher depression scores than the other two groups, and importantly, all the Korean players exceeded the clinical depression cut-off score of ≥ 16. The CES-D score correlates well with the number of awakenings, WASO, time in bed, wake-up time and daily training time. While it is difficult to ascertain the causality between sleep and mood from this study, there is significant literature that supports the impact of sleep on depression (Lovato & Gradisar, 2014). Additional studies with larger sample sizes will be needed to disentangle the relationship between these variables. Regardless, the present study highlights the importance of considering both sleep and mood for intervention in this population.

When we note the high correlation between depression and training time, it is conceptually possible to suggest that a longer duration of training time increases depression. It is well known that working excessively long hours is significantly associated with the development of depressive symptoms (Ogawa et al., 2018), and intensive training is reported to cause sleep disturbances and mood changes in traditional athletes (Killer et al., 2017). We may suggest depression is closely related to the esports athlete’s stress level. Another possibility to consider is that a large amount of training degrades the quality of sleep itself, resulting in increased depression (De Francisco et al., 2016). Sleep disturbances are reported as one of the symptoms of overtraining (Kellmann, 2010; Meeusen et al., 2013). During periods when training loads are high, some traditional athletes report difficulties falling asleep, restlessness during sleep and heavy feeling in their upper legs during sleep (Fry et al., 1994; Halson et al., 2006).

### 3.5.3 Cross-Cultural Issues Associated with Sleep in Esports Athletes

Despite the low sample size, the significant differences between esports athletes in South Korea, Australia and the US align with previous study findings. Young people from Asian countries (especially South Korea) obtain less sleep and demonstrate delayed sleep timing compared with their peers in Western cultures (Gradisar et al., 2011; Kuula et al., 2019; Olds et al., 2010), as was found in the present study. Worth noting is that compared with normative data (Gradisar et al., 2011), the sleep timing of esports athletes was considerably later (e.g. midsleep ~ 05:15 am v. ~ 08:30 am; Suh et al., 2018). While young people in the US usually obtain less sleep than their Australian counterparts (Gradisar et al., 2011), this was not the case here with esports athletes. The reduced sleep duration observed in North American young people is usually owing to early school start times (Short et al., 2013). As these esports athletes were not school attendees, their sleep was not truncated. Furthermore, chronotype delays until around 20 years of age (Roenneberg et al., 2004) and then begins to advance in its timing. As the esports athletes from the US in our sample were slightly older (~ 22 years) than their Australian and South Korean peers (~ 19 years), this may be one factor contributing to their earlier sleep midpoint.

### 3.5.4 Chronotype and Performance

The strong preference for an evening-type (i.e. late chronotype) sleep pattern found in our study has potential implications for esports athletes' sleep and performance. Research into the effect of chronotype on athletic performance has recently increased (Vitale & Weydahl, 2017). Although some studies have observed no effect (Burgoon et al., 1992), other studies have shown a relationship (Kunorozva et al., 2014; Rae et al., 2015). For example, in one study evaluating chronotype and training time in a group of swimmers, it was reported that morning types and those who habitually train in the morning were faster, less fatigued and more energetic during morning training sessions. Conversely, neither-types and those who regularly train in the evening felt more energetic and less fatigued during evening training sessions (Rae et al., 2015). Hence, it would appear that an individual's chronotype and training schedule could affect performance, and it may be important to consider individual chronotypes depending on competition timing. In terms of esports, evening-type esports athletes with evening training and matches are less likely to experience sleep and performance impairments, as their competition and chronotype are aligned. However, for earlier-scheduled matches, there would be a greater risk for both acute sleep loss (owing to being unable to sleep in until a typical wake-up time) and possible performance decrements associated with being awake and needing to perform close to the core body temperature nadir (Drust et al., 2005; Wright et al., 2002).

### 3.5.5 Clinical Implications

Sleep interventions designed to enhance sleep and performance outcomes of esports athletes appear warranted, especially given the low number (23.5%) of players who previously attempted to improve their sleep. Sleep education (both verbal and written) should be tailored to esports players to enhance relevance and promote active engagement (Bonnar et al., 2015, 2018). Given the risk for poor sleep hygiene (e.g. proclivity for late-night technology use and regular caffeine use), sleep education should include sleep hygiene recommendations, which, pertinently for esports athletes, has been found to be useful for traditional athletes following late-night matches (Fullagar et al., 2016). The typical apathy toward sleep-related behavioural change observed in young people might indicate the inclusion of motivational strategies to enhance sleep treatment compliance (Micic et al., 2019).

The delayed sleep timing of participants found across all countries highlights the importance of incorporating chronobiological strategies, including the use of blue-light-blocking glasses following late training sessions (Sasseville et al., 2009), exogenous melatonin administration at the beginning of the sleep period and scheduled light exposure at the end of it (Lack et al., 2007), as well as team-based activities (e.g. eating breakfast together) that anchor sleep/wake behaviour (McKenna & Wilkes, 2018). Other team social cues could also be implemented by team coaches, such as set training times, which would help regulate sleep timing. Cognitive and behavioural techniques could prove useful (Bonnar, Lee et al., 2019); for example, MBSR has been helpful for younger people's sleep (Bartel et al., 2018; Blake et al., 2017).

### 3.5.6 Limitations

The current study had a small sample with 17 participants. However, it should be noted that elite athletes of any kind are very difficult to recruit, which is why in traditional sports science research, small sample sizes are common (e.g. Staunton et al., 2017) and considered acceptable, including in landmark studies such as Mah et al. (2011). Moreover, the two previous studies (Rudolf et al., 2020; Thomas et al., 2019) that measured the sleep of esports athletes had smaller samples than the present study. However, further studies will be needed to complement our findings to enhance generalisability. An additional sampling consideration is that although available normative data offers a useful comparison, the inclusion of a control group would enable a more direct comparison between esports athletes and non-esports athletes. For this study, actigraphy was used to analyse objective sleep data. Considering previous studies that show significant discrepancies may exist for WASO and TST between objective and subjective sleep data (Short et al., 2012), further studies using both actigraphy and sleep diary data may be necessary (including monitoring daily alcohol and medication use). Furthermore, some criticism has been made regarding the confidential nature of the mathematical modelling that underpins the proprietary algorithms used in wrist activity monitors (de Zambotti et al., 2016) such as Readibands, Polar and Garmin. However, we note that 'big data' and smaller-scale studies that use wrist activity monitors with automated proprietary algorithms are increasingly being published in reputable journals within the sleep literature (e.g. Kuula et al., 2019; Ong et al., 2019). Finally, because we did not include performance measures, we were unable to determine how these sleep patterns influence performance in esports.

## 3.6 Conclusion

Findings from the present study indicate that esports athletes have delayed sleep patterns, experience prolonged WASO and obtain < 7 hours of sleep per night. These sleep patterns may be associated with mood (depression) and training time in some esports athletes, particularly those from South Korea. Future research should aim to measure the impact of sleep on performance in esports and design sleep interventions specifically tailored for esports athletes and the conditions that characterise competing at elite levels in esports.

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# Chapter 4: Evaluation of a Brief Sleep Intervention Designed to Improve the Sleep, Mood, and Cognitive Performance of Esports Athletes

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## 4.1 Abstract

This study evaluated a brief sleep intervention designed to improve the sleep, mood and cognitive performance of professional electronic sports (esports) athletes from three major esports regions (i.e. Asia, North America and Oceania). Fifty-six esports athletes from South Korea ($N = 34$), the US ($N = 7$) and Australia ($N = 15$) completed the study. Participants completed an initial two-week pre-intervention phase to establish a baseline, followed by a two-week intervention phase that involved a group sleep education class, a 1:1 session with a trained clinical psychologist, and daily biofeedback. A wrist activity monitor and daily sleep diary were used to monitor sleep during both phases, while at pre- and post-intervention, participants completed a battery of sleep and mood questionnaires and underwent cognitive performance testing. Sleep knowledge increased from pre- to post-intervention ($d = 0.83$ [95% CI −1.21, −0.43], $p = < .001$), while there were modest improvements in sleep diary estimates (i.e. SOL [$M_{diff} = -2.9$ minutes, $p = .02$], sleep onset time [$M_{diff} = -12$ minutes, $p = .03$], sleep efficiency [$M_{diff} = 1.1\%$, $p = .004$]) and wrist activity monitor estimates (i.e. sleep onset time [$M_{diff} = -18$ minutes, $p = .01$]). Insomnia severity scores decreased significantly ($d = 0.47$ [95% CI 0.08, 0.84], $p = .001$), while sleepiness scores increased but not meaningfully ($d = -0.23$ [95% CI −0.61, 0.14], $p = .025$). However, there was no significant change in mood (i.e. depression and anxiety) or cognitive performance scores (i.e. mean reaction time or lapses). Sleep interventions for esports athletes require further investigation. Future research should examine whether a stepped-care model, whereby increasing therapeutic input is provided as needed, can optimise sleep, mood and cognitive performance outcomes.

**Keywords:** esports, sleep, performance, intervention, mood, cognition.

## Evaluation of a Brief Sleep Intervention Designed to Improve the Sleep, Mood, and Cognitive Performance of Esports Athletes

### 4.2 Introduction

Electronic sports (esports) is a form of organised video game competition that has become increasingly popular and professionalised over the last decade (Bonnar, Castine et al., 2019). The global esports industry is predicted to generate 1.084 billion USD in revenue and reach a worldwide audience of 474 million in 2021 (Newzoo, 2021). In response to this growth, researchers have begun to investigate factors that influence the performance and wellbeing of professional competitors—known as esports athletes. Within this budding field of academic enquiry, the function of sleep has emerged as a particular area of interest, owing to its central role in supporting human health (physical and mental) and performance (Firth et al., 2020; Walsh et al., 2021). However, the unique characteristics and conditions experienced by esports athletes, including but not limited to long training hours (mean = 9.2 hours per day; Lee et al., 2021), performance stress (Lee et al., 2020) and a tendency towards a late chronotype (i.e. a delayed sleep pattern; Lee et al., 2021), may increase the risk of suboptimal sleep outcomes.

A small but growing body of evidence on the sleep patterns of esports athletes has been documented. Studies (Gomes et al., 2021; Lee et al., 2020, 2021) comprising participants from South Korea, Australia, Brazil and the US have found that esports athletes have significantly delayed sleep timing (e.g. median = 3:43–11:24 am; Lee et al., 2021). TST is low, ranging from 6.5 to 7.2 hours per night, with sleep diary estimates being greater than actigraphy estimates. SOL is typically adequate (i.e. < 30 minutes; Ohayon et al., 2017) when measured with a sleep diary and wrist actigraphy. However, while sleep diary estimates of WASO are within normal limits (i.e. < 20 minutes; Ohayon et al., 2017), actigraphy estimates are excessive, which may reflect the discrepancy between these measures observed in the sleep literature (Short et al., 2012). Collectively, these findings suggest that some esports athletes have delayed sleep timing and are sleep restricted, which aligns with subjective estimates of high daytime sleepiness (Lee et al., 2020, 2021).

There are two important implications for esports athletes who obtain poor sleep. First, sleep restriction has a well-known deleterious effect on cognitive performance, including slower reaction times, increased memory lapses, decreased vigilance and attention, and impaired executive functioning (Fullagar et al., 2015; Lowe et al., 2017; Van Dongen et al., 2003). Importantly, these aforementioned cognitive abilities (among others) have been proposed to play a role in esports, in which games are often fast-paced, require complex decision-making and adaptation, and can be played for varying periods (i.e. 5–45 minutes) over successive matches during multi-day tournaments (Bonnar, Castine et al., 2019). Second, some research has shown a relationship between esports and poor mental health outcomes (Palanichamy et al., 2020). Sleep restriction contributes to disturbed mood states (e.g. depression and anxiety; Dinges et al., 1997; Ferrara & De Gennaro, 2001), with preliminary evidence showing a possible link between sleep and depressive symptoms in esports athletes (Lee et al., 2020, 2021). Thus, esports athletes' performance and mental health could be compromised owing to poor sleep.

Suboptimal sleep experienced by esports athletes and the potential consequences for performance and mood suggest that sleep interventions are warranted. We have previously proposed that CBT-I, a multi-component treatment package, could be adapted to meet the needs of esports athletes (Bonnar, Lee et al., 2019). CBT-I treatment components include education to improve sleep knowledge, cognitive techniques to reduce nocturnal arousal levels, behavioural strategies to establish consistent sleep scheduling and motivational tasks to enhance treatment compliance (Bonnar, Lee et al., 2019), which are usually delivered over 4–8 weekly sessions. However, the demands of training and competition schedules to which esports athletes are required to adhere (Lee et al., 2021) suggest that a brief low-intensity (i.e. small dose) sleep intervention, which has shown to be effective in traditional athlete populations (Walsh et al., 2021), may be more feasible and realistic for teams to accommodate.

Moreover, since esports athletes are young (e.g. mean = 20 years; Lee et al., 2021) and therefore inclined to be high-technology users, biofeedback may be an engaging adjunctive intervention component. In a sleep context, biofeedback typically refers to a wrist-worn activity monitor being paired with a smartphone application to relay sleep (and sometimes subsequent cognitive performance) data back to an individual following a period of sleep (Walsh et al., 2021). Biofeedback has shown mixed results in the treatment of sleep disorders such as insomnia (Melo et al., 2019). However, it has been recommended to use an appropriately validated wrist activity monitor for traditional athletes as a non-intrusive means of increasing sleep awareness (Walsh et al., 2021). The benefit of increased sleep awareness for esports athletes participating in a sleep intervention is that it would enable the active monitoring of progress while simultaneously making sleep-related behavioural changes.

The present study aimed to evaluate a brief low-intensity sleep intervention designed to improve the sleep, mood and cognitive performance of esports athletes from three major esports regions (i.e. Asia, North America and Oceania), using a single-arm open-label multi-centre interventional study design. To the best of the authors' knowledge, this is the first time a sleep intervention has ever been trialled with esports athletes in any context. We predicted that participants would obtain short-term improvements in sleep (e.g. TST), mood (i.e. depression and anxiety symptoms) and performance (i.e. mean reaction time and lapses) at post-intervention relative to pre-intervention.

## 4.3 Method

### 4.3.1 Participants

Participants were South Korean, US and Australian esports athletes. Top esports organisations (i.e. organisations that had teams in Tier 1 and 2 leagues) in each country were contacted via email regarding the study. When an organisation indicated interest by responding, potential participants were debriefed on what would be involved in the study, after which they provided informed written consent. Participant enrolment and study participation were completed in cohorts (i.e. team-based). The countries were selected because they are part of official esports regions (i.e. Asia, North America and Oceania) and these are where the authors resided. Thirty-four South Korean esports athletes have previously had their pre-intervention subjective sleep estimates reported (Lee et al., 2020), while a total of 17 esports athletes from Australia, South Korea, and the US have previously had their pre-intervention objective sleep estimates reported (Lee et al., 2021). Ethics approval was obtained in all three countries from relevant ethics boards, including the Flinders University Social and Behavioural Research Ethics Committee (project number: 8408), the Sungshin Women's University Review Board (project number: SSWUIRB-2019-030) and the North Texas Regional Institutional Review Board (project number: 2019-165). Participants were eligible for inclusion in the study if they competed on a professional team as part of an official esports league. No exclusion criteria (e.g. sleep medication use) were used to increase the generalisability of the sample.

### 4.3.2 Measures

#### *4.3.2.1 Demographic/General Information*

A self-report questionnaire was used to measure demographic and general information, including self-reported anthropometric data (i.e. height [cm] and weight [kgs]) used to calculate BMI values, esports background (i.e. career length and training hours [i.e.

total number of hours, initial start and final stop times for the day]), sleep history (i.e. sleep medication use), self-reported caffeine use (in mg) per day, and self-reported sleep disturbance the night before a competition (in the last year).

#### *4.3.2.2 Sleep Measures*

**Wrist Activity Monitor.** Wrist activity monitors (i.e. Readiband V5 Fatigue Science Inc., Vancouver, BC, Canada) were used to obtain an objective measure of esports athletes' sleep. Analyses of the wrist activity monitor yield raw acceleration signals with a proprietary algorithm to generate sleep/wake data. Evidence suggests that it adequately compares to both gold standard in-laboratory polysomnography and several other popular wrist activity monitors (Chinoy et al., 2021). Sleep data derived from the wrist activity monitor included SOL, sleep onset time, WASO, sleep efficiency (i.e. TST/time in bed × 100; time in bed was calculated from the time participants attempted sleep to their wake-up time), TST, time in bed and wake-up time. Accelerometer data were also used to establish sleep timing (i.e. sleep onset time and wake-up time; Ancoli-Israel et al., 2003).

**Sleep Diary.** The American Academy of Sleep Medicine recommends that sleep diaries be used in conjunction with wrist activity monitors (Morgenthaler et al., 2007). Hence, a daily online sleep diary based on the Consensus Sleep Diary developed by Carney et al. (2012) was administered upon waking at the end of each major sleep period. The questions were related to bedtime, lights-out time, sleep onset time, WASO and wake-up time. These data were also used to calculate additional sleep variables, including SOL, TST, sleep efficiency (i.e. TST/time in bed × 100; time in bed was calculated from the time participants attempted sleep to their wake-up time), and sleep timing (i.e. sleep onset time, wake-up time).

**Insomnia Severity Index.** The ISI (Morin et al., 2011) is a 7-item self-report instrument used to assess the presence and severity of insomnia in participants. Items (e.g.

‘How worried/distressed are you about your current sleep problem?’) are rated on a 5-point Likert scale from 0 (*not at all*) to 4 (*very much*) and summed to generate a total score. Higher total scores (range 0–28) indicate greater insomnia severity. The ISI has sound internal consistency (in the present study, α = .75 across time), test-retest reliability and construct validity, while a cut-off score of 10 had 86.1% sensitivity and 87.7% specificity for detecting insomnia cases in community samples (Manzar et al., 2021). A Korean version of the ISI was used (Cho et al., 2014).

**Paediatric Daytime Sleepiness Scale.** The PDSS (Drake et al., 2003) is an 8-item self-report instrument used to assess levels of daytime sleepiness in participants. The wording of Items 1 and 2 was altered to increase relevance for esports athletes, as the original items were school-related, and no participants were attending school. Items (e.g. ‘How often do you fall back to sleep after being woken in the morning?’) are rated on a 5-point Likert scale from 0 (*never*) to 4 (*always*). Item 3 is reverse-scored. Item scores are summed to generate a total score (range 0–32,) with higher total scores indicating greater daytime sleepiness. The PDSS has good internal consistency (in the present study, α = .78 across time) and is correlated with reduced sleep duration (Drake et al., 2003). The PDSS was chosen over other popular sleepiness scales (e.g. Epworth Sleepiness Scale) owing to its items showing greater face validity (i.e. questions aimed at morning sleepiness v. situations in the Epworth Sleepiness Scale such as being in a car stopped in traffic). It has been used in samples with participants up to age 24 years (Richardson et al., 2018) and with esports athletes (Lee et al., 2021). A Korean version of the PDSS was used (Rhie et al., 2011).

**Sleep Knowledge.** Sleep and performance knowledge was measured using a quiz (see Appendix C) adapted from Bonnar et al. (2015). Participants answered ‘true’, ‘false’ or ‘don’t know’ to 16 items relating to information about sleep and performance (e.g. ‘Most young adults need between 7–9 hours of sleep per night’). Correct answers were scored 1 and incorrect and 'don't know' responses as 0. Individual item scores were summed to generate a total score out of 16, with higher total scores indicating greater knowledge. In the present study, the Kuder–Richardson formula-20 coefficient was adequate ($\alpha$ = .69 across time). This measure was translated into Korean and back-translated by a bilingual member of the research team.

***4.3.2.3 Mood Measures***

**Centre for Epidemiological Studies-Depression.** The CES-D (Radloff, 1977) is a 20-item self-report instrument used to assess depressive symptomatology. Items (e.g. 'I was happy') are rated on a 4-point Likert scale from 0 (*rarely or none of the time*) to 3 (*most or all of the time*). Individual item scores were summed to generate a total score ranging from 0 to 60, with higher total scores indicating greater levels of depressive symptoms. A cut-off score of $\geq$ 16 was used as an indicator of depression. The CES-D has adequate internal consistency (in the present study, $\alpha$ = .76 across time), test-retest reliability and construct validity (Cosco et al., 2017; Radloff, 1977). A Korean version of the CES-D was used (Chon et al., 2001).

**State-Trait Anxiety Inventory-Y.** The STAI-Y (Spielberger et al., 1983) consists of two anxiety scales (i.e. trait and state), with the 20-item self-report state scale used to assess state anxiety in the current study. Items (e.g. 'I am tense') are rated on a 4-point Likert scale from 1 (*not at all*) to 4 (*very much so*). Individual item scores were summed to generate a total score ranging from 20 to 80, with higher total scores indicating greater levels of state anxiety. The STAI-Y has adequate psychometric properties, with sound internal consistency (in the present study, $\alpha$ = .92 across time), test-retest reliability and construct validity (Ortuno-Sierra et al., 2016; Spielberger, 1989). A Korean version of the STAI-Y was used (Hahn, 1996).

#### *4.3.2.4 Cognitive Performance Measure*

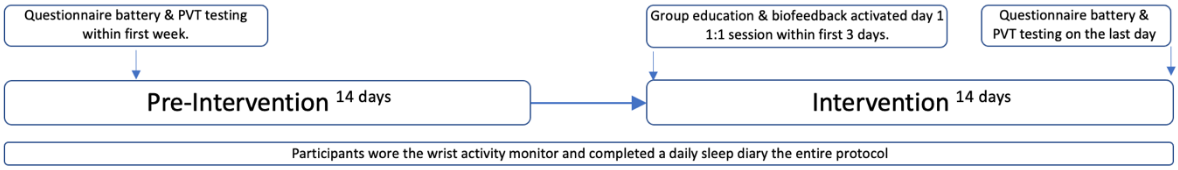
**Psychomotor Vigilance Task.** The PVT-5 is a measure of vigilant attention (Loh et al., 2004) that was delivered on an iPad using Joggle Research software V2.7 (Seattle, WA, USA). Participants were presented with a screen with a red rectangle in the centre, in which a visual stimulus (i.e. yellow counter) appeared randomly every 2–10 seconds over a 5-minute trial period (participants completed 49–51 responses depending on their reaction time). The participant was required to respond to the appearance of the on-screen counter by touching the screen as quickly as possible. Once the screen had been touched, the counter was stopped, and the reaction time (in milliseconds) was displayed for 1 second. False starts or a reaction time $< 100$ milliseconds were labelled as 'errors'. Based on previous research (e.g. Jones et al., 2018), lapses were defined as a reaction time $\geq 500$ milliseconds. The primary outcomes of interest from the PVT-5 were mean reaction time and number of lapses per 5-minute trial period. The PVT-5 is considered an acceptable substitute for the gold-standard PVT-10 based on evidence showing similar performance between the two tests (Roach et al., 2006), which has also been established using Joggle Research software (Jones et al., 2018).

### 4.3.3 Procedure

The study protocol took place during a regular competitive season in each team's respective league. Hence, participants were actively training and competing at the time of the study, thereby maximising ecological validity. Data were collected between July 2019 and March 2020 (prior to COVID-19 impacting each country). Participants were assigned an anonymised study ID for all data collection points. Figure 4.1 outlines the study procedure.

**Figure 4.1**

*Study Procedure Flow from Pre-Intervention to Intervention Period*




#### *4.3.3.1 Pre-Intervention Period*

Participants completed 14 days of pre-intervention data collection, except for one US team (5 participants) that completed seven days owing to a conflict with a major tournament. Participants were instructed to maintain their typical sleep-wake behaviour during this time. They continuously wore the wrist activity monitor on their non-dominant wrist (unless impractical to do so, such as when showering) and completed an online daily sleep diary via a web link. Sleep diary entries were monitored by a member of the research team, and if participants had not completed their sleep diary by late afternoon (afternoon was selected owing to some participants having very delayed circadian timing), they were contacted and reminded to do so. Participants also completed a battery of questionnaires (i.e. ISI, PDSS, CES-D, STAI-Y and sleep knowledge quiz via paper or online with Qualtrics) and underwent cognitive testing individually with a member of the research team within the first week (testing for each team occurred within a 12:00–9:00 pm window) to establish baseline scores for the pre-intervention period.

#### *4.3.3.2 Intervention Period*

Following the pre-intervention period, participants completed a 14-day intervention period. On Day 1 of the intervention period, participants completed a group sleep education class. The class included a presentation that outlined information on the importance of sleep for health and performance in esports, sleep physiology, sleep hygiene, sleep myths (e.g.

waking during the night is abnormal), characterisation of adequate sleep and a brief introduction to brief behavioural therapy for insomnia. The class was 40 minutes long and conducted by a clinical psychologist specialising in behavioural sleep medicine (i.e. authors DB, SS, SL, BR or DJB.; experience ranged 5–15 years).

At the end of the group presentation, participants downloaded a phone application (Fatigue Science) and paired it with their wrist activity monitor. The app enabled participants to access biofeedback on their phones (i.e. their sleep data). The Readiband has an additional function that allows captured sleep data to be analysed to produce a daily cognitive performance score ranging 0–100 that is also relayed to the user via the app (Hursh et al., 2004). Higher scores indicate faster and more accurate reaction times (Hursh et al., 2004). For further information about the cognitive performance function's use and validation, see Hursh et al. (2004), Hursh et al. (2006), and Van Dongen et al (2003). Participants were encouraged to check the app daily to track their progress. Use of the app was not monitored.

Between Days 1–3 of the intervention period, each participant completed a 30 minute 1:1 session with the same clinical psychologist who conducted the group education. Sessions occurred over three days to accommodate busy team training schedules. During the 1:1 session, participants were provided with a brief report that outlined a summary of their sleep and cognitive performance data from the wrist monitor obtained during the baseline period. Data included sleep variables (e.g. sleep onset time, SOL, WASO, TST and wake-up time) and average cognitive performance score for each day. The clinical psychologist described four recommendations adapted from brief behavioural therapy for insomnia (Troxel et al., 2012). These included the following: (1) reduce time in bed if sleep quality is poor; (2) keep a consistent wake-up time; (3) do not go to bed unless sleepy; and (4) do not stay in bed unless you are sleeping (Troxel et al., 2012). A relaxation exercise (i.e. diaphragmatic breathing for 2–3 minutes) was practised to help esports athletes reduce pre-sleep arousal levels if needed (Friedrich & Schlarb, 2018). At the end of the session, three motivational interviewing questions based on the themes of desire, ability and commitment (e.g. 'How confident are you about improving your sleep?') were used to enhance motivation and treatment compliance (Micic et al., 2019). Finally, a sleep and performance manual that summarised the content covered in the group education and individual 1:1 session was provided as a reference. Participants were encouraged to read the manual and use the information gained in the group education and 1:1 sessions to try to improve their sleep until the conclusion of the intervention period.

On the last day of the intervention period, participants returned their wrist activity monitor, completed a battery of questionnaires (i.e. ISI, PDSS, CES-D, STAI-Y and sleep knowledge quiz via paper or online with Qualtrics) and underwent cognitive testing. Cognitive testing for each team occurred within 2 hours of their pre-intervention testing time.

#### *4.3.3.3 Data Analysis*

Descriptive statistics, including frequencies, means and standard deviations, were used to summarise sample characteristics. Data for all variables were inspected for missing values and outliers prior to commencing data analysis. Missing data for sleep diary variables ranged 2.7–2.8%, while missing data for wrist activity monitor variables ranged 13.9–14.5%. Unreliable data owing to technical issues were removed. Linear mixed-model regressions were used to test the main effect of time on all primary outcome measures, with SPSS v.26.0 (Armonk, NY, USA) used for questionnaires and PVT, and R v3.6.3 (R Foundation for Statistical Computing, Vienna, Austria) and RStudio v1.2.5033 (Boston, MA, USA) used for sleep diary and wrist activity monitor data, owing to their nested structure (multiple nights per assessment period). Linear mixed-model regressions accounted for missing data using maximum likelihood estimation. All linear mixed-model regressions were adjusted for participant age, gender, BMI, training hours and country. A significance level of $p < .05$ was used. Effect sizes (i.e. Cohen's *d* for questionnaire scores and PVT number of lapses per trial, and mean difference [$M_{diff}$] for sleep variables and PVT mean reaction time) were calculated for primary outcome measures.

## 4.4 Results

### 4.4.1 Sample Characteristics

Participants were South Korean ($N = 34$), US ($N = 7$) and Australian ($N = 15$) esports athletes (for sample characteristics, see Table 4.1). The response rate was 95% (56/59). A total of 57 participants initially commenced the study. One participant from Australia was excluded (i.e. they left their team during the pre-intervention period). Thus, a total of 56 participants were included in the final analysis. Most participants were male ($N = 54$, 96.4%), with a mean age of 20.9 years ± 2.4 (range = 14–27), and the mean BMI was 23.8 ± 5.3 (range = 16.1–37). There was no significant difference in age or BMI between countries. Participants' mean career as a professional esports athlete was 2.6 years ± 1.6 (range = 0–9). Participants competed in either FPS games ($N = 24$), MOBA games ($N = 22$), battle royale games ($N = 6$), sport games ($N = 3$) or fighting games ($N = 1$). Korean participants had significantly longer training hours than Australian ($M_{diff} = 6.91$, standard error [SE] = 0.63, $p < .001$) and US participants ($M_{diff} = 5.78$, SE = 0.84, $p < .001$). The difference between Australian and US training hours was non-significant ($M_{diff} = 1.13$, SE = 0.93, $p = .23$).

With respect to training timing, on average, Korean participants trained between 1:00 pm and 2:00 am, Australian participants trained between 4:00 pm and 11:00 pm, and US participants trained between 12:00 pm and 6:00 pm. Regarding sleep aids, only one participant from Australia used melatonin.

**Table 4.1**

*Characteristics of Study Participants by Country of Origin*

| Measure | South Korea *N* = 34 | United States *N* = 7 | Australia *N* = 15 | Total Sample *N* = 56 | F(*p*) |
|---|---|---|---|---|---|
| Age (years) | 21.0 (2.42) | 21.9 (3.16) | 20.0 (1.94) | 20.9 (2.43) | 1.64 (.20) |
| BMI (kg/m$^2$) | 24.2 (5.39) | 25.0 (5.88) | 22.4 (4.69) | 23.8 (5.26) | 0.82 (.44) |
| Training hours per day | 12.71 (2.04) | 6.93 (1.79) | 5.80 (2.10) | 10.13 (3.81) | 70.27 (.001) |
| Career length in years | 2.9 (1.6) | 2.9 (1.5) | 1.8 (1.2) | 2.6 (1.6) | 2.74 (.074) |
| | | | | | Chi-square(*p*) |
| Female sex, *n* (%) | 0 (0%) | 2 (29%) | 0 (0%) | 2 (4%) | 14.52 (.001) |
| Sleep disturbance pre-competition, *n* (%) | 14 (42%) | 3 (43%) | 10 (67%) | 27 (49%) | 2.55 (.28) |
| Sleep medication use *n* (%) | 0 (0%) | 0 (0%) | 1 (7%) | 1 (2%) | 2.78 (.24) |
| | | | | | Kruskal–Wallis |
| Caffeine intake (mg per day), *n* (%) | | | | | 3.94 (.14) |
| < 100 | 14 (44%) | 4 (57%) | 8 (67%) | 26 (51%) | |
| 100–200 | 7 (22%) | 2 (29%) | 4 (33%) | 13 (25%) | |
| 300–400 | 7 (22%) | 1 (14%) | 0 (0.0%) | 8 (16%) | |
| > 400 | 4 (12%) | 0 (0%) | 0 (0%) | 4 (8%) | |

*Note.* To test for differences between countries of origin on age, BMI, training hours and career length, we used ANOVA (F = Fisher-Snedecor). Least-significant difference post-hoc testing was conducted to interpret significant effects. Chi-square was used to establish the frequency of sex, sleep disturbances pre-competition and sleep medication use. Differences in caffeine intake were examined with the Kruskal–Wallis test.

### 4.4.2 Sleep Knowledge

There was a significant main effect of time for the sleep knowledge quiz ($d = 0.83$, 95% CI [−1.21, −0.43], $p \leq .001$). From pre- to post-intervention, participants' sleep knowledge improved by 14.3%.

### 4.4.3 Sleep Diary

Daily sleep diary estimates are presented in Table 4.2. There was a significant main effect of time for SOL, sleep onset time and sleep efficiency. From pre- to post-intervention, participants initiated sleep 2.9 minutes quicker on average, fell asleep 12 minutes earlier, and slept 1.1% more efficiently. There was no significant main effect for TST, WASO or wake-up time.

**Table 4.2**

*Sleep Diary Estimates of Sleep Parameters Pre- and Post-Intervention*

| Sleep parameter | Main effect-time | | Pre-intervention M(SE) | Post-intervention M(SE) | $M_{diff}$ |
|---|---|---|---|---|---|
| | *t* | *p* | | | |
| TST (hrs) | 1.67 | .09 | 7.4 (0.38) | 7.5 (0.38) | 0.1 |
| SOL (mins) | −2.31 | .02 * | 28.3 (9.12) | 25.4 (9.12) | −2.9 |
| WASO (mins) | −1.12 | .26 | 9.6 (8.67) | 8.2 (8.68) | −1.4 |
| SOT (hh:mm) | −2.28 | .03 * | 03:42 (00:38) | 03:30 (00:37) | −00:12 |
| WUT (hh:mm) | −1.45 | .15 | 11:06 (00:30) | 10:54 (00:33) | −00:12 |
| SE (%) | 2.88 | .004 * | 91.5 (0.03) | 92.6 (0.03) | 1.1 |

*Note.* TST = total sleep time; SOL = sleep onset latency; WASO = wake after sleep onset; SOT = sleep onset time; WUT = wake-up time; SE = sleep efficiency.

*Indicates significant *p*-value ($p \leq .05$).

### 4.4.4 Wrist Activity Monitor

Wrist activity monitor estimates are presented in Table 4.3. There was a significant main effect of time for sleep onset time, whereby participants fell asleep 18 minutes earlier on average at post-intervention compared with baseline. The main effects for time were non-significant for TST, SOL, WASO, wake-up time and sleep efficiency.

**Table 4.3**

*Wrist Activity Monitor Estimates of Sleep Parameters Pre- and Post-Intervention*

| Sleep parameter | Main effect-time | | Pre-intervention M(SE) | Post-intervention M(SE) | $M_{diff}$ |
|---|---|---|---|---|---|
| | *t* | *p* | | | |
| TST (hrs) | 1.87 | .06 | 6.9 (0.31) | 7.05 (0.32) | 0.15 |
| SOL (mins) | −0.77 | .44 | 31.6 (4.09) | 30.3 (4.11) | −1.3 |
| WASO (mins) | −1.13 | .26 | 44.7 (11.4) | 42.5 (11.4) | −2.2 |
| SOT (hh:mm) | −2.53 | .01 * | 04:00 (00:26) | 03:42 (00:26) | −00:18 |
| WUT (hh:mm) | −1.17 | .24 | 11:36 (00:23) | 11:24 (00:23) | −00:12 |
| SE (%) | 1.18 | .24 | 80.3 (2.84) | 80.8 (2.84) | 0.5 |

*Note.* TST = total sleep time; SOL = sleep onset latency; WASO = wake after sleep onset; SOT = sleep onset time; WUT = wake-up time; SE = sleep efficiency.

*Indicates significant *p*-value ($p \leq .05$).

### 4.4.5 Sleep, Mood and Psychomotor Vigilance Task Scores

Sleep (i.e. ISI, PDSS), mood (i.e. STAI-Y, CES-D) and PVT (i.e. mean reaction time and lapses) scores are presented in Table 4.4. There was a significant main effect of time for the ISI and PDSS. From pre- to post-intervention, participants' ISI scores decreased by 2.0 (i.e. participants reported fewer insomnia symptoms), and PDSS scores increased by 1.3 (i.e. participants reported higher sleepiness levels). There was no main effect of time for mood or PVT scores.

**Table 4.4**

*Sleep, Mood and PVT Scores Pre- and Post-Intervention*

| Measure | Main effect-time | | Pre-intervention M(SE) | Post-intervention M(SE) | Effect size (95% CI)/$M_{diff}$ |
|---|---|---|---|---|---|
| | $F$ | $p$ | | | |
| ISI | 12.79 | .001* | 10.50 (1.52) | 8.47 (1.47) | 0.47 (0.08, 0.84) ** |
| PDSS | 5.32 | .02* | 14.75 (1.81) | 16.07 (1.82) | −0.23 (−0.61, 0.14) |
| STAI-Y | 1.03 | .31 | 44.96 (3.30) | 43.78 (3.39) | 0.12 (−0.26, 0.49) |
| CES-D | 0.01 | .94 | 27.33 (1.85) | 27.40 (1.99) | −0.009 (−0.38, 0.36) |
| Mean reaction time (ms) | 0.26 | .61 | 251.3 (10.90) | 249.6 (11.11) | -1.7 |
| Lapses (≥ 500 ms) | 2.04 | .16 | 3.0 (1.03) | 2.5 (1.02) | 0.2 (−0.18, 0.58) |

*Note.* ISI = Insomnia Severity Index; PDSS = Paediatric Daytime Sleepiness Scale; STAI-Y = State-Trait Anxiety Inventory; CES-D = Centre for Epidemiological Studies Depression; ms = milliseconds. Please note that Cohen's *d* is used to express effect size for all variables apart from mean reaction time, which is expressed with $M_{diff}$.

*Indicates significant *p*-values. ** indicates meaningful Cohen's *d*.

## 4.5 Discussion

An accumulating body of evidence suggests that esports athletes experience suboptimal sleep, characterised by delayed sleep timing and restricted TST, with direct implications for mood and performance (Lee et al., 2021). To the best of our knowledge, this study is the first to trial a brief low-intensity sleep intervention specifically designed to improve the sleep, mood and performance of esports athletes over a short period. Overall, mixed results were observed. Based on self-report questionnaires, participants improved their sleep knowledge and reduced the severity of their insomnia symptoms, yet might have experienced greater sleepiness. In terms of sleep measures, sleep diary estimates showed improvements in SOL, an earlier sleep onset time, and improved sleep efficiency, while wrist activity monitor estimates corroborated the earlier sleep onset time. However, these modest improvements in sleep did not confer any mood (i.e. depression and anxiety) or cognitive performance (i.e. PVT) benefits. We now examine these findings in more detail and discuss considerations for future interventions.

### 4.5.1 Sleep Outcomes

Although there are no other sleep interventions in esports with which to compare our findings, similar brief low-intensity sleep interventions trialled in professional athlete samples (who are also sleep restricted) offer a useful contrast. For example, Van Ryswyk et al. (2017) provided an education session that outlined sleep hygiene information and strategies to increase TST and sleep quality, in addition to weekly sleep parameter feedback (e.g. SOL, WASO and TST) and a mid-intervention feedback session. Despite results showing subjective benefits for TST and sleep efficiency, there were no objective sleep benefits or changes in PVT (Van Ryswyk et al., 2017). In another study, Driller et al. (2019) provided a group education session and a 30 minute 1:1 session that outlined personalised sleep hygiene recommendations. Results indicated improvements in subjective sleepiness and sleep quality and objective estimates of sleep efficiency, SOL and sleep onset variance. The findings from our study are more aligned with Van Ryswyk et al. in that there were mostly modest subjective short-term sleep benefits. Importantly, findings from Driller et al. combined with other recent evidence suggest that individualising sleep interventions may produce more robust sleep benefits than a one-size-fits-all approach (Walsh et al., 2021) and should thus also be investigated in esports.

Notably, there was a small, non-significant change (6–9 minutes) in TST post-intervention. As part of the brief behavioural therapy for insomnia recommendations (Troxel et al., 2012), esports athletes were encouraged to keep a consistent wake-up time, which our findings suggest they did. Hence, a further increase in TST was likely constrained by esports athletes' difficulty in advancing sleep onset time more significantly than the 12–18 minutes (subjective and objective estimates) observed over the short timeframe. Given that there was a negligible change in SOL, this suggests that esports athletes did not dramatically shift the time they attempted sleep despite being mildly sleep restricted. A previous qualitative study comprising Korean esports athletes found that late training times may increase arousal levels post-training, leading to bedtime procrastination characterised by technology use (Lee et al., 2020). Recent evidence indicates that bedtime procrastination is related to delayed sleep timing, poor mood (anxiety and depression), and insomnia symptoms (Chung et al., 2020). Hence, bedtime procrastination might have prevented esports athletes in our study from attempting to sleep earlier when feeling sufficiently sleepy (as recommended in brief behavioural therapy for insomnia). Future research should quantify the level of bedtime procrastination in esports athletes (e.g. using the bedtime procrastination scale; Kroese et al., 2014) and investigate whether this does indeed interfere with their readiness to attempt sleep.

Consistent with the modest improvement in some subjective sleep estimates, there was a decrease in insomnia severity scores (i.e. ISI) to below the cut-off score of 10 at post-intervention. This decrease indicates that esports athletes perceived less sleep disturbance from pre- to post-intervention. In contrast, these improvements for subjective sleep were not reflected on our daytime sleepiness measure (i.e. PDSS), with participants experiencing possible increased sleepiness levels at post-intervention (i.e. results were significant but not meaningful). However, similar findings have been reported in previous research, whereby sleepiness scores initially increase at post-intervention but then decrease at the two-month follow-up (Gradisar et al., 2007). Hence, future research should include a follow-up to monitor for lagged improvements in sleepiness levels.

Although not a primary focus of the present study, it should be noted that pre-intervention objective sleep estimates of participants are largely consistent with previously reported findings from our group involving a subset of esports athletes from Australia, South Korea, and the US (Lee et al., 2021) also involved in the present study. In both studies, participants from all countries were found to have significantly delayed sleep patterns and long WASO, leading to reduced TSTs of < 7 hours per night. There were some small discrepancies compared with our previous study, with SOL being slightly longer and sleep efficiency lower in the present study. However, the generally congruent findings between the initial smaller subset and our expanded sample increase confidence in the objective evidence obtained thus far regarding the sleep patterns of esports athletes in these countries.

#### 4.5.2 Mood and Cognitive Performance Outcomes

Despite participants obtaining modest short-term sleep benefits, there was no subsequent change in mood or performance. Regarding mood, meta-analytic evidence indicates that non-pharmacological sleep interventions (e.g. individualised CBT-I) are effective in reducing symptoms of anxiety and depression (Belleville et al., 2011; Gee et al., 2019). Hence, in our study, either the benefits of sleep were too small to affect mood, or other factors (e.g. pressure to perform) unrelated to sleep might have been negatively impacting mood. Regardless, using sleep interventions to target mood in esports athletes remains a plausible mechanism to be tested further. Additionally, previous research investigating sleep interventions in adolescents with delayed sleep timing has demonstrated that an improvement in depression symptoms can lag (Gradisar et al., 2011). In one study, despite improvements across multiple sleep parameters, there was no change in depression scores post-intervention, but there was at the 6-month follow-up (Gradisar et al., 2011). Hence, future research could include a longer follow-up to monitor for delayed changes in mood.

With respect to cognitive performance (i.e. PVT), the level of sleep restriction in our sample should first be highlighted. Esports athletes slept 6.9 (objective) and 7.4 (subjective) hours per night on average. Van Dongen et al. (2003) found that < 8 hours per night led to cumulative, dose-dependent degradation in cognitive performance. Thus, our study's finding adds further weight to the existing evidence base (Gomes et al., 2021; Lee et al., 2020, 2021) that some esports athletes are most likely competing while cognitively impaired.

In terms of the lack of PVT improvement, findings from the present study are consistent with previous sleep extension research showing that a large increase in TST (e.g. 1.3–1.7 hours) can generate PVT improvement (Mah et al., 2011; Ritland et al., 2019), while a smaller increase (e.g. 0.4 hours) may not (Famodu et al., 2017). Although it is difficult to determine the exact TST change threshold at which PVT improves, the additional 6–9 minutes per night found in the present study appears insufficient. Furthermore, cognitive performance was limited to the PVT (i.e. mean reaction time and lapses) in the present study. There are a range of cognitive abilities that contribute to overall performance in esports that are also sleep-sensitive (Bonnar, Castine et al., 2019). Thus, future sleep interventions should aim to include additional cognitive performance measures and possibly perceptual measures related to performance (e.g. motivation to perform).

### 4.5.3 Considerations for Future Sleep Interventions in Esports

The sleep intervention trialled in the present study was designed to be brief and low-intensity so that it could be accommodated within the demanding training and competition schedule of esports athletes. Accordingly, the sleep education component was limited to a 40-minute group education session, and the 1:1 session was 30 minutes long, while biofeedback allowed participants to maintain a passive awareness of their sleep. As mentioned earlier, similar brief low-intensity sleep interventions trialled in traditional athletes and consisting of group education and a 1:1 session have produced improvements in both subjective and objective sleep outcomes (Driller et al., 2019; Van Ryswyk et al., 2017). However, there may be a limit to what a brief low-intensity sleep intervention can achieve in an esports population. That is, although some esports athletes may experience benefits, others requiring greater therapeutic input may not.

A stepped-care model may be more effective in meeting the idiosyncratic sleep needs of esports athletes. In stepped-care models, an individual's needs are assessed and matched against a hierarchy of interventions. This approach has become increasingly popular within the sleep health field in recent years (Cheung et al., 2019) and has also been proposed for traditional athletes (Bonnar et al., 2018; Walsh et al., 2021). In esports, for example, all esports athletes could receive sleep education and then undergo an assessment to determine which players require further therapeutic input and to what degree. Esports athletes identified as being 'at risk' could participate in a brief low-intensity sleep intervention, while those found to be at 'high risk' (e.g. diagnosed with insomnia) could receive more specialised therapy (e.g. individualised CBT-I). Importantly, a stepped-care model could feasibly fit within the busy lives of esports athletes.

There are several other additions that could be included to improve the effectiveness of an esports sleep intervention. For example, existing organisational personnel, such as coaches and support staff (e.g. health and wellbeing officer and team psychologist), could be leveraged. Previous research has found that coaches and support staff in traditional sporting teams play a pivotal role in providing health- and performance-related advice to players, including sleep (Miles et al., 2019). Hence, with appropriate training and guidance, esports coaches and support staff could participate in the delivery of a sleep intervention. Participation could include taking an active role in maintaining player engagement and accountability (e.g. checking in or encouragement), in a similar way to other aspects of training and team management.

Another potential means of improving a sleep intervention's effectiveness is to 'gamify' educational and clinical content. Gamification could promote contextual learning, which refers to the concept that people learn best when new information being taught aligns with their existing frames of reference (Järvinen & Poikela, 2001), as it enables the construction of meaning based on prior experience. Gamification has been used to increase physical activity (González et al., 2018) and could likewise be used to promote healthy sleep habits in a sleep intervention setting. For example, this could include modifying language to reflect esports nomenclature (e.g. suggesting players could obtain a sleep 'buff', which is a gaming term for a power increase) while using esports and gaming culture to shape intervention tools/resources (e.g. sleep variable leader boards) and the environment/delivery medium (e.g. esports discourse platforms).

The finding of improved sleep knowledge (14.5%) but only modest sleep benefits is consistent with several studies investigating group sleep interventions for young people. In these studies, increased sleep knowledge (ranging 8–13%) has not always translated into behavioural change, owing to low motivation (Cain et al., 2011; Moseley & Gradisar, 2009). In the present study, motivational interviewing questions based on the themes of desire, ability and commitment were included to enhance treatment compliance (Micic et al., 2019). However, actual motivation levels were not measured. Hence, these motivational interviewing questions might have been insufficient to motivate participants to make greater changes to their sleep behaviour. More relatable and engaging motivational tasks (e.g. playing a video game that simulates the impact of sleep restriction on performance) could enhance the intrinsic motivation to make sleep-related behavioural changes.

Finally, because sleep research in esports is in its infancy, there is still much to learn about the sleep experiences of esports athletes. As researchers gain a better understanding of the specific risk factors for suboptimal sleep in esports, other more evidence-based intervention add-ons will become evident. For example, like traditional sports, it has been proposed that esports athletes who compete in different games may have varying risk profiles and associated sleep challenges (Bonnar, Lee et al., 2019). Although available evidence is limited, preliminary findings suggest that training length and timing differ between games (and potentially regions), which, therefore, displaces sleep patterns differentially (Lee et al., 2021). Hence, a stronger focus on chronobiological strategies (e.g. light therapy or endogenous melatonin) could be more important for some esports athletes than others.

#### 4.5.4 Limitations

Although we have already discussed several limitations (e.g. the present study examined short-term effects with no long-term follow-up data) throughout the Discussion section, there are additional limitations worth noting. First, there was no control group. Thus, caution should be used when interpreting and generalising our findings, with further research using more robust study designs being required before stronger conclusions can be drawn. Esports athletes are difficult to recruit, given their demanding training and competition schedules. We found that esports organisations were strongly opposed to 'burdening' players by having them participate as part of a control group that had no potential immediate benefit. Second, our sample primarily comprised males. Despite our best efforts, the pool of female esports athletes (i.e. professional players) is much smaller than their male counterparts, owing to a significant under-representation in esports compared with casual gaming. Although our study is the first to present sleep data on female esports athletes, further efforts must be made to recruit and better understand the sleep of female esports athletes. Third, we cannot rule out a time-of-day influence on reaction time testing, owing to the testing time window of 9 hours between teams. Although this window of time was a function of the busy schedules of teams, future research should aim to reduce the potential influence of time of day. Finally, the study was not pre-registered with the World Health Organisation, which was an oversight owing to the speed at which the study had to be deployed.

## 4.6 Conclusion

The present study was the first to trial a brief sleep intervention in an esports population and set a benchmark to compare future interventions. Sleep knowledge increased, and there were modest short-term sleep benefits (subjective and objective), but this did not translate into improved mood (i.e. depression and anxiety) and cognitive performance (i.e. PVT). Further research is required to enhance the sleep, mood and performance outcomes of sleep interventions in esports. More specifically, a stepped-care model that addresses the individual sleep needs of esports athletes (i.e. which provides an increased therapeutic dose of sleep knowledge and skills to those who need it) should be investigated next. Importantly, this type of intervention framework may not only be effective but also feasible by being able to fit within the constraints of esports athletes' training and competition schedules.

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# Chapter 5: The Influence of Coaches and Support Staff on the Sleep Habits of Esports Athletes Competing at Professional and Semi-Professional Level

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## 5.1 Abstract

The present study investigated the influence and perspective of esports coaches and support staff on the sleep habits of esports athletes competing at professional and semi-professional levels. Eighty-four esports coaches and support staff from 19 countries completed an online questionnaire. The first section obtained demographic information. The second section evaluated sleep hygiene knowledge using the Sleep Beliefs Scale. The third section assessed sleep monitoring and sleep hygiene practices used by coaches and support staff with esports athletes, barriers to the use of these practices, and conditions that affect the sleep of esports athletes. Overall, sleep hygiene knowledge was inadequate (< 75%, based on the study of Miles et al.). Sleep monitoring frequency was low (48.8%), while sleep hygiene practices were implemented more often (66.7%). The most common barrier to sleep monitoring and sleep hygiene practices was players not liking it (50% and 46.3%, respectively). Night competitions (64.6%), congested competition times (51.2%), and night training schedules (47.6%) all rated highly as having an impact on esports athletes' sleep. Sleep education and training for coaches and support staff in the optimal use of sleep monitoring and sleep hygiene practices may increase the frequency and quality of sleep health support provided to esports athletes.

**Keywords**: monitoring, sleep knowledge, sleep hygiene practices.

# The Influence of Coaches and Support Staff on the Sleep Habits of Esports Athletes Competing at Professional and Semi-Professional Level

## 5.2 Introduction

As research on esports (electronic sports) has expanded, the health status of competitors, known as esports athletes, has begun to take shape. With respect to sleep, two preliminary studies that investigated sleep as a secondary aim observed TST estimates of 7.8–8.1 hours per night (Rudolf et al., 2020; Thomas et al., 2019). However, these studies used single-item retrospective questions (e.g. 'On average, how many hours of sleep do you get each night?') that are considered low-grade sleep measures prone to recall bias (Mallinson et al., 2019). In comparison, several subsequent studies (Bonnar et al., 2022; Gomes et al., 2021; Lee et al., 2020, 2021) which used more robust sleep measures have found contrasting findings. That is, esports athletes from South Korea, the US, Australia and Brazil typically experienced delayed sleep timing (i.e. late sleep onset and wake-up times) and obtained a TST of 6.5–7.4 hours per night (Bonnar et al., 2022; Gomes et al., 2021). Established guidelines recommend a TST of 7–9 hours per night for adults and 8–10 hours per night for adolescents (Hirshkowitz et al., 2015). Hence, although further research is required to develop a more nuanced understanding of esports athletes' sleep behaviour (e.g. investigating sleep parameters in professional v. semi-professionals), it would appear that some esports athletes are training and competing while sleep restricted (i.e. moderately reduced TST over one or more nights). This finding reflects evidence from the sports science literature, which shows that sleep restriction is also prevalent among traditional athletes (Walsh et al., 2021).

Compared with the more well-developed sports science literature, there is currently a lack of empirical evidence about sleep restriction studies in esports. This absence of work is likely owing to the fact that esports research is still emerging, the cost and time associated with sleep restriction study designs, and the difficulty of recruiting esports athletes. However, drawing on the wider sleep literature, we can infer some important implications for esports athletes who obtain suboptimal TST. From a performance perspective, sleep restriction is known to have a detrimental impact on cognitive functioning, and esports is proposed to have a strong cognitive basis (Pedraza-Ramirez et al., 2020). For example, a recent systematic review by Smithies et al. (2021) evaluated the impact of sleep restriction on elite cognitive performers. They found that performance on rudimentary cognitive tasks (e.g. PVT) was reliably impaired by sleep restriction, while more complex tasks (e.g. multitask tests) were also affected, but only if cognitive flexibility (i.e. adaptation to changing task requirements) was required. These findings are pertinent given that esports is often fast-paced and involves complex decision-making within unpredictable match circumstances (Bonnar, Castine et al., 2019). From a mental health perspective, sleep restriction is also known to contribute to disturbed mood states such as depression (Short et al., 2020), which is relevant given evidence of high depression scores in some esports athletes (Lee et al., 2020).

Consequently, researchers have begun to investigate ways of improving the sleep of esports athletes. In the first sleep intervention trial in an esports sample, Bonnar et al. (2022) implemented a brief (2 weeks) low-intensity sleep intervention with 56 esports athletes from South Korea, the US and Australia. The sleep intervention included a group sleep education class, daily biofeedback from a wrist activity monitor, and an individual session with a clinical psychologist, which covered the four rules of brief behavioural therapy for insomnia, a relaxation task and motivational interviewing questions to enhance treatment compliance. Overall, there were modest changes for subjective and objective sleep onset time, as well as for subjective SOL and sleep efficiency. However, sleep did not improve enough to affect change in mood (i.e. depression and anxiety) or performance (i.e. PVT). These results are consistent with those from similarly structured sleep interventions implemented in traditional athlete samples (e.g. Van Ryswyk et al., 2017). Unsurprisingly, Bonnar et al. (2022) concluded that further research is required to develop more effective sleep interventions for esports athletes. Accordingly, they made several suggestions, including the development of a stepped-care model involving coaches and support staff, a better understanding of the risk factors for poor sleep in esports and using contextual learning. Thus, the broad purpose of the present study was to start exploring some of these suggestions (i.e. involving coaches and support staff and understanding risk factors for poor sleep) to determine their utility.

One suggestion by Bonnar et al. (2022) that warrants attention from researchers is that coaches and support staff could help support sleep health in esports. This idea was premised on the fact that in traditional sports, coaches and support staff can play a central role in promoting and implementing performance and health-related strategies for athletes (Miles et al., 2019; Van Hoye et al., 2016). From a sleep perspective, the optimal use of sleep monitoring and sleep hygiene practices is recommended for traditional athletes and is within the capacity of coaches and support staff to provide (Walsh et al., 2021). Miles et al. (2019) found in their study that, overall, participants (coaches and support staff) had adequate sleep hygiene (i.e. good sleep habits) knowledge, while sleep monitoring and implementation of sleep hygiene practices were low (56% and 43% respectively). Key barriers to the use of sleep monitoring and sleep hygiene practices were a lack of resources and knowledge. Based on these findings, the authors were able to suggest some pragmatic strategies to improve how coaches and support staff approach sleep health support for athletes. In esports, presumably some coaches and support staff are also attempting to support the sleep health of esports athletes using sleep monitoring and sleep hygiene practices. However, their current sleep hygiene knowledge, the frequency and methods of practices used, and barriers to these practices remain to be established. This information will give insight as to what additional sleep training and resources are required to provide maximum benefit for esports athletes.

Bonnar et al. (2022) also suggested that identifying and better understanding the risk factors associated with poor sleep in esports athletes will help improve the precision of sleep interventions, thereby making them more effective. In an early paper, a number of potential risk factors for suboptimal sleep in esports were initially proposed by Bonnar, Castine et al. (2019), including caffeine use, air travel, elevated arousal on pre-competition and competition nights, evening technology use combined with late training time, sleep disorders and performance-enhancing substances. In a subsequent review, game genre and gaming culture were also proposed (Bonnar, Lee et al., 2019). Over time, evidence has emerged in support of some of these (e.g. late training time) or been found lacking (e.g. caffeine use), while others are yet to be investigated (e.g. game genre). Overall, current evidence on the risk factors for poor sleep in esports is limited but slowly expanding, highlighting the need for further research in this area. Notably, research to date has focused on the experience of esports athletes directly. However, there may be value in also obtaining additional information from individuals who regularly interact with esports athletes, as has been done with traditional athletes (Miles et al., 2019). For example, coaches and support staff are likely able to provide a unique and, as of yet, untapped perspective on the sleep-related challenges experienced by esports athletes. Given the comprehensive understanding they have of training and competition conditions, their view on these areas may be particularly valuable.

The present study aimed to evaluate the sleep hygiene knowledge of esports coaches and support staff, the sleep monitoring and sleep hygiene practices they use with esports athletes, barriers to the use of these practices and conditions that affect the sleep of esports athletes. As a secondary aim, we also sought to determine whether these outcomes differed based on the level of esports athletes worked with (i.e. professional v. semi-professional). Addressing these aims will help guide how coaches and support staff can be better equipped with knowledge and skills to support the sleep health of esports athletes at all professional levels, which in turn, may begin to inform how coaches and support staff could fit into future models of care. Currently, research on coaches and support staff in esports is extremely limited, and to the best of our knowledge, this is the first study to involve coaches and support staff in a sleep and esports study.

## 5.3 Method

### 5.3.1 Participants

Participants were 48 coaches and 36 support staff from 19 countries (see Table 5.1 for sample characteristics based on job role and the professional level of esports athletes worked with). Countries included the US ($N = 36$), Australia ($N = 17$), Korea ($N = 5$), Canada ($N = 5$), Belgium ($N = 3$), Malaysia ($N = 2$), New Zealand ($N = 2$), Germany ($N = 2$), United Kingdom ($N = 2$), Croatia ($N = 1$), Hong Kong ($N = 1$), Singapore ($N = 2$), Lebanon ($N = 1$), France ($N = 1$), Austria ($N = 1$), Czech Republic ($N = 1$), Argentina ($N = 1$), India ($N = 1$) and South America country not specified ($N = 1$). Overall, most participants were male, with a significant difference between coaches and support staff (i.e. all coaches were male; $\chi^2 = 11.79$, $p = .001$). The mean age of the sample was 29.0 years ($SD = 7.8$; range = 19–65 years), with support staff being significantly older than coaches, $t(82) = -2.9$, $p = .006$, but no difference based on professional level. The average length of time in a role was relatively short (i.e. ~2 years), with no difference found based on job role or professional level. The most common game genre within which participants worked was shooter, followed by massive online battle arena, sports and fighting genres. There was no difference between game genre worked in based on job role, but more participants worked with professional shooter esports athletes than semi-professionals ($\chi^2 = 6.13$, $p = .01$). Most participants worked with male esports athletes, with no difference found based on job role or professional level. Overall education levels were high, with approximately half of participants reporting undergraduate degrees and one-third reporting postgraduate degrees. Support staff were more likely to have higher levels of education compared with coaches ($\chi^2$ = 1,357, $p$ = .001), while there was no difference in education based on professional level. Only a very small number of participants had a coaching qualification, with no difference based on job role or professional level. Furthermore, no coaching qualification was esports-specific. In terms of employment status, there was no difference based on job role. However, there was a significant difference for professional level ($\chi^2$ = 19.01, $p$ = .001), where participants working in professional settings were more likely to be employed full-time, and participants working in semi-professional settings were more likely to be part-time. Ethics approval was obtained from the Flinders University Social and Behavioural Research Ethics Committee (project number 8408).

**Table 5.1**

*Sample Characteristics by Job Role and Professional Level*

| | | Job role | | | Professional level | | |
|---|---|---|---|---|---|---|---|
| | Overall<br>*N* = 84 | Coach<br>*N* = 48 | Support staff<br>*N* = 36 | t/$\chi^2$/Fisher's/*U*<br>*(p)* | Pro<br>*N* = 55 | Semi-pro<br>*N* = 29 | t/$\chi^2$/Fisher's/*U*<br>*(p)* |
| Male sex (%) | 76 (90.5%) | 48 (100%) | 28 (77.8%) | 11.79 (.001)* | 52 (94.5%) | 24 (82.8%) | 3.06 (.08) |
| Age (years) | 29.0 (7.8) | 26.7 (3.8) | 31.9 (10.3) | −2.90 (.006)* | 30.3 (8.3) | 26.6 (6.2) | 2.11 (.04) |
| Years in role | 2.3 (2.1) | 2.5 (2.2) | 1.9 (2.1) | 1.08 (.28) | 2.3 (2.3) | 2.2 (1.8) | 0.15 (.88) |
| Game genre worked with | | | | | | | |
| *Sports* | 16 (20.3%) | 10 (21.3%) | 6 (18.8%) | 0.08 (.78) | 11 (20.8%) | 5 (19.2%) | 0.03 (.87) |
| *Shooter* | 43 (54.4%) | 21 (44.7%) | 22 (68.8%) | 4.45 (.03) | 34 (64.2%) | 9 (34.6%) | 6.13 (.01)* |
| *MOBA* | 34 (43.0%) | 19 (40.4%) | 15 (46.9%) | 0.32 (.57) | 19 (35.8%) | 15 (57.7%) | 3.39 (.06) |
| *Fighting games* | 5 (6.3%) | 1 (2.1%) | 4 (12.5%) | Fisher's Exact Test (0.15) | 4 (7.5%) | 1 (3.8%) | Fisher's Exact Test (1.0) |
| Sex of players worked with (% male only) | 61 (72.6%) | 38 (79.2%) | 23 (63.9%) | 9.97 (.04) | 43 (78.2%) | 18 (62.1%) | 11.28 (.02) |
| Employment status | | | | 1.75 (.04) | | | 19.01 (< .001)* |
| *Full-time* | 42 (50%) | 27 (56.3%) | 15 (41.7%) | | 37 (67.3%) | 5 (17.2%) | |
| *Part-time* | 42 (50%) | 21 (43.8%) | 21 (58.3%) | | 18 (32.7%) | 24 (82.8%) | |
| Education | | | | 1,357 (< .001)* | | | 830 (.74) |
| *High school* | 16 (19.0%) | 14 (29.2%) | 2 (5.6%) | | 10 (18.2%) | 6 (20.7%) | |
| *Undergraduate* | 43 (51.2%) | 30 (62.5%) | 13 (36.1%) | | 30 (54.5%) | 13 (44.8%) | |
| *Postgraduate* | 25 (29.8%) | 4 (8.3%) | 21 (58.3%) | | 15 (27.3%) | 10 (34.5%) | |
| Coaching qualification (% acquired) | 6 (7.1%) | 4 (8.3%) | 2 (5.6%) | Fisher's Exact Test (0.70) | 6 (10.9%) | 0.0 (0.0%) | Fisher's Exact Test (0.09) |

*Note.* Data are provided as M(SD) for continuous outcomes (i.e. age and years in role) and *n* (%) for all remaining categorical outcomes.

*Indicates significant *p*-value ($p = \leq .01$).

### 5.3.2 Eligibility Criteria

Participants were eligible for inclusion in the study if they coached or played a role in supporting the health and performance of esports athletes (i.e. team manager or owner, psychologist/mental health worker, physical therapist, dietician, chiropractor, health/performance advisor) at a professional or semi-professional level. Participants had to be actively engaged with an esports organisation, although the team did not have to be competing in season at the time of data collection. There were no exclusion criteria.

### 5.3.3 Measures

A questionnaire developed by Miles et al. (2019) for coaches and support staff in traditional sports was adapted (i.e. the term 'athletes' was replaced with 'esports athletes') for the present study. The questionnaire had three sections. The first section of the questionnaire collected demographic information about participants. This included country of origin, age, sex, occupation within esports, employment status, length of time in their role, characteristics of esports athletes with whom they worked (sex, game genre and professional level), highest coaching level and the highest level of academic education.

The second section of the questionnaire evaluated sleep hygiene knowledge using the Sleep Beliefs Scale (SBS; Adan et al., 2006). The SBS is a 20-item scale that evaluates knowledge of sleep hygiene practices and their effect on sleep in general. Participants responded to items (e.g. 'drinking alcohol in the evening') by indicating whether they had a 'positive effect', 'negative effect' or 'neither effect.' Items 5, 9, 15 and 19 corresponded to a positive effect, with the remaining items having a negative effect. Correct responses were scored 1, and incorrect responses scored 0. Individual item scores were summed to generate a total score (range from 0 to 20). Higher total scores indicated greater sleep hygiene knowledge. In addition, separate factor scores relating to discrete areas of sleep knowledge were also generated. Factors included sleep-incompatible behaviours (range from 0 to 8), sleep-wake cycle behaviours (range from 0 to 7) and thoughts and attitudes towards sleep (range from 0 to 5). Consistent with Miles et al. (2019), SBS total and factor scores ≥ 75% were defined as adequate, while scores < 75% were considered inadequate.

The third section of the questionnaire collected information on the sleep monitoring and sleep hygiene practices used by coaches and support staff with esports athletes, barriers to the use of these practices and conditions that affect the sleep of esports athletes. Regarding sleep monitoring practices, participants were asked to respond 'yes' or 'no' as to whether they monitored the sleep of their esports athletes. If a participant responded 'yes', they were instructed to complete a closed-answer response format consisting of multiple-choice answers. Options included 'self-reported sleep diaries', 'wrist activity monitors (actigraphy)', 'sleep questionnaires', 'testing for morning larks or night owls' or 'other'. If participants selected 'other', they were required to specify the method used. Participants could select multiple options. These options reflect the most common sleep monitoring practices in the sports science literature owing to their affordability, accessibility and ease of use (Walsh et al., 2021), while the 'other' option allowed participants to describe alternative methods.

With respect to sleep hygiene practices, participants were again asked to respond 'yes' or 'no' as to whether they implemented sleep hygiene practices with their esports athletes. If a participant responded 'yes', they were instructed to complete a closed-answer response format consisting of multiple-choice answers. Options included 'establishing a regular sleep/wake routine', 'short naps (< 2 hours) during the day if required', 'no hard exercise within 1 hour before bedtime', 'no alcohol or caffeinated beverages within 4 hours of bedtime', 'not using the bed for things other than sleeping or sex', 'creating a cool, dark and quiet bedroom', 'reducing thinking, planning or worrying in bed' and 'other'. If participants selected 'other', they were required to specify the sleep hygiene practice used. Participants could select multiple options. These options represent established sleep hygiene practices that are based on the sleep hygiene index (Mastin et al., 2006), while the 'other' option allowed participants to describe alternative methods.

The two questions relating to sleep monitoring and sleep hygiene barriers were answered with a closed-answer response format, in which participants could select multiple options. Options for both questions were the same and included 'too busy', 'lack of resources (e.g. financial, equipment)', 'lack of knowledge', 'players do not like it', 'do not think it is important', 'no barriers' and 'other'. These response options reflect those from Miles et al. (2019).

The question relating to conditions that affect the sleep of esports athletes was also answered with a closed-answer response format, in which participants could select multiple options. Options included 'morning training schedules', 'night training schedules', 'night competitions', 'congested competition times', 'these situations are commonly experienced, but I do not think they affect sleep', 'none of these situations are commonly experienced and therefore do not affect sleep' and 'other'. These options were selected as they tap into the potential impact of training and competition conditions on esports athletes, which has received minimal research attention to date. It should be noted that because data collection occurred before and during COVID, the closed answer response relating to domestic travel was removed.

### 5.3.4 Procedure

Data were collected between July 2019 and October 2021. As Twitter is a popular social platform for members of the esports industry, a Twitter post was created and shared with an attached link to the online questionnaire administered via Qualtrics. Coaches and support staff working with esports athletes were asked to respond. As the post was shared and retweeted, it is impossible to know how many coaches and support staff received information about the study relative to how many responded. Eight participants who took part in another sleep and esports study by our research group also completed the questionnaire.

### 5.3.5 Data Analysis

SPSS (version 26.0) was used for all data analyses. Descriptive statistics, including frequencies, means and *SD*s, were used to summarise sample characteristics. For job role (coach v. support staff) and professional level (professional v. semi-professional) comparisons, *t* tests were computed for continuous outcomes (i.e. age and years in role), and chi-square tests were computed for categorical variables (i.e. sex, game genre, sex of esports athletes and employment status). Fisher's exact test was used when cell counts were $\leq 5$ (i.e. coaching qualification and fighting game genre) and the Mann–Whitney test was performed for ordinal outcomes (i.e. education). In terms of primary outcome variables, analyses of variance (adjusting for education level) were used for the SBS with means and *SD*s reported. Furthermore, frequencies were reported for all other outcome variables (i.e. sleep monitoring and sleep hygiene practices, barriers to the use of these practices, and conditions that affect the sleep of esports athletes) with chi-square and Fisher exact test (used when cell counts were $\leq 5$) used. A significance level of .01 was used for all analyses. Please note that qualitative responses related to the closed answer response 'other' were not formally analysed or reported, as a large portion of the responses were either missing or uninterpretable. Hence, only the frequency of 'other' being selected is reported.

## 5.4 Results

### 5.4.1 Sleep Hygiene Knowledge

No significant differences were found for sleep hygiene knowledge as assessed by the SBS based on job role, $F(1, 81) = 0.03$, $p = .86$, or professional level, $F(1, 81) = 0.00$, $p = .99$ (see Table 5.2). Based on the cut-off of 75% (Miles et al., 2019), overall participant sleep hygiene knowledge was inadequate. However, support staff had adequate sleep hygiene knowledge, while coaches did not. More specifically, coaches had inadequate sleep hygiene knowledge on all SBS factors (i.e. sleep-incompatible behaviours, sleep-wake cycle behaviours and thoughts and attitudes toward sleep), while support staff had inadequate sleep hygiene knowledge on the SBS factor thoughts and attitudes toward sleep.

**Table 5.2**

*Sleep Hygiene Knowledge as Assessed by the Sleep Beliefs Scale*

| | | Job role | | F (p) | Professional level | | F (p) |
|---|---|---|---|---|---|---|---|
| | Overall | Coach | Support staff | | Pro | Semi-pro | |
| | M(SD) | M(SD) | M(SD) | | M(SD) | M(SD) | |
| Total score | 14.(3.3) | 13.9(3.7) | 15.5(2.4) | 0.03 (.86) | 14.5(3.0) | 14.7(3.9) | 0.00 (.99) |
| *Sleep-incompatible behaviours* | 6.1(1.6) | 5.7(1.8) | 6.5(1.1) | 1.62 (.21) | 6.0(1.5) | 6.1(1.8) | 0.001 (.97) |
| *Sleep-wake cycle behaviours* | 5.1(1.6) | 4.9(1.8) | 5.4(1.3) | 0.65 (.42) | 5.2(1.6) | 5.1(1.6) | 0.14 (.71) |
| *Thoughts and attitudes about sleep* | 3.4(1.2) | 3.2(1.2) | 3.6(1.1) | 0.04 (.84) | 3.3(1.2) | 3.5(1.2) | 0.29 (.59) |

*Note*. The SBS generates a total score (range from 0 to 20) and scores for individual factors, including sleep-incompatible behaviours (range 0–8), sleep-wake cycle behaviours (range 0–7) and thoughts and attitudes to sleep (range 0–5). Consistent with Miles et al. (2019), SBS total and factor scores ≥ 75% were defined as adequate, while scores < 75% were considered inadequate.

### 5.4.2 Sleep Monitoring Practices

No significant differences were found for sleep monitoring frequency based on job role ($\chi^2 = 2.29$, $p = .13$) or professional level ($\chi^2 = 0.15$, $p = .70$). The primary sleep monitoring method used by participants (see Table 5.3) was self-reported sleep diaries, followed by 'other,' testing for morning larks or night owls, sleep questionnaires, and wrist activity monitors (Actigraphy). No differences were found between the types of sleep monitoring methods used by participants based on job role or professional level.

**Table 5.3**

*Sleep Monitoring Frequency and Practices by Job Role and Professional Level*

| | | Job role | | $\chi^2$/Fisher's *(p)* | Professional level | | $\chi^2$/Fisher's *(p)* |
|---|---|---|---|---|---|---|---|
| | Overall | Coach | Support staff | | Pro | Semi-pro | |
| Do you monitor the sleep of the esports athletes you support? (% yes) | 41 (48.8%) | 20 (41.7%) | 21 (58.3%) | 2.29 (.13) | 26 (47.3%) | 15 (51.7%) | 0.15 (.70) |
| *Self-reported sleep diaries* | 21 (52.5%) | 9 (45.0%) | 12 (60.0%) | 0.90 (.34) | 13 (52.0%) | 8 (53.3%) | 0.01 (.94) |
| *Activity wrist monitors (actigraphy)* | 4 (10.0%) | 2 (10.0%) | 2 (10.0%) | Fisher's Exact Test (1.00) | 2 (8.0%) | 2 (13.3%) | Fisher's Exact Test (0.62) |
| *Sleep questionnaire* | 7 (17.5%) | 2 (10.0%) | 5 (25.0%) | Fisher's Exact Test (0.41) | 4 (16.0%) | 3 (20.0%) | Fisher's Exact Test (1.00) |
| *Testing for 'morning larks' or 'night owls'* | 9 (22.5%) | 5 (25.0%) | 4 (20.0%) | Fisher's Exact Test (1.00) | 5 (20.0%) | 4 (26.7%) | Fisher's Exact Test (0.71) |
| *Other* | 14 (35.0%) | 8 (40.0%) | 6 (30.0%) | 0.44 (0.51) | 11 (44.0%) | 3 (20.0%) | Fisher's Exact Test (0.18) |

*Note.* *Indicates significant *p*-value ($p = \leq .01$).

### 5.4.3 Sleep Hygiene Practices

No significant differences were found for sleep hygiene implementation frequency based on job role ($\chi^2 = 5.47$, $p = .02$) or professional level ($\chi^2 = 0.66$, $p = .42$). The primary sleep hygiene practices used by participants were establishing a regular sleep/wake routine, followed by creating a cool, dark and quiet bedroom, reducing thinking, planning or worrying in bed, no alcohol or caffeinated beverages within 4 hours of bedtime, not using the bed for things other than sleep or sex, no hard exercise within 1 hour of bedtime, short naps (< 2 hours) during the day if required and 'other' (see Table 5.4). As for differences between groups, significantly more support staff than coaches suggested no hard exercise within 1 hour before bedtime ($\chi^2 = 7.00$, $p = .008$); not using the bed for things other than sleep and sex ($\chi^2 = 6.32$, $p = .01$); and creating a cool, dark and quiet bedroom to facilitate sleep ($\chi^2 = 7.25$, $p = .007$). No other differences were found between coaches and support staff or as a function of professional level.

**Table 5.4**

*Sleep Hygiene Administration Frequency and Practices by Job Role and Professional Level*

| | | Job role | | $\chi^2$/Fisher's *(p)* | Professional level | | $\chi^2$/Fisher's *(p)* |
|---|---|---|---|---|---|---|---|
| | Overall | Coach | Support staff | | Pro | Semi-pro | |
| Do you implement sleep hygiene practices with your esports athletes? (% yes) | 56 (66.7%) | 27 (56.3%) | 29 (80.6%) | 5.47 (.02) | 35 (63.6%) | 21 (72.4%) | 0.66 (.42) |
| *Establishing a regular sleep/wake routine* | 53 (93.0%) | 24 (88.9%) | 29 (96.7%) | 1.32 (.25) | 34 (94.4%) | 19 (90.5%) | 0.32 (.57) |
| *Short naps (< 2 hrs) during the day if required* | 16 (28.1%) | 6 (22.2%) | 10 (33.3%) | 0.87 (.35) | 12 (33.3%) | 4 (19.0%) | Fisher's Exact Test (0.36) |
| *No hard exercise within 1 hr before bedtime* | 23 (40.4%) | 6 (22.2%) | 17 (56.7%) | 7.00 (.008)* | 13 (36.1%) | 10 (47.6%) | 0.73 (.39) |
| *No alcohol or caffeinated beverages within 4 hrs of bedtime* | 35 (61.4%) | 14 (51.9%) | 21 (70.0%) | 1.97 (.16) | 20 (55.6%) | 15 (71.4%) | 1.41 (.23) |
| *Not using the bed for things other than sleeping or sex* | 29 (50.9%) | 9 (33.3%) | 20 (66.7%) | 6.32 (.01)* | 19 (52.8%) | 10 (47.6%) | 0.14 (.71) |
| *Creating a cool, dark and quiet bedroom* | 43 (75.4%) | 16 (59.3%) | 27 (90.0%) | 7.25 (.007)* | 28 (77.8%) | 15 (71.4%) | 0.29 (.59) |
| *Reducing thinking, planning or worrying in bed* | 38 (66.7%) | 15 (55.6%) | 23 (76.7%) | 2.85 (.09) | 24 (66.7%) | 14 (66.7%) | 0.0 (1.00) |
| *Other* | 7 (12.3%) | 4 (14.8%) | 3 (10.0%) | Fisher's Exact Test (0.69) | 4 (11.1%) | 3 (14.3%) | Fisher's Exact Test (0.70) |

*Note.* * indicates significant *p*-value ($p = \leq .01$).

### 5.4.4 Barriers to Sleep Monitoring Practices

Overall, the highest rated response for barriers to sleep monitoring was players not liking it, followed by lack of resources, lack of knowledge, too busy, do not think it is important, 'other' and no barriers (see Table 5.5). Significantly more participants working with semi-professional esports athletes than those working with professional esports athletes rated do not think it is important ($\chi^2 = 7.56$, $p = .006$). No other differences were found based on job role or professional level.

### 5.4.5 Barriers to Sleep Hygiene Practices

Overall, the highest rated response for barriers to sleep hygiene practices was players not liking it, followed by lack of knowledge, lack of resources, 'other', too busy, do not think it is important and no barriers (see Table 5.5). Significantly more support staff than coaches rated players not liking it ($\chi^2 = 6.90$, $p = .009$). No other differences were found based on job role or professional level.

**Table 5.5**

*Barriers to Sleep Monitoring and Sleep Hygiene Practices*

| | | Job role | | $\chi^2$/Fisher's *(p)* | Professional level | | $\chi^2$/Fisher's *(p)* |
|---|---|---|---|---|---|---|---|
| | Overall | Coach | Support staff | | Pro | Semi-pro | |
| Sleep monitoring practices | | | | | | | |
| *Too busy* | 20 (25.0%) | 11 (24.4%) | 9 (25.7%) | 0.02 (.90) | 14 (27.5%) | 6 (20.7%) | 0.45 (.50) |
| *Lack of resources (e.g. financial, equipment)* | 34 (42.5%) | 18 (40.0%) | 16 (45.7%) | 0.26 (.61) | 23 (45.1%) | 11 (37.9%) | 0.39 (.53) |
| *Lack of knowledge* | 27 (33.8%) | 18 (40.0%) | 9 (25.7%) | 1.80 (.18) | 18 (35.3%) | 9 (31.0%) | 0.15 (.70) |
| *Players do not like it* | 40 (50.0%) | 21 (46.7%) | 19 (54.3%) | 0.46 (.50) | 24 (47.1%) | 16 (55.2%) | 0.49 (.48) |
| *Do not think it is important* | 17 (21.3%) | 9 (20.0%) | 8 (22.9%) | 0.10 (.76) | 6 (11.8%) | 11 (37.9%) | 7.56 (.006)* |
| *No barriers* | 9 (11.3%) | 4 (8.9%) | 5 (14.3%) | Fisher's Exact Test (0.49) | 5 (9.8%) | 4 (13.8%) | Fisher's Exact Test (0.72) |
| *Other* | 14 (17.5%) | 7 (15.6%) | 7 (20.0%) | 0.27 (.60) | 10 (19.6%) | 4 (13.8%) | Fisher's Exact Test (0.76) |
| Sleep hygiene practices | | | | | | | |
| *Too busy* | 15 (18.8%) | 9 (20.0%) | 6 (17.1%) | 0.11 (.75) | 10 (19.6%) | 5 (17.2%) | Fisher's Exact Test (1.00) |
| *Lack of resources (e.g. financial, equipment)* | 25 (31.3%) | 12 (26.7%) | 13 (37.1%) | 1.01 (.32) | 14 (27.5%) | 11 (37.9%) | 0.94 (.33) |
| *Lack of knowledge* | 32 (40.0%) | 19 (42.2%) | 13 (37.1%) | 0.21 (.64) | 22 (43.1%) | 10 (34.5%) | 0.58 (.45) |
| *Players do not like it* | 37 (46.3%) | 15 (33.3%) | 22 (62.9%) | 6.90 (.009)* | 21 (41.2%) | 16 (55.2%) | 1.46 (.23) |
| *Do not think it is important* | 14 (17.5%) | 9 (20.0%) | 5 (14.3%) | Fisher's Exact Test (0.57) | 5 (9.8%) | 9 (31.0%) | Fisher's Exact Test (0.03) |
| *No barriers* | 13 (16.3%) | 8 (17.8%) | 5 (14.3%) | Fisher's Exact Test (0.77) | 9 (17.6%) | 4 (13.8%) | Fisher's Exact Test (0.76) |
| *Other* | 16 (20.0%) | 9 (20.0%) | 7 (20.0%) | 0.00 (1.00) | 11 (21.6%) | 5 (17.2%) | Fisher's Exact Test (0.77) |

*Note.* *Indicates significant *p*-value ($p = \leq .01$).

### 5.4.6 Conditions Impacting Sleep

The highest rated condition by participants that affects the sleep of esports athletes was night competitions, followed by congested competition times, night training schedules, morning training schedules, and ‘other’ (see Table 5.6). Only a small number of participants reported that these conditions were commonly experienced but did not affect sleep. Fewer still indicated that none of these conditions were commonly experienced and, therefore, did not affect sleep. In terms of differences between groups, significantly more support staff than coaches rated night competitions ($\chi^2 = 6.31$, $p = .01$), congested competition times ($\chi^2 = 7.36$, $p = .007$) and night training schedules ($\chi^2 = 10.81$, $p = .001$) as having an impact. No other differences were found based on job role or professional level.

**Table 5.6**

*Conditions that Affect the Sleep of Esports Athletes*

| | | Job role | | $\chi^2$/Fisher's *(p)* | Professional level | | $\chi^2$/Fisher's *(p)* |
|---|---|---|---|---|---|---|---|
| | Overall | Coach | Support staff | | Pro | Semi-pro | |
| *Morning training schedules* | 21 (25.6%) | 10 (21.3%) | 11 (31.4%) | 1.08 (.30) | 14 (26.4%) | 7 (24.1%) | 0.05 (.82) |
| *Night training schedules* | 39 (47.6%) | 15 (31.9%) | 24 (68.6%) | 10.81 (.001)* | 21 (39.6%) | 18 (62.1%) | 3.79 (.06) |
| *Night competitions* | 53 (64.6%) | 25 (53.2%) | 28 (80.0%) | 6.31 (.01)* | 30 (56.6%) | 23 (79.3%) | 4.23 (.04) |
| *Congested competition times* | 42 (51.2%) | 18 (38.3%) | 24 (68.6%) | 7.36 (.007)* | 25 (47.2%) | 17 (58.6%) | 0.98 (.32) |
| *These situations are commonly experienced, but I do not think they affect sleep* | 7 (8.5%) | 7 (14.9%) | 0 (0.0%) | Fisher's Exact Test (0.02) | 6 (11.3%) | 1 (3.4%) | Fisher's Exact Test (0.41) |
| *None of these situations are commonly experienced and therefore do not affect sleep* | 4 (4.9%) | 4 (8.5%) | 0 (0.0%) | Fisher's Exact Test (0.13) | 4 (7.5%) | 0 (0.0%) | Fisher's Exact Test (0.29) |
| *Other* | 11 (13.4%) | 6 (12.8%) | 5 (14.3%) | Fisher's Exact Test (1.00) | 8 (15.1%) | 3 (10.3%) | Fisher's Exact Test (0.74) |

*Note.* *Indicates significant *p*-value ($p = \leq .01$).

## 5.5 Discussion

Coaches and support staff are critical to the functioning of an esports team, including the provision of performance and health-related advice. In the present study, we evaluated the sleep hygiene knowledge of esports coaches and support staff, the sleep monitoring and sleep hygiene practices they use with esports athletes, barriers to the use of these practices, and conditions that affect the sleep of esports athletes. As a secondary aim, we also sought to determine whether these outcomes differed based on the level of esports athletes worked with (i.e. professional v. semi-professional). Results indicated that overall sleep hygiene knowledge was inadequate (i.e. < 75%; Miles et al., 2019), with support staff being the exception. Approximately half of the participants monitored the sleep of their esports athletes, with key barriers being players not liking it and lack of resources. Two-thirds of participants implemented sleep hygiene practices with their esports athletes, with key barriers being players not liking it and lack of knowledge. Notable conditions that affect the sleep of esports athletes are night competitions, congested competition times and night training schedules. Overall, there were few differences between coaches and support staff working with professional and semi-professional esports athletes. We now discuss emerging findings from our study and examine how coaches and support staff working across different professional levels can optimally support the sleep needs of esports athletes and how they might fit into future models of care.

### 5.5.1 Sleep Hygiene Knowledge

Overall, participant sleep hygiene knowledge was inadequate (i.e. < 75%; Miles et al., 2019). However, although there was no significant difference between coaches and support staff, support staff had adequate sleep hygiene knowledge (i.e. > 75%), while coaches did not. More specifically, coaches had inadequate sleep hygiene knowledge on all SBS factors (i.e. sleep-incompatible behaviours, sleep-wake cycle behaviours, and thoughts and attitudes toward sleep), while support staff had inadequate sleep hygiene knowledge on SBS factor thoughts and attitudes toward sleep. These findings are similar to those reported by Miles et al. (2019) in a sample of traditional sports coaches and support staff. They found overall adequate sleep hygiene knowledge, but as found in our study, support staff had adequate sleep hygiene knowledge, and coaches did not. One possible explanation for the finding of adequate sleep hygiene knowledge among support staff versus coaches in our study is the higher education levels among support staff and low qualification levels among coaches (see Table 5.1). That is, support staff may have greater pre-existing sleep knowledge attained through their education and training. In addition, support staff may be more effective consumers of health-related information owing to the academic literacy developed through their formal education.

Interestingly, the sleep hygiene knowledge of those working with professional esports athletes was no different to those working with semi-professionals, with both having inadequate sleep hygiene knowledge. Thus, in summary, sleep hygiene education (and presumably sleep health education more broadly) may be required for coaches and, to a lesser degree, support staff across all professional levels. As coaches and support staff are the main conduit of health information to esports athletes, enhancing their knowledge may, in turn, improve the accuracy and quality of information provided to esports athletes.

### 5.5.2 Sleep Monitoring Practices and Barriers

Sleep monitoring is essential to understanding and supporting sleep health (Halson, 2019). Overall, approximately half (48.8%) of participants monitored the sleep of their esports athletes, with no significant difference found between coaches and support staff or the professional level of esports athletes. This rate of sleep monitoring is low and indicates that many esports athletes are operating within team environments, including at a professional level, with no available information available regarding their sleep health. Without this information, coaches and support staff would be unaware that sleep may be a crucial factor in explaining when an esports athlete is underperforming, experiencing mental health issues or when there is a need to refer to specialist services (e.g. a clinical psychologist for insomnia treatment). Furthermore, the sleep monitoring frequency (48.8%) in our study is approximately 8% lower than that reported by Miles et al. (2019), suggesting that sleep monitoring may occur more often in traditional sports settings than in esports.

Regarding the types of sleep monitoring practices used, there were no significant differences between coaches and support staff or professional level. Self-reported sleep diaries were the most popular sleep measure used, which is most likely owing to them being accessible, simple, and cost effective (Walsh et al., 2021). The second highest rated response was ‘other.’ Although we are unable to determine what ‘other’ entails, this finding indicates that some participants are using alternative sleep monitoring methods to those specified in our study. Surprisingly, only a small proportion of participants reported using wrist activity monitors despite their relative affordability and widespread use among the public (Walsh et al., 2021). The use of sleep questionnaires and chronotype testing was also low, which limits additional information (e.g. subjective sleepiness and fatigue levels) that can help clarify overall sleep health. Together, these findings suggest that the specificity and scope of sleep information gathered could be improved.

The two main barriers to the more frequent use of sleep monitoring practices were esports athletes not liking it and lack of resources, while significantly more participants working in semi-professional settings considered sleep monitoring unimportant. Although we cannot specifically determine why esports athletes do not like sleep monitoring, one explanation may be the strong reliance on sleep diaries, which have a moderate subject burden (Walsh et al., 2021). Hence, validated wearables (e.g. wrist activity monitors) may be more accepted by esports athletes, given their lower subject burden (Walsh et al., 2021). In addition, nearables (i.e. non-contact sleep trackers) are another alternative, which has an even lower subject burden than wearables. Nearables were not included as an option in this study as, at the time, they lacked sufficient validation. However, evidence has recently emerged in support of some nearable devices (Chinoy et al., 2021). With respect to the lack of resources, our results indicate that coaches and support staff may be unaware of or unable to locate existing sleep monitoring resources (e.g. questionnaires). Hence, education to enhance awareness, use and accessibility of sleep monitoring resources may improve both the frequency and effectiveness of sleep monitoring in esports.

### 5.5.3 Sleep Hygiene Practices and Barriers

Sleep hygiene practices are a relatively easy method for coaches and support staff to assist esports athletes in optimising sleep outcomes for nonclinical sleep problems at all professional levels. Overall, two-thirds (66.7%) of coaches and support staff implemented sleep hygiene practices with esports athletes, which is approximately 20% more than that reported by Miles et al. (2019). There was no significant difference found between coaches and support staff or professional level worked with. It is promising that so many participants indicated trying to help esports athletes improve their sleep via sleep hygiene practices. However, the low sleep monitoring rates relative to sleep hygiene implementation suggests that recommendations made to esports athletes may often be generic rather than targeted and data-informed, potentially limiting their effectiveness (Driller et al., 2019).

With respect to the types of sleep hygiene practices used, the most common overall strategy promoted by participants was establishing a regular sleep/wake routine. Attempts at regularising sleep schedules are pertinent as previous evidence from our group shows some esports athletes have irregular sleep scheduling (i.e. sleep onset/wake-up times), leading to reduced sleep duration (Lee et al., 2021). Other popular practices endorsed by most participants were creating a cool, dark and quiet bedroom, reducing thinking, planning or worrying in bed, and having no caffeine or alcohol within 4 hours of bedtime. In contrast, not using the bed for things other than sleep or sex, short naps (< 2 hours) if required, and 'other' were rated much lower. It should be noted that the frequency of sleep hygiene implementation, which was not assessed in the current study, may be important, given that findings show single-dose sleep hygiene sessions have limited benefits (Miles et al., 2019).

The two main barriers to more frequent implementation of sleep hygiene practices were esports athletes not liking it and lack of knowledge, with significantly more support staff than coaches rating esports athletes not liking it. The fact that esports athletes do not like to work on improving their sleep is unsurprising. Esports athletes are typically young (mean = 20 years; Bonnar et al., 2022), and the broader sleep literature shows that young people can be apathetic to sleep behaviour change (Micic et al., 2019). Borrowing from other group-based sleep intervention research involving young people, designing sleep interventions to be interactive and motivating can aid engagement (Bonnar et al., 2015). Furthermore, esports athletes may be more inclined to comply with proposed sleep hygiene practices if they appear relevant and personalised. Regarding lack of knowledge, education and improved sleep hygiene knowledge should increase coaches' and support staff's confidence in the use of sleep hygiene practices.

### 5.5.4 Conditions Impacting the Sleep of Esports Athletes

A large proportion of esports coaches and support staff working in both semi-professional and professional settings indicated that night competitions, congested competition times and night training schedules negatively affect the sleep of esports athletes. The impact of night training schedules has been documented previously by our group (Lee et al., 2021). We found that night training schedules can delay esports athletes' sleep patterns, resulting in reduced sleep duration if daytime commitments necessitate an earlier than desired wake-up time (Lee et al., 2021). In addition, it has previously been proposed that evening light exposure could affect the sleep of esports athletes (Bonnar, Castine et al., 2019), which was based on concerns in the general sleep literature that late-night exposure to light emitted by screens can delay sleep onset via the suppression of melatonin (Wong & Bahmani, 2022). However, with many contrary findings reported over time, the current body of evidence is equivocal, and whether device use translates to disturbed sleep is contentious (Wong & Bahmani, 2022). For example, in the sports science literature, meta-analytic evidence indicates no impact of electronic device use on the sleep of traditional athletes and no sleep benefits when devices are removed from the bedroom (Roberts et al., 2019). In saying that, it remains to be tested whether light exposure has an impact on sleep outcomes in more extreme tech users like esports athletes.

The influence of night competitions is even less well understood than night training schedules but was rated higher by participants, indicating a different type of impact even though both occur at night. The sports science literature and meta-analytic evidence suggest that traditional athletes often have short TST on the night of competition compared with pre-competition nights, which is primarily owing to a delay in bedtime and subsequently reduced sleep opportunities (Roberts et al., 2019). A delay in bedtime has been attributed to a range of post-competition factors, including muscle soreness, increased circulating cortisol, sympathetic hyperactivity, and lingering high caffeine levels (Roberts et al., 2019). Whether these same factors apply to esports is yet to be examined, although some may be less relevant (e.g. muscle soreness) to esports than others. For example, considering findings of high stress levels among esports athletes (Leis & Lautenbach, 2020), it is plausible that, like traditional athletes, sympathetic hyperactivity could induce increased arousal levels postmatch (e.g. excitement, anxiety and alertness) and interfere with sleep.

This is the first study to highlight the impact of congested competition times on the sleep of esports athletes. Further research is therefore required to investigate the exact cause of this impact. Similar to night competitions, evidence from the sports science literature indicates that congested competition times can lead to short TST via reduced sleep opportunity, which is owing to factors such as sustained competition anticipation, travel, and simply being busy (Fullagar et al., 2015; Saidi et al., 2022). Once again, some of these factors would likely apply to esports. However, other factors may be unique to esports. For example, unlike traditional sports, which have training constraints owing to the need for physical recovery, esports athletes often ‘grind’ (i.e. train for long hours) after matches (Abbott et al., 2022). Based on anecdotal evidence, one explanation for the impact of congested competition times on sleep is that during multi-day tournaments, esports athletes may feel pressure to restrict their sleep opportunity and grind to prepare for their following matches (e.g. scrim, learn strategies and counter-strategies).

It is worth noting that support staff rated night competitions, congested competition times and night training schedules significantly higher than coaches. These differences suggest that support staff, more so than coaches, perceive a greater impact of these conditions on esports athletes’ sleep behaviour. Hence, support staff could be more attuned to the sleep health and needs of esports athletes.

### 5.5.5 Professional Versus Semi-professional

Overall, findings from the present study suggest few differences between coaches and support staff working in professional and semi-professional settings. Rather than being inconsequential, we believe this lack of difference is a noteworthy finding in and of itself. Research has yet to investigate whether sleep habits differ between professional and semi-professional esports athletes. However, it is plausible that professional and semi-professional esports athletes operate under different conditions (e.g. training/lifestyle and access to resources), which result in nuanced sleep needs and associated implications for sleep health support. Comparatively, research on this topic in traditional sports is limited, but preliminary evidence suggests differences in TST based on professional level exist in some sports (i.e. Rugby; Teece et al., 2022). In esports, the answer to this question will become clearer as more research is published, with findings from the present study acting as a starting point on which future studies can build.

**5.5.6 Clinical Implications**

Evidence from the present study suggests that some esports coaches and support staff in both professional and semi-professional settings are already taking an active role in managing the sleep health of esports athletes. With additional training and guidance, it is likely that coaches and support staff could aid esports athletes in addressing their sleep needs even more effectively. Specifically, coaches and, to a lesser extent, support staff need to be better educated about sleep hygiene. However, there may also be benefits in including broader sleep health education (e.g. the importance of sleep for physical and mental health and performance). Given indications that some coaches and support staff working in semi-professional settings are more likely to believe sleep monitoring is unimportant, sleep education might also help modify these types of unhelpful beliefs.

Sleep monitoring frequency needs to be increased, wrist activity monitors and nearables used where available to improve tolerability, and resources (e.g. questionnaires) made accessible so that a more comprehensive understanding of esports athletes' sleep health can be obtained. With the information collected via sleep monitoring, a needs-based assessment could be completed (which could include referring to specialist services). This assessment would enable coaches and support staff to provide more personalised sleep hygiene recommendations, which increases the likelihood of optimal outcomes, especially if reinforced over time and delivered in an engaging and interactive manner. Moreover, particular consideration may be required to mitigate the impact of night competitions, congested competition times and night training schedules. In addition, the specific role that coaches and support staff play in supporting the sleep health of esports athletes (e.g. support staff taking the lead with coaches providing ancillary support) is another factor that warrants consideration.

**5.5.7 Future Models of Care**

In light of findings from the present study, let us consider how coaches and support staff might fit into future models of care. As noted in the introduction, Bonnar et al. (2022) proposed a stepped-care model, which has gained traction in the sleep health field over recent years (Cheung et al., 2019), which might be appropriate for esports. In a seminal paper, Espie (2009) posited that stepped-care models must (a) provide benefits at the entry level, (b) efficiently use resources at each level and (c) be acceptable to the consumer. Coaches and support staff have a 'boots on the ground' presence, essentially making them an existing resource that could be leveraged and utilised. This point is accentuated by our results, which show that some coaches and support staff are already actively engaged in supporting the sleep health of esports athletes and with additional training, may be able to enhance their support further and provide greater sleep benefits. Furthermore, most sleep monitoring and hygiene practices are resource-efficient and minimally invasive. Taken together, coaches and support staff could potentially provide suitable entry-level sleep health support to esports athletes within a stepped-care model at both a professional and semi-professional level. However, although this idea may have merit, future research is required to investigate whether (and to what degree) sleep training for coaches and support staff translates into effective and meaningful sleep behaviour change for esports athletes. This will ultimately determine if coaches and support staff can deliver entry-level sleep health support to esports athletes.

### 5.5.8 Sleep Training Implementation

A notable industry-related challenge is the implementation of the sleep training itself (i.e. knowledge and practices) for coaches and support staff. In the short term, professional development is likely the most feasible option for existing coaches and support staff. However, it could be argued that this type of approach is a 'band-aid' solution and would only provide patchwork coverage across the industry. Contrastingly, as previously proposed by Pedraza-Ramirez et al. (2020), a potential long-term solution is the development of more systemic learning and educational pathways (which could incorporate sleep training) for coaches and support staff that possibly lead to qualifications. The same approach has been applied to some traditional sports in a bid to attempt to improve coaching knowledge and skills that ultimately benefit athletes (Smith et al., 2022).

In esports, the implementation of such a system would take time and likely require collaboration between researchers and key stakeholders such as game developers, leagues and esports organisations. However, the potential payoff for esports athletes in terms of health provision quality could be significant. It is worth highlighting that in our study (see Table 5.1), very few participants had any type of coaching qualification, and no participants had an esports coaching qualification. This finding corroborates those of Watson et al. (2022), who found that coach learning and education in esports is primarily informal and experiential. The reason for this is that there are currently no official esports coaching qualifications, although unofficial programs like that developed by the Esports Health and Performance Institute have recently become available (ehpi.org). In summary, the development of formal learning and educational pathways leading to qualifications may represent the best opportunity to systemically implement sleep training for coaches and support staff.

### 5.5.9 Limitations

There are some limitations worth noting. Participants largely worked with esports athletes from shooter and MOBA genres and, to a lesser degree, sports genre games (see Table 5.1). Moreover, only a small proportion worked with esports athletes from fighting genre games. Hence, findings from the present study are most representative of coaches and support staff who work within the shooter and MOBA genre specifically. Similarly, participants mostly worked with male esports athletes (see Table 5.1), which is consistent with the general discrepancy between male and female esports athlete participation levels. Therefore, like game genre, findings are most reflective of coaches and support staff who work with male esports athletes. Furthermore, although our sample was approximately equivalent to Miles et al. (2019), it was still relatively small, and a priori power analysis was not conducted owing to there being no prior studies involving coaches and support staff at the time. Lastly, the third section of the questionnaire included the response option 'other' and allowed qualitative answers. Unfortunately, this response option produced missing and largely uninterpretable data. Future research should use more robust qualitative study designs (i.e. formal interviews) to elicit better quality and more informative data.

## 5.6 Conclusion

This is the first study to evaluate the influence and perspective of coaches and support staff on the sleep behaviour of esports athletes competing at professional and semi-professional levels. Positively, it appears that some coaches and support staff are already trying to support the sleep health of esports athletes. Emerging findings from our results suggest that this support could be enhanced if coaches and support staff underwent sleep health education and used more frequent and comprehensive sleep monitoring practices while also providing more targeted sleep hygiene practices. Importantly, coaches and support staff need to be equipped with adequate knowledge and resources, while efforts to improve the experience of esports athletes engaging in sleep health-related practices appear critical to overcoming noncompliance. Overall, there is potential for coaches and support staff to provide entry-level support within a broader stepped-care model, although further research is required to investigate this idea. Notably, there were few differences found between coaches and support staff working in professional versus semi-professional settings. Finally, according to coaches and support staff, night competitions, congested competition times and night training schedules appear to have an impact on the sleep of esports athletes.

**5.6.1 Research Contribution: Key Points**

1. The overall sleep hygiene knowledge of coaches and support staff was inadequate, and sleep monitoring was low, but implementation of sleep hygiene practices was reasonable. There were minimal differences between those working in professional and semi-professional settings.
2. Sleep training is required to enhance the ability of coaches and support staff to optimally support the sleep health of esports athletes. Importantly, sleep resources need to be made available, and there should be a focus on making sleep health an engaging experience for esports athletes.
3. Further research is required to determine the effectiveness of sleep health support led by coaches and support staff. In the future, there may be potential for coaches and support staff to feature more formally within a stepped-care model, providing entry-level sleep health support.
4. Night competitions, night training schedules, and congested competition schedules were all rated highly by coaches and support staff as having an impact on the sleep of esports athletes. Further research is required to identify the mechanistic relationship between sleep and these risk factors.

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# Chapter 6: The Sleep, Anxiety, Mood, and Cognitive Performance of Oceanic Rocket League Esports Athletes Competing in a Multi-Day Regional Event

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## 6.1 Abstract

The overall aim of the present study was to examine the daily patterns and relationships between sleep behaviour, anxiety, mood (i.e. depression symptoms) and cognitive performance (i.e. reaction time) in esports athletes competing in an Oceanic Rocket League Championship Series regional event. Sixteen participants completed a daily sleep diary, an evening anxiety measure, an afternoon mood measure and a cognitive performance task. Measures were taken (i) pre-competition), (ii) across the competition days, and (iii) post-competition. We found that participants' lights-out time was earliest across the competition nights. SOL gradually lengthened pre-competition and across the competition nights, eventually exceeding normal limits. WASO was longest across the competition nights but remained within normal limits. Wake-up time was earliest at the start of the competition period but consistently late on most other days. TST was generally adequate but mildly reduced the night before the first day of competition. There was no significant relationship between anxiety and subsequent sleep, nor a relationship between TST and next-day mood or cognitive performance. Future research should investigate whether these findings generalise to esports athletes from other games, at higher levels of competition and different start times.

**Keywords:** competition, sleep disturbance, depression, reaction time

# The Sleep, Anxiety, Mood and Cognitive Performance of Oceanic Rocket League Esports Athletes Competing in a Multi-Day Regional Event

## 6.2 Introduction

It has been documented that esports athletes competing in esports (electronic sports) can experience suboptimal sleep. Converging evidence from studies comprising esports athletes in multiple countries suggests that, on average, esports athletes have delayed sleep timing (i.e. late sleep onset and wake-up times) and obtain TST ranging from 6.5–7.4 hours per night (Bonnar et al., 2022; Gomes et al., 2021; Lee et al., 2020, 2021). These TST estimates are noteworthy given that established guidelines suggest adults need 7–9 hours of sleep per night and adolescents need 8–10 hours per night (Hirshkowitz et al., 2015), indicating that some esports athletes operate under partial sleep restriction. This finding mirrors evidence from the sports science literature that shows high prevalence rates of sleep restriction among traditional athletes (Walsh et al., 2021).

Importantly, there is a strong consensus in the broader sleep literature that sleep restriction has implications for human health and performance, including but not limited to a negative impact on cognitive and affective functioning. For example, research shows that sleep restriction can lead to slower reaction times (Smithies et al., 2021), impair the ability to complete cognitively demanding tasks that require cognitive flexibility (Smithies et al., 2021) and contribute to disturbed mood states (Watling et al., 2017). Thus, the sleep health of esports athletes is highly relevant given that performance in esports has a strong cognitive basis (Pedraza-Ramirez et al., 2020) and reports of depression symptoms in some esports athletes (Lee et al., 2020).

An emerging area of interest in esports sleep research is the impact of competition on esports athletes' sleep. In two studies, 49–53% of esports athletes reported experiencing a sleep disturbance (i.e. sleep initiation, maintenance, or early awakening) the night before competition within the last 12 months (Bonnar et al., 2022; Lee et al., 2021). These findings were later supported by another study, which found that coaches and support staff working with esports athletes rated night competitions and congested competition times as having an impact on the sleep of esports athletes (Bonnar et al., 2023). Comparatively, in the sports science literature, not all studies have found an impact of competition on traditional athletes' sleep (Roberts et al., 2019), although some studies have (Erlacher et al., 2011; Lastella et al., 2014). Moreover, evidence suggests that sleep initiation difficulty may be the most common issue (Erlacher et al., 2011; Juliff et al., 2015). Notably, Lee and colleagues (2021) and Bonnar and colleagues (2022) did not *prospectively* measure sleep behaviour around competition in their studies and instead used a single-item retrospective question, which is prone to recall bias (Mallinson et al., 2019). Furthermore, in the subsequent study by Bonnar and colleagues (2023), coaches and support staff provided indirect evidence of the effect of competition on esports athletes' sleep. Hence, the impact of competition on the sleep of esports athletes remains to be established using more robust study designs. Accordingly, a sub-aim of Aim 1 was to examine daily sleep patterns at pre-competition, across competition days and post-competition.

The factors that influence the sleep behaviour of esports athletes around competition also need to be identified. One factor that has been found to affect the sleep of traditional athletes around competition is anxiety (Ehrlenspiel et al., 2018; Juliff et al., 2015). Cognitive models posit that sleep is susceptible to the effects of anxiety owing to activation of the sympathetic nervous system and corresponding physiological arousal, which delays and disrupts sleep initiation (Harvey, 2002). For traditional athletes, the main cause of anxiety around competition is thoughts about competing (Juliff et al., 2015). Similarly, increased stress and anxiety around competition have been observed in esports athletes (Leis et al., 2022; Poulus et al., 2022; Smith et al., 2019). In one study by Poulus et al. (2022), LoL esports athletes reported self-performance and teammate performance as prominent competitive stressors, with other stressors including general performance (e.g. poor team performance), match outcome, critical moment performance and teammate mistakes. Likewise, in a qualitative study by Smith et al. (2019) involving Counter-Strike: Global Offensive esports athletes, a multitude of internal and external stressors were identified. Internal stressors included team issues (e.g. communication issues and intra-team criticism) and individual issues (e.g. life balance and managing a professional lifestyle). External stressors included external scrutiny and criticism (e.g. from social media and opposition) and competition event organisation (e.g. audience, media interview and logistics). Importantly, some participants reported that these stressors could manifest as anxiety prior to competition. These qualitative findings have also been supported by experimental evidence demonstrating the impact of psychological pressure on anxiety, threat appraisal and gaze behaviour (Sharpe, Obine et al., 2023). However, the effect of competition-related anxiety on sleep is yet to be examined in esports. Consistently, a sub-aim of Aim 1 was to examine daily anxiety patterns at both pre-competition and across competition days. Further, Aim 2 was to explore the relationship between anxiety and same-night sleep around competition.

When investigating sleep behaviour around competition, it is important also to assess the subsequent impact on match-day outcomes, such as mood and performance (Bonnar et al., 2018). Only a few studies have investigated this relationship in traditional athletes, with mixed findings reported (Brandt et al., 2018; Lastella et al., 2014; Staunton et al., 2017). With respect to mood, evidence suggests that there may be an association between prior sleep and match-day mood (Brandt et al., 2018; Lastella et al., 2014). For example, Lastella et al. (2014) found using the Brunel Mood Scale (BRUMS) that participants who had poor sleep quality, low TST and more awakenings reported greater levels of fatigue and tension and less next-day vigour. Likewise, Brandt et al. (2018) found that Brazilian elite athletes with better sleep quality had higher vigour and lower tension, depression, anger, fatigue and confusion. The findings from Lastella et al. (2014) and Brandt et al. (2018) map onto the broader sleep literature, with two meta-analyses showing that suboptimal sleep is strongly related to mood outcomes (Lovato & Gradisar, 2014; Short et al., 2020). Indeed, previous research comprising professional esports athletes evaluating sleep and mood outcomes (i.e. sleep and depression over a two-week period) has also found a link between these variables (Lee et al., 2021). However, whether sleep predicts next-day mood around competition in esports is unknown. Thus, a sub-aim of Aim 1 was to examine daily mood (i.e. depression) patterns at pre-competition, across competition days and post-competition. Additionally, a sub-aim of Aim 3 was to assess whether TST was related to next-day mood around competition.

In terms of the relationship between sleep and match-day performance, evidence from the sports science literature is equivocal. While Lastella et al. (2014) observed that relative performance (expected finish times v. actual finish times) of marathon runners was unaffected by sleep the previous night, Brandt et al. (2018) reported that Brazilian athletes who had poor sleep quality were 173% more likely to lose compared with if they had good sleep quality. Furthermore, Staunton et al. (2017) found in a group of elite female basketball athletes that the relationship between prior sleep behaviour and participants' on-court efficiency scores was highly variable. A potential explanation for the lack of clarity among existing data is that these studies used global outcome measures (e.g. win v. lose), which may be influenced by a multitude of factors other than sleep (e.g. nutrition, motivation). Hence, the use of measures that have a high sleep sensitivity and can isolate the effect of sleep more effectively appears warranted. For example, one commonly used performance measure in other sleep research involving traditional athletes is the PVT (Jones et al., 2018). The PVT provides several outcome metrics with the most common being reaction time. In a recent study by Sharpe, Besombes, et al. (2023), the authors proposed that action performance metrics (which include reaction time) directly contribute to outcome performance (e.g. winning or losing). Although this study related to Counter-Strike: Global Offensive, given that many esports games are fast-paced, reaction time likely plays an important role across games (Bonnar et al., 2019). Hence, the PVT appears suitable for esports sleep research. The last sub-aim of Aim 1 was to examine daily cognitive performance (i.e. reaction time) patterns around competition (i.e. pre-competition, across competition days and post-competition). Moreover, another sub-aim of Aim 3 was to assess whether TST was related to next-day cognitive performance.

In summary, to explore the daily patterns and relationships between sleep behaviour, anxiety, mood (i.e. depression symptoms) and cognitive performance (i.e. reaction time) of esports athletes around competition, three aims were proposed: (1) to quantify daily patterns of sleep behaviour, anxiety, mood and reaction time at pre-competition, across competition days and post-competition; (2) to determine whether anxiety (i.e. cognitive) was related to sleep at pre-competition and across competition days; and (3) to assess whether TST was related to next-day mood and cognitive performance at pre-competition, across competition days and post-competition. Addressing these aims will help provide greater insight as to how esports athletes' sleep functions within the context of a competitive event and, thus, potentially inform clinical practice as to how best to support their sleep health needs during these times.

## 6.3 Method

### 6.3.1 Participants

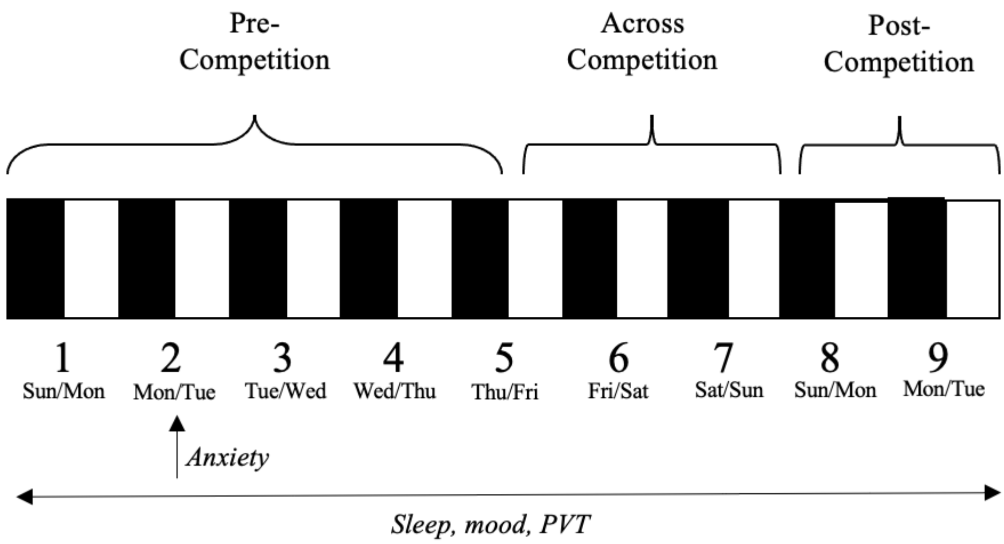
Participants were 16 professional esports athletes from the Oceania esports region competing in Rocket League during Season 11 of the Rocket League Championship Series. As part of a multi-day regional event (there are nine regional events per season), participants competed for $30,000 USD in prize pool and points that accrued toward a spot to play at international majors. Participants were eligible for inclusion if they were ≥ 15 years of age (which is the minimum eligible age to compete) and played for a team competing in Season 11 of the Oceania Rocket League Championships Series. Participants were excluded if they reported a current sleep disorder diagnosis. Ethics approval was obtained from the Flinders University Human Research Ethics Committee (project number 4077). All participants were debriefed on the study and provided informed consent. For participants under 18 years of age, parents were contacted directly via phone to be debriefed and provided the opportunity to ask any questions about the study. Subsequently, to indicate willingness to participate in the study, parents and the participant were both required to co-sign the consent form.

### 6.3.2 Design

A within-subjects design was used to evaluate the daily patterns and relationships between sleep behaviour, anxiety, daytime mood (i.e. depression scores) and cognitive performance (i.e. reaction time) around a competition period (i.e. pre-competition, across competition days and post-competition; see Figure 6.1).

**Figure 6.1**

*Study Period by Competition Phase and When Measures Were Taken*




*Note.* The sleep diary was first administered upon waking on Monday and assessed the previous night of sleep. The mood questionnaire and PVT were first administered on Monday afternoon, while the anxiety questionnaire was first administered on Monday evening.

### 6.3.3 Measures

#### *6.3.3.1 Demographic Information*

A self-report questionnaire adopted from Lee et al. (2021) was used to measure demographic and general information. This included self-reported anthropometric data (i.e. height [cm] and weight [kgs]), esports background (i.e. career length, training start/finish times and duration) and sleep history (i.e. current sleep disorder diagnosis, sleep medication use, competition-related sleep disturbance). Participants also indicated the level of importance they placed on the upcoming match using a 4-point Likert scale from 1 (*not at all*) to 4 (*very much*).

#### *6.3.3.2 Sleep Diary*

An online sleep diary was used to assess participants' sleep behaviour. The sleep diary was based on the Consensus Sleep Diary developed by Carney et al. (2012). It was accessed via a web link and completed each day upon waking from the major sleep period. Sleep variables derived from these data included lights-out time (i.e. time sleep was attempted), sleep onset time, WASO and wake-up time. These data were used to calculate additional sleep variables, including SOL and TST. The sleep diary also obtained information regarding sleep medication (i.e. type and dose), caffeine use (number of caffeinated beverages consumed per day and timing of last beverage), and alcohol use (number of alcoholic drinks consumed per day and timing of last drink).

#### *6.3.3.3 Competitive State Anxiety Inventory 2R*

As mentioned earlier, esports athletes' anxieties can often extend from competition-related thoughts. Thus, to assess the cognitive aspects of anxiety, the cognitive subscale of the Competitive State Anxiety Inventory 2 Revised (CSAI-2R; Cox et al., 2003) was used. Broadly speaking, the CSAI-2R is a self-report measure of competitive state anxiety and comprises several subscales. Each of these subscales can further be broken down into intensity and directional components. To reduce participant burden, we only used the intensity component of the cognitive subscale. The cognitive subscale of the CSAI-2R contains five items (scores range from 5 to 20) and assesses negative feelings about performance and the consequences of performance. Items are rated on a 4-point Likert scale from 1 (*not at all*) to 4 (*extremely*). The CSAI-2R is used widely in the sports science literature and has been validated in several countries (e.g. Lundqvist & Hassmén, 2005; Putra & Guntoro, 2022). Subscales have adequate internal consistency (α = .83–.88; Cox et al., 2003) and test-retest reliability coefficients (e.g. .74–.87; Tomczak et al., 2022).

#### *6.3.3.4 Brunel Mood Scale*

The BRUMS (Terry et al., 1999) is a 24-item self-report measure of mood derived from the Profile of Mood States. Items consist of mood descriptors (e.g. 'panicky') that are rated on a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*extremely*) with the standard reference timeframe (i.e. 'how you feel right now') employed. There are six subscales (i.e. anger, confusion, depression, fatigue, tension and vigour) that each contain four items, which are summed to generate a score ranging from 0–16. For this study, only data from the depression subscale was used, given the link between sleep and depression (Dinges et al., 1997). The BRUMS is used extensively in clinical and competition-related settings (Han et al., 2022) and has been validated in multiple populations, including traditional athletes (Terry et al., 1999). Subscales have adequate internal consistency ($\alpha$ = .79 −.86; Terry et al., 1999) and test-retest reliability coefficients (e.g. .44 −.64; Han et al., 2022), which is considered acceptable for transient mood states (Parsons-Smith et al., 2017).

#### *6.3.3.5 Psychomotor Vigilance Task*

Owing to COVID-19 travel restrictions and the inability to see participants face-to-face, a smartphone-based app called PeakAlert (licensed from the US Army) was used to measure vigilant attention using its PVT function (Reifman et al., 2019). Participants were presented with a stimulus on their phone screen at random intervals over a 3-minute trial period. Participants were instructed to touch the screen as quickly as possible once the stimulus appeared, after which the reaction time in milliseconds was displayed for 1 second. At the end of the trial period, the mean reaction time was presented on the screen. Participants were instructed to complete the PVT in a quiet, distraction-free environment. The Peak Alert app has been validated against computer-based PVT (Reifman et al., 2019), and remote assessment of reaction time with PVT has been conducted in seminal research (Mah et al., 2011).

### 6.3.4 Procedure

Data were collected between 8 November 2021 and 31 May 2022. All participants were competing during Season 11 of the Rocket League Championship Series. Hence, they were training throughout the protocol. Owing to COVID travel restrictions, all participants were competing online and playing from home.

#### *6.3.4.1 Pre-Competition Days*

On Day 1 (i.e. the Sunday prior to their first scheduled matches of the regional event on Friday), participants completed the demographic questionnaire, were provided with a link to access the online sleep diary and mood questionnaires (CSAI-2R, BRUMS) and downloaded the PeakAlert app on their phone. In the week leading up to their scheduled matches (i.e. Monday morning onwards), participants completed the sleep diary each day upon waking (hence, the first sleep diary entry was for Sunday night). Sleep diary responses were monitored for compliance and a text reminder was sent if it was not completed. To monitor daily patterns of anxiety, mood and cognitive performance, measures of these variables were collected at two time points across each day of the study period starting on Monday. Specifically, participants completed the BRUMS and PVT between 4–5 pm (which was just prior to the start time of competition for the upcoming regional event), while the CSAI-2R was completed within 1 hour of attempting sleep. It is worth noting that CSAI-2R data were not collected for Day 1 (i.e. Sunday night).

#### *6.3.4.2 Competition Days*

Participants completed the sleep diary upon waking in addition to the CSAI-2R, BRUMS and PVT at the same time points as the pre-competition days.

#### *6.3.4.3 Post-Competition Days*

Data were also gathered for two nights and days following the last match day to assess changes in sleep, mood and cognitive performance post-competition. Participants once again completed a sleep diary, BRUMS and PVT at the same time points on both days. The CSAI-2R was not used as it only refers to pre-competition anxiety.

### 6.3.5 Data Analysis

SPSS v.26.0 (Armonk, NY, USA) was used for all data analyses. Descriptive statistics, including frequencies, means and standard deviations, were used to summarise sample characteristics (i.e. age, BMI, training time, caffeine and alcohol use, history of sleep disturbances and match importance). Prior to conducting the primary statistical analyses, data were screened, and outliers were windsorised. For Aim 1, linear mixed models were used to test the main effect of time on all primary outcome measures (i.e. all sleep variables, anxiety, mood and PVT). Linear mixed models use expectation maximisation (an unbiased, efficient and stable way of dealing with missing data) to create a regression line for each individual regardless of data missing from one or more time points (Landau & Everitt, 2004). According to a post-hoc power analysis, the linear mixed models were adequately powered (0.82–0.85) to detect moderate effects ($F = 0.25$) but were underpowered (0.16–0.17) to detect small effects ($F = 0.1$). Hence, we focused on effect size change over time instead of significance testing. For Aim 2, Pearson correlations were used to examine the relationship between anxiety and same-night sleep (i.e. SOL, WASO and TST), with data collapsed across Days 2–7 of the study (i.e. pre-competition and across competition days). Likewise, for Aim 3, Pearson correlations were used to examine the relationship between TST and next-day mood (i.e. depression) and cognitive performance (i.e. PVT), with data collapsed across Days 1–9 of the study (i.e. pre-competition, across competition days and post-competition). A significance level of $p < .05$ was used. Effect sizes (i.e. Cohen's d [0.2 = small, 0.5 = medium, 0.8 = large] for questionnaire scores and mean difference [$M_{\text{diff}}$] for sleep variables and PVT) were calculated for primary outcome measures. Time is the most effective way to express an effect size for sleep and PVT data, which is why we used $M_{\text{diff}}$ for sleep variables (expressed in hours and minutes) and PVT (expressed in milliseconds). Please note that when we use the term meaningful in the Results section, we are suggesting that the observed effect size change over time was practically or clinically significant.

## 6.4 Results

### 6.4.1 Sample Characteristics

All participants were male with a mean age of 20.3 years (*SD* = 2.3; range = 16–25 years) and a BMI of 23.8 (*SD* = 7.8). The average career length of participants was 3.4 years. Moreover, the mean training duration was 4.25 hours per day, with an average start time of 4:18 pm and a finish time of 9:24 pm.

Most participants (68.8%) indicated they had experienced a sleep disturbance the night before the competition within the last year. Of this group, the most common problem (of which participants could select more than one type) was with sleep initiation (67%), followed by sleep maintenance (31%) and early morning awakening (25%). Furthermore, the highest rated frequency for experiencing these sleep disturbances was ‘often’ (45.5%), followed by ‘rarely’ (36.4%), ‘sometimes’ (9.1%) and ‘almost always’ (9.1%).

With respect to factors that can influence sleep, caffeine was used on 48% of days, with an average of 1.6 drinks consumed per day and an average time of last consumption of 5:48 pm. Furthermore, alcohol was consumed on 8% of days, with an average of 2.6 drinks consumed per day and an average time of last consumption of 10:36 pm. No participants reported having a sleep disorder diagnosis. One participant reported using sleep medication (20 mg quetiapine) but only used it once during the protocol.

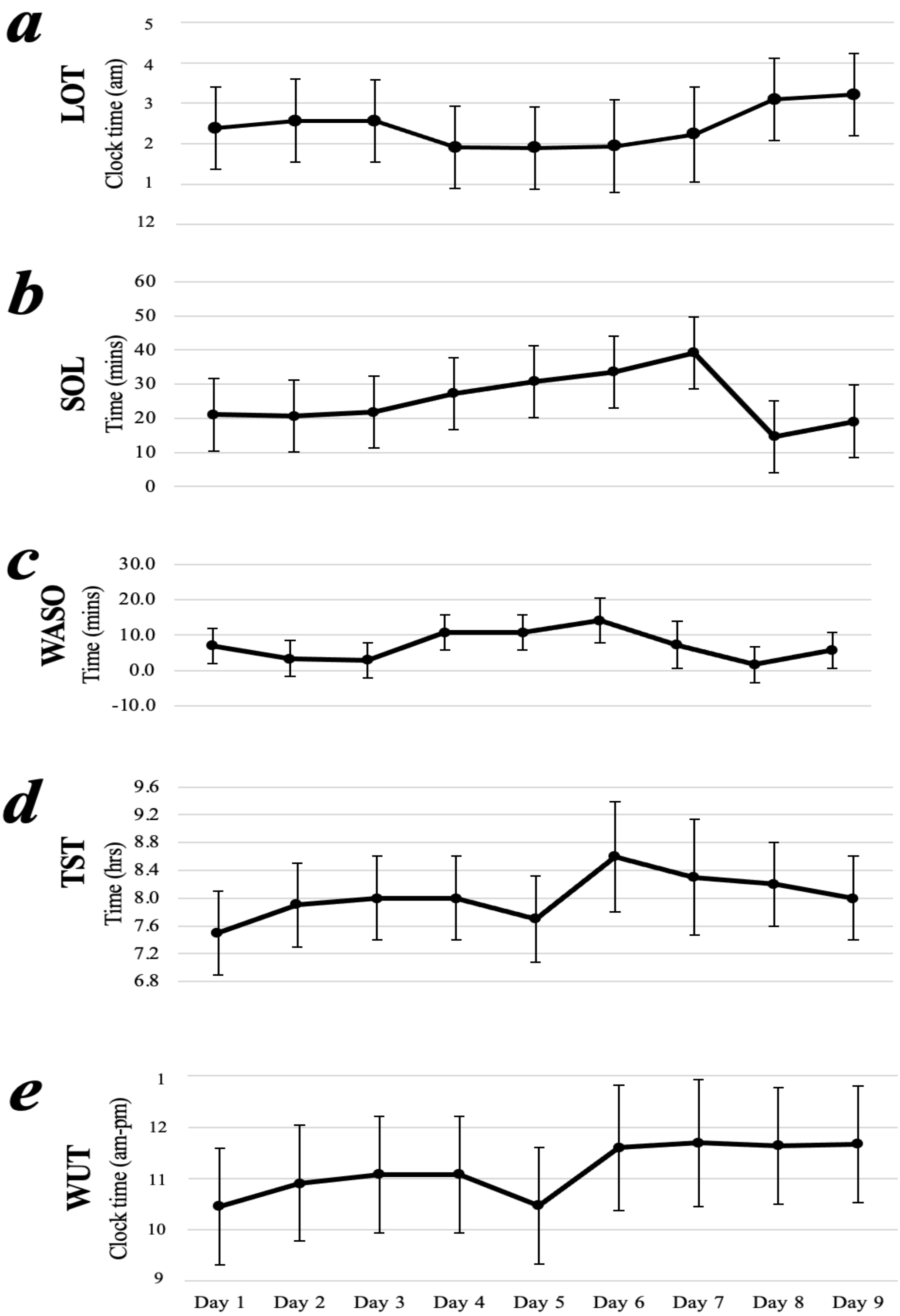
In terms of how important the upcoming match was to participants, 75% said ‘very much’, 18% said ‘much’, 6% said ‘a little’ and 0% said ‘not at all’.

### 6.4.2 Daily Sleep Patterns (Aim 1)

Changes in sleep metrics pre-competition, across competition days and post-competition can be seen in Figure 6.2.

**Figure 6.2**

*Sleep Variables Across the Study Period*




*Note.* LOT = lights out time, SOL = sleep onset latency, WASO = wake after sleep onset, TST = total sleep time, WUT = wake-up time.

#### *6.4.2.1 Lights Out Time*

The mean lights-out time was stable in the first few days pre-competition (Days 1–3 $M_{\text{diff}} =$ +11 minutes, $p$ = .697), shifted earlier and remained steady across the competition nights (Days 4–7 $M_{\text{diff}} =$ −19 minutes, $p$ = .612) and then drifted to its latest point at post-competition (Days 7–9 $M_{\text{diff}} =$ +58 minutes, $p$ = .093). There was no main effect of time, $F$(8, 89) = 1.41, $p$ = .34, yet the effect sizes suggest meaningful change across time (pre-competition, across competition nights and post-competition).

#### *6.4.2.2 Sleep Onset Latency*

Mean SOL gradually increased in the days pre-competition and across the competition nights (e.g. Days 1–7 $M_{\text{diff}} =$ +18 minutes, $p$ = .04), peaked on the night before the last day of competition and then decreased to normal levels post-competition (e.g. Days 7–8 $M_{\text{diff}}$ = −24 minutes, $p$ = .001). Although there was no significant main effect for time, $F$(8, 86) = 1.75, $p$ = .09, the effect sizes suggest meaningful changes in SOL between phases of the competition (pre-competition, across competition days and post-competition).

#### *6.4.2.3 Sleep Onset Time*

Mean sleep onset time was stable in the first few days pre-competition, shifted earlier for the start and middle of competition (Days 3–6 $M_{\text{diff}}$ = −25 minutes, $p$ = .52), before steadily delaying from the end of competition through to post-competition (Days 6–9 $M_{\text{diff}}$ = +1 hour 1 minute, $p$ = .13). There was no main effect of time, $F$(8, 88) = 0.63, $p$ = .74, although the effect sizes suggest a meaningful change in sleep onset time between phases of the competition (pre-competition, across competition nights and post-competition).

#### *6.4.2.4 Wake After Sleep Onset*

Mean WASO was stable in the first few days pre-competition (Days 1–3 $M_{\text{diff}} =$ −4 minutes, $p$ = .21) before it gradually increased to a peak on Day 6 (i.e. the night before the second day of competition) and then decreased to normal levels post-competition (Days 6–9

$M_{\text{diff}} = -8$ minutes, $p = .035$). Although the main effect of time for WASO was significant, $F(8, 84) = 2.53$, $p = .016$, effect size change over time for WASO (pre-competition, across competition nights and post-competition) was relatively small.

#### *6.4.2.5 Wake-Up Time*

Mean wake-up time appeared to delay across the first few days pre-competition (Days 1–4 $M_{\text{diff}} = +37$ minutes, $p = .219$) before it reverted earlier on the first morning of the competition but quickly delayed again to its latest point on the last day of competition (Days 5–7 $M_{\text{diff}} = +1$ hour 13 minutes, $p = .017$) and remained later post-competition. The main effect of time was not significant, $F(8, 94) = 1.9$, $p = .065$, yet the change in effect sizes for wake-up time over time (pre-competition, across competition days and post-competition) was meaningful.

#### *6.4.2.6 Total Sleep Time*

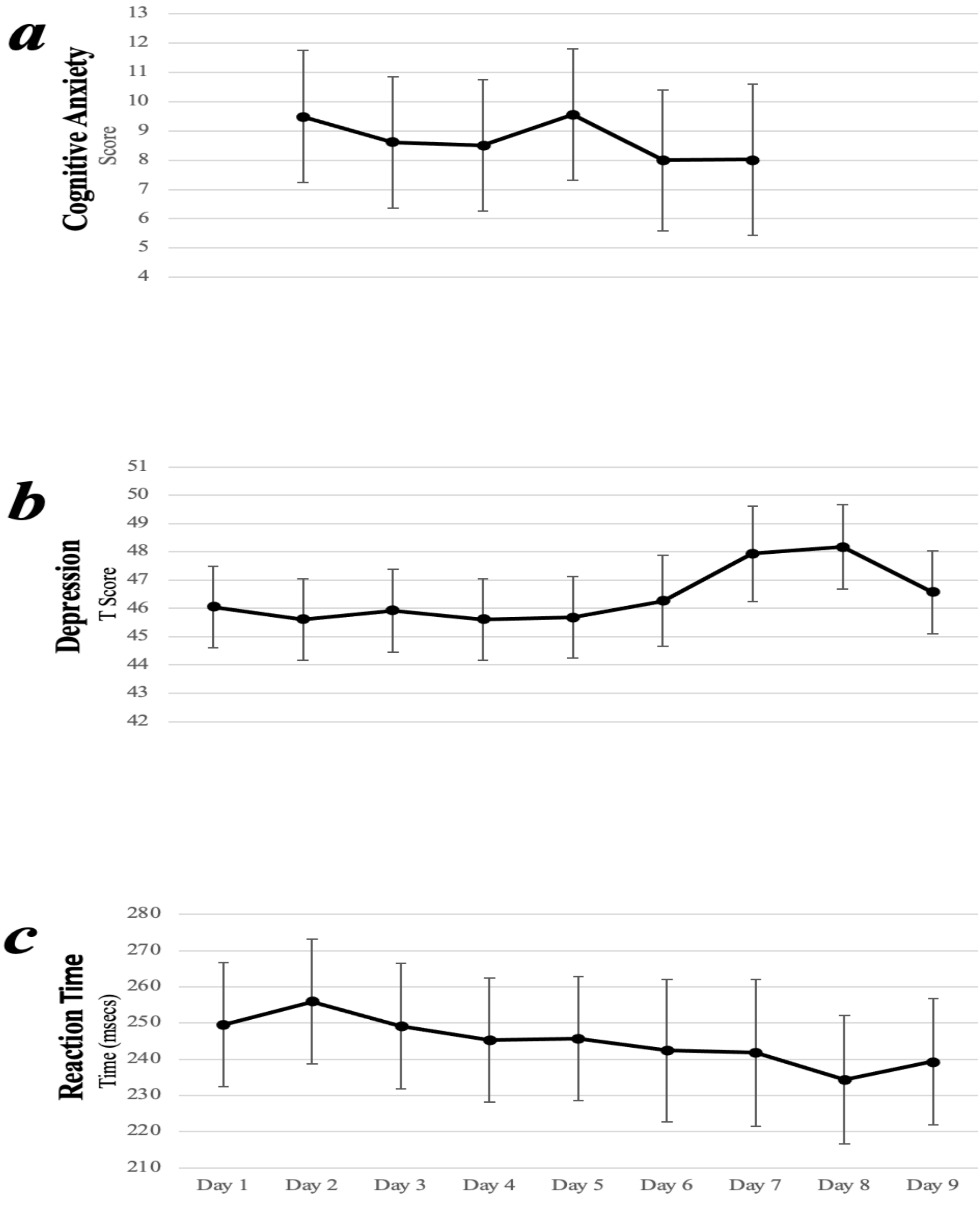
Mean TST increased over the first few days pre-competition, decreased on the night before the first day of competition (Days 4–5 $M_{\text{diff}} = -21$ minutes, $p = .35$) and peaked on the second night of competition before decreasing to normal levels post-competition (Days 6–9 $M_{\text{diff}} = -35$ minutes, $p = .24$). The main effect of time for TST was not significant, $F(8, 87) = 0.86$, $p = .55$; however, effect size changes in TST over time (pre-competition, across competition nights and post-competition) were meaningful.

#### *6.4.2.7 Daily Anxiety Patterns (Aim 1)*

Changes in cognitive anxiety pre-competition, across competition days and post-competition can be seen in Figure 6.3.

**Figure 6.3**

*Anxiety, Depression and Reaction Time Scores Across the Study Period*




*Note.* The cognitive anxiety measure commenced on Day 2 and finished the evening prior to the last day of competition (i.e. Day 7).

### *6.4.2.8 Cognitive Anxiety*

Mean cognitive anxiety decreased over the first few days pre-competition before there was an increase and peak the night before the first day of competition (Days 4–Day 5

$M_{\text{diff}}$ = +1.06, [95% CI = −0.02, 2.14], $p$ = .055, $d$ = 0.25), followed by a decrease on subsequent competition nights (Days 5–7 $M_{\text{diff}}$ = −1.54, [95% CI = −3.52, 0.44], $p$ = .13, $d$ = −0.33). The main effect of time for cognitive anxiety was not significant, $F(5, 59) = 2.1$, $p$ = .073, and effect size changes over time were small.

### 6.4.3 Daily Mood Patterns (Aim 1)

Changes in depression symptoms pre-competition, across competition days and post-competition can be seen in Figure 6.3.

#### *6.4.3.1 Depression*

Mean depression scores were stable until an increase on the last day of competition (Days 1–7 $M_{\text{diff}}$ = +1.87, [95% CI = −0.12, 3.88], $p$ = .07, $d$ = 0.60), peaked on the first day post-competition and then decreased on the second day post-competition (Days 8–9 $M_{\text{diff}}$ = −1.61, [95% CI = −2.69, −0.54], $p$ = .004, $d$ = −0.56). The main effect of time for depression scores was significant, $F(8, 86) = 2.41$, $p$ = .021, and effect size changes for depression scores over time (pre-competition, across competition days and post-competition) were moderate.

### 6.4.4 Daily Cognitive Performance Patterns (Aim 1)

Changes in reaction time at pre-competition, across competition days and post-competition can be seen in Figure 6.3.

#### *6.4.4.1 Reaction Time*

Mean reaction time gradually decreased across the different phases of the competition (pre-competition, across competition days, post-competition), with the fastest mean reaction time occurring on the first day post-competition (Days 1–8 $M_{\text{diff}} =$ −15 milliseconds, $p$ = .19). The main effect of time for reaction time was not significant, $F(8, 88) = 0.64$, $p$ = .75, and it is unknown whether the changes in reaction time effect sizes over time (pre-competition, across competition days and post-competition) were meaningful.

### 6.4.5 Association Between Anxiety and Sleep (Days 2–7; Aim 2)

#### *6.4.5.1 Cognitive Anxiety: Sleep Onset Latency, Wake After Sleep Onset and Total Sleep Time*

The relationship between cognitive anxiety and SOL was small and not significant, $r(16) = -0.18$, $p = .51$. The relationship between cognitive anxiety and WASO was small and not significant, $r(16) = 0.19$, $p = .48$. The relationship between cognitive anxiety and TST was small and not significant, $r(16) = -0.14$, $p = .60$.

### 6.4.6 Association Between Total Sleep Time and Next-Day Mood and Cognitive Performance (Days 1–9; Aim 3)

The relationship between TST and next-day mood (i.e. depression) was small and not significant, $r(16) = -0.07$, $p = .79$**,** and the relationship between TST and next-day cognitive performance (i.e. reaction time) was small and not significant, $r(16) = -0.31$, $p = .24$.

## 6.5 Discussion

The present study aimed to quantify daily patterns of sleep behaviour, anxiety, mood and cognitive performance and the relationships between these variables in professional esports athletes competing in a multi-day regional event. Based on effect size change over time (not significance testing) relative to pre-competition and post-competition, our findings indicate that esports athletes' sleep may be influenced by competition. More specifically, across the competition period, participants tended to have an earlier lights-out time, experience longer SOL and WASO and have a delayed wake-up time. Consequently, participants managed to obtain adequate TST on most nights of the competition, with an increase in TST on some competition nights. However, correlations suggested there was no relationship between anxiety and sleep behaviour, nor TST and next-day mood (i.e. depression) and cognitive performance (i.e. reaction time). We now examine these findings in more detail and consider the clinical implications.

### 6.5.1 Daily Sleep Patterns (Aim 1)

Participants had a lights-out time that varied across the different phases of the study. At the start of the week, participants tended to have a lights-out time of approximately 2:30 am. However, as the event drew closer, and across the competition nights, participants' lights-out time shifted earlier to approximately 2:00 am. Although we cannot specifically determine why this shift occurred, it may reflect participants trying to sleep earlier (and thus obtain more sleep) in preparation for competition days. However, once the competition was over, esports athletes' lights-out time quickly delayed much later to after 3:00 am (these were the two latest days of the study period).

Once lights out occurred, SOL gradually increased in the days leading up to the competition, peaked on the night before the last day of competition, and then decreased to normal levels post-competition. Importantly, SOL was clinically significant (i.e. > 30 minutes per night; Ohayon et al., 2017) on the nights before each day of competition. This finding is consistent with evidence from the sports science literature showing that long SOL is the most common sleep problem experienced by traditional athletes around competition (Juliff et al., 2015). In our study, the earlier lights-out time across the competition could have contributed to longer SOL (i.e. participants may have attempted to sleep too early).

Despite the change in SOL across the different phases of the competition, sleep onset time generally paralleled the same pattern as lights out time. At the beginning of the week, participants had a sleep onset time of approximately 3:00 am, which then shifted earlier to approximately 2:30 am across the competition period. However, sleep onset time started to drift later the night before the last day of competition, which was likely (at least in part) owing to the longer SOL on that night. This drift continued until participants reached approximately 3:30 am on the second day post-competition, which is consistent with Counter-Strike: Global Offensive esports athletes from Oceania (Lee et al., 2021).

During the night, WASO was elevated from two nights before the start of the competition through to the second night of competition, relative to pre-competition and post-competition nights. Interestingly, WASO was relatively low on Saturday night (i.e. the night before the last day of the competition). Hence, the early and middle parts of the competition period were more likely to negatively influence WASO. However, this elevated WASO was not clinically significant. That is, the highest average WASO (i.e. the night following the first day of competition) was only 14 minutes, which is well below the 20 minutes per night norm for adults (Ohayon et al., 2017).

At the end of the sleep period, participants' wake-up times gradually shifted later across time except for one night. More specifically, in the pre-competition period, esports athletes in our sample had a wake-up time that drifted later from about 10:30 am to 11:00 am. However, on the first day of the competition, wake-up time moved back to 10:24 am, which was the earliest day for the entire study period. Once again, we cannot say why this earlier wake-up time occurred. It is plausible that it had something to do with the start of the event (e.g. excitement and preparation). Subsequently, wake-up times gradually delayed at post-competition to after 11:40 am, which would make it difficult to stabilise sleep timing.

Despite the elevated SOL and WASO across competition nights, esports athletes managed to obtain adequate TST apart from the night prior to the first day of competition. Indeed, the night that participants had the most TST was the second night of the competition. It would appear that earlier lights-out times and later wake-up times around competition resulted in increased TST. The reason the night prior to the first day of competition is different is likely because of the earlier wake-up time that morning, which curtailed sleep opportunity. Overall, this finding indicates that Rocket League esports athletes can increase TST around competition during regional events by modifying lights-out and wake-up time.

In summary, based on effect size change over time, our sample of Rocket League esports athletes appeared to shape their sleep around competition relative to pre-competition and post-competition. Notably, participants tended to shift their lights-out time earlier and wake-up time later, which enabled them to obtain more TST despite a deterioration in SOL and WASO. Although our results cannot determine why participants changed their sleep schedule around competition, it is plausible that they were intentionally trying to increase TST. The 5:00 pm competition start time was likely helpful in this respect, as it allowed participants the flexibility of increasing their sleep opportunity without interference.

#### 6.5.2 Daily Anxiety Patterns (Aim 1)

Cognitive symptoms of competition-related anxiety were mostly stable pre-competition, increased the night prior to the first day of competition, before decreasing across subsequent competition days (based on effect size change over time). This finding suggests that participants noticed more negative feelings about performance and the consequences of performance at the start of competition than at any other time during the study protocol.

#### 6.5.3 Daily Mood Patterns (Aim 1)

Mood (i.e. depression) scores from the BRUMS were stable in the pre-competition period but increased on the final day of competition and were highest on Day 8 (i.e. the first day post-competition) before decreasing again on Day 9 (i.e. the second day post-competition; based on effect size change over time). However, even with this increase, scores were still below the 50th percentile. Hence, although the main effect of time was significant and effect size change was moderate, the clinical significance of mood change across the study appears negligible.

### 6.5.4 Daily Cognitive Performance Patterns (Aim 1)

Cognitive performance (i.e. reaction time) scores improved across the study period (based on effect size change over time). Although the main effect of time was not significant, the effect size change may be meaningful. That is, from the start of the study period to the competition period, reaction time improved by approximately 10-milliseconds. As noted in the introduction, action performance metrics such as reaction time have been proposed to contribute toward outcome performance (Sharpe, Besombes, et al., 2023). However, whether a 10-millisecond improvement benefits esports athletes is currently unknown.

### 6.5.5 Association Between Anxiety and Sleep (Aim 2)

Correlations suggested there was no relationship between cognitive anxiety and sleep (i.e. SOL, WASO, TST). This finding suggests that participant anxiety levels were not high enough to negatively affect sleep, as outlined in cognitive theoretical models (Harvey, 2002). It is plausible that bigger events with higher stakes (i.e. international events) may elicit a greater anxiety response, which could affect sleep, although this remains to be investigated.

### 6.5.6 Association Between Total Sleep Time and Next-Day Mood and Cognitive Performance (Aim 3)

We found no relationship between TST and next-day mood (i.e. depression). This finding is unsurprising, considering participants obtained adequate TST across most of the study period. Hence, the increase on Days 7 and 8 occurred independently of TST. Given the proximity to the end of the competition, the most likely reason for the increase in depression scores was participants losing matches. Although not the focus of the present study, future research should more directly investigate the impact of lost matches on the mental health of esports athletes.

As with mood, there was no relationship between TST and improved cognitive performance (i.e. faster reaction times). Extensive research suggests that the PVT is free of practice effects (e.g. Basner et al., 2018). Hence, this finding is difficult to reconcile with our data as we cannot determine why reaction time improved over time.

### 6.5.7 Sample Characteristics

It is difficult to compare participants from the present study to the esports literature as, to the authors' knowledge, there is no published research involving professional Rocket League esports athletes. Despite a lack of direct reference data, the average age of participants in our study (20 years) was similar to that of other studies comprising professional esports athletes from different games (Leis et al., 2022; Poulus et al., 2022; Smith et al., 2019), which reflects the generally younger demographic seen in esports. Likewise, the average BMI of participants was also consistent with previous research (Trotter et al., 2020) and within the healthy weight range, which indicates BMI likely had minimal effect on sleep.

Training time (i.e. 4.25 hours per day) was slightly shorter than other games (i.e. Counter-Strike: Global Offensive) in the Oceania region (Lee et al., 2021) and much shorter than games from other regions (e.g. Korean Overwatch esports athletes; Lee et al., 2021). Given there is minimal research available involving professional Rocket League esports athletes, this finding may be reflective of the typical training time for this game. Interestingly, the average training start time was 4:18 pm, while the average finish time was 9:24 pm. These training times are earlier than many other games (e.g. Overwatch and Counter-Strike: Global Offensive) and would not displace sleep to the same degree as previously documented (Lee et al., 2021).

Caffeine use was common across the study period. However, the average number of caffeinated drinks consumed per day was low (i.e. 1.6 per day), and the average time of last consumption was approximately 7.5–9 hours before lights-out time. The half-life of caffeine is generally 3–5 hours (McLellan et al., 2016). Thus, circulating caffeine levels were likely very low when participants attempted to sleep. Similarly, alcohol use was non-problematic as the frequency of alcohol use and the average level of consumption (i.e. 2.6 per day) was low, while the average time of last consumption was approximately 4 hours before lights-out time. Hence, alcohol is also unlikely to have influenced the sleep of participants in our sample.

Self-reported sleep disturbances (67%) within the last 12 months were higher than previous research (Bonnar et al., 2022; Lee et al., 2021) by approximately 14–18%. Sleep initiation was the most commonly reported issue, which aligns with findings from the present study (see below in the daily sleep patterns section), followed by sleep maintenance problems and waking too early. It is difficult to know why self-reported sleep disturbances over the last 12 months were higher in the present study. However, it is plausible that esports athletes who compete in different games may experience varying degrees of risk for sleep disturbances, although this remains to be investigated.

Notably, a majority (75%) of participants rated the regional event as the highest possible level of importance. Hence, it can be inferred that most participants felt a similar level of pressure to perform well going into the event.

### 6.5.8 Clinical Implications

Even though TST was adequate on most nights, there was notable variability in sleep timing (sleep onset and wake-up time) across the different phases of the competition (i.e. pre-competition, across competition days, post-competition). The circadian system, one of two additive processes that determines the sleep-wake schedule, has natural variations in multiple physiological functions across a 24-hour period (Lack & Wright, 2007a). For example, an individual with an average timed sleep pattern (i.e. 11:00 pm–7:00 am) has a dip in alertness between approximately 2:00–4:00 pm (Monk, 2005). Importantly, these variations have been found to influence athletic performance (Walsh et al., 2021). Irregular sleep schedules make it difficult to predict these daily variations. Consequently, mitigation actions, such as the use of ergogenic aids like caffeine, are more difficult to implement as they require accurate timing for best effects (Hayat et al., 2022). Irregular sleep schedules have also been found to lead to poorer sleep quality (Kang & Chen, 2009) and, as mentioned earlier, can affect other aspects of sleep, such as SOL. Thus, a more stable sleep schedule may enable esports athletes to manage the circadian influence on performance more effectively, enhance sleep quality and reduce the impact on SOL, while still ensuring adequate TST. Importantly, our findings suggest that sleep timing stabilisation is achievable for esports athletes, at least for those with a later competition start time (i.e. 5:00 pm in our study). Indeed, as noted earlier, it appears participants shifted their sleep timing to increase TST. However, this attempt occurred within close proximity to the start of the competition. With guidance from a health professional (e.g. a clinical psychologist trained in behavioural sleep medicine), esports athletes could instead be assisted to shift their sleep patterns earlier (i.e. a week out from the competition) using chronobiological interventions such as morning bright light therapy (Lack & Wright, 2007b). It is worth noting that sleep timing stabilisation may be more challenging for esports athletes with delayed sleep timing and earlier competition start times owing to the magnitude of shift required, possibly necessitating other solutions. But first, further research is required to understand the relationship between earlier competition start times and the sleep of esports athletes.

### 6.5.9 Strengths and Limitations

A key strength of the present study is that the sample comprised professional esports athletes competing in a Tier 1 league (i.e. Rocket League Championship Series, Season 11) within an established international esports title. Many studies within the esports literature use easier-to-recruit samples such as high school (e.g. Moen et al., 2022) and college students (e.g. Kraemer et al., 2022) or high-ranked non-professionals (e.g. Poulus et al., 2020) who are less elite and compete within a very different competitive environment compared with professionals. However, the trade-off for recruiting professional esports athletes is that the sample size is smaller. Consequently, the study was underpowered to detect small effects, which is why we focused on effect size change over time (generated using linear mixed-model regressions). However, although effect sizes provide valuable insight into practical and clinical significance, the strength of our findings is limited without an adequately powered sample that allows significance testing for small effects. The smaller sample also limited us to more rudimentary statistical techniques (i.e. correlations) when examining the link between sleep and other variables (i.e. anxiety, mood, cognitive performance), meaning we were unable to take a more fine-grained approach to understanding these daily relationships. For further context, it should be noted that our sample size is reflective of other studies comprising professional esports athletes (e.g. Leis et al., 2022; Poulus et al., 2022) and those from esports sleep studies specifically ($N$ = 16–17; Gomes et al., 2021; Lee et al., 2021). Another limitation of our study is that we focused on the intensity component of the cognitive anxiety subscale from the CSAI-2R and did not use the directional component. Although the intensity component provides insight into the presence of cognitive anxiety symptoms, it does not capture an individual's interpretation of anxiety (i.e. whether it facilitates or debilitates performance), which can influence how cognitive anxiety is experienced (Mellalieu et al., 2004). Lastly, keeping external validity in mind, findings from the present study are most informative of Rocket League players competing in a regional event with a later start time (i.e. 5:00 pm).

**6.5.10 Directions for Future Research**

We have briefly mentioned several directions for future research throughout the Discussion section but here we elaborate further on some key points that will potentially help advance our study's line of inquiry. First, subsequent research should investigate whether our findings generalise to esports athletes from other games. Some authors have argued that not all esports athletes are alike, in the same way, that not all traditional athletes are alike (e.g. Bonnar et al., 2022; Poulus et al., 2020). Untangling possible differences between esports athletes from different games would address questions regarding external validity, contribute toward a more nuanced understanding of sleep in relation to competition, and allow more targeted interventions to be developed. Furthermore, to better elucidate the experience of competition-related anxiety and its relationship with sleep, future research should take a more theory-driven approach and assess not just the presence of anxiety symptoms but also the interpretation of anxiety symptoms. Moreover, the impact of higher levels of competition (e.g. international events with higher stakes) on anxiety experiences and associated sleep behaviour should also be explored, although realistically, recruitment of esports athletes competing in major tournaments would likely be extremely difficult. Another avenue worth exploring is the influence of earlier competition start times on esports athletes' sleep (i.e. is it more difficult for them to adapt their sleep patterns?). From an intervention standpoint, prospective research should evaluate the utility of sleep timing stabilisation using morning bright light therapy, given the possible sleep and performance benefits. This type of intervention would be brief and require minimal resources. Thus, it may be a plausible research path, even for professional esports athletes who might prefer brief interventions that fit within their busy schedules (Bonnar et al., 2022). Lastly, future research should aim to incorporate larger sample sizes that are adequately powered, as this would support more rigorous statistical analyses (i.e. significance testing) from which stronger conclusions could be drawn. Larger sample sizes would also enable more sophisticated analysis (e.g. cross-correlations and structured equation modelling) of daily relationships between sleep and other variables (e.g. anxiety, mood and cognitive performance).

## 6.6 Conclusion

The sleep patterns of Rocket League esports athletes may be influenced by competing in a multi-day regional event. Based on effect size change over time (not significance testing), daily sleep patterns showed that although SOL and WASO worsened across the competition period, participants were able to obtain adequate TST via modification of lights-out and wake-up time. A more stable sleep schedule might have sleep and performance benefits. Correlations suggested there was no relationship between anxiety and same-night sleep, nor between TST and next-day mood (i.e. depression) and cognitive performance (i.e. reaction time). Together, these findings indicate that the observed change in mood and cognitive performance occurred independently of TST. Future research should seek to investigate whether these findings generalise to esports athletes from other games, at higher levels of competition (e.g. international events), and different start times. Furthermore, larger sample sizes that are adequately powered would enable significance testing, as well as a more sophisticated statistical examination of the link between sleep and other variables (i.e. anxiety, mood and PVT).

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# Chapter 7: General Discussion

## 7.1 Chapter Overview

The present thesis aimed to explore the sleep behaviour of professional esports athletes, identify the risk factors contributing to suboptimal sleep within this population and subsequently devise and evaluate a targeted sleep intervention. These aims were addressed across five studies. This final chapter summarises and then integrates the study findings within the broader literature. Subsequently, the methodological and clinical implications stemming from our research are considered. Finally, limitations and future research directions are discussed before a conclusion is presented.

## 7.2 Summary of Key Findings

Study 1 (Chapter 2; Bonnar, Lee et al., 2019) evaluated potential risk factors for poor sleep in esports and provided practical guidance for sleep interventions. We found that both game genre and gaming culture may plausibly affect the sleep of esports athletes via cognitive and behavioural pathways. Spielman's 3-P model may be a useful conceptual framework for organising and understanding how risk factors contribute to developing and maintaining poor sleep in esports. Additionally, a sleep intervention for esports athletes needs to accommodate their unique sleep needs and professional lifestyles.

Study 2 (Chapter 3; S. Lee et al., 2021) examined the sleep behaviour and mood of professional esports athletes from South Korea, the US and Australia. Results showed that participants from all three countries displayed delayed sleep timing, although US participants had earlier sleep timing than participants from South Korea and Australia. WASO was excessive, and TST was below the recommended guidelines of 7−9 hours per night. Furthermore, 47% of participants exceeded the clinical cut-off for insomnia, while 41% reported excessive daytime sleepiness levels. Depression scores were correlated with WASO, the number of awakenings, time in bed, wake-up time and training timing.

Study 3 (Chapter 4; Bonnar et al., 2022) implemented a brief sleep intervention with 56 esports athletes designed to improve the sleep, mood (i.e. depression and anxiety), and cognitive performance (i.e. PVT) of esports athletes. We observed from pre-intervention to post-intervention that sleep knowledge improved while there were modest changes for subjective and objective sleep onset time and for subjective SOL and sleep efficiency. Insomnia scores decreased, but sleepiness scores increased. However, sleep did not improve enough to cause changes in mood or cognitive performance.

Study 4 (Chapter 5; Bonnar et al., 2023) investigated the influence and perspective of esports coaches and support staff on the sleep habits of esports athletes competing at professional and semi-professional levels. Broadly, results revealed that overall sleep hygiene knowledge was inadequate, sleep monitoring frequency was low, and sleep hygiene practices were implemented more often. The most common barrier to sleep monitoring and sleep hygiene practices was esports athletes' dislike of the process. Night competitions, congested competition times and night training schedules all rated highly as affecting esports athletes' sleep.

Study 5 (Chapter 6; Bonnar et al., 2024) explored the daily patterns and relationships between sleep behaviour, anxiety, mood (i.e. depression) and cognitive performance (i.e. PVT) of esports athletes around a competition period. We found that relative to pre-competition and post-competition, SOL and WASO worsened across the competition period. However, participants were able to obtain adequate TST via modification of lights-out (earlier) and wake-up times (later). There was no relationship between anxiety and subsequent sleep, nor a relationship between TST and next-day mood or cognitive performance.

## 7.3 Integration of Findings Within the Broader Literature

### 7.3.1 Aim 1: Sleep Behaviour, Mood and Cognitive Performance in Esports

Research investigating the sleep behaviour of esports athletes has evolved. As described in Chapter 1, preliminary studies in 2019–2020 examined sleep as a secondary aim and consequently used more rudimentary sleep measures (i.e. Rudolf et al., 2020; Thomas et al., 2019). In contrast, subsequent studies from 2020 onwards (including chapters from the present thesis) examined sleep as a primary aim and used more robust study designs and sleep measures. Hence, the characteristics of esports athletes' sleep patterns have become increasingly clear and more accurate with a change in the methodologies and sleep measures used.

#### *7.3.1.1 Previous Research*

To briefly recap the section pertaining to esports athletes' sleep behaviour from Chapter 1, initial studies that documented sleep in esports athletes used single-item retrospective questions (e.g. 'How much sleep have you obtained each night over the last month?'). The first of these studies comprised esports athletes from the US, with TST estimated to be 8.1 hours per night (Thomas et al., 2019). Similarly, a study comprising esports athletes from Germany reported estimates of 7.8 hours per night and a mode sleep quality of 'quite good' (Rudolf et al., 2020). Thus, both studies reported TST within the recommended 7–9 hours per night for adults but borderline for adolescents who need 8–10 hours per night (Hirshkowitz et al., 2015), which is noteworthy considering some esports athletes are young (e.g. 14 years of age; see Chapter 4). When taken together, these findings suggest that esports athletes sleep adequately. However, both studies are beset by methodological flaws (namely, inaccurate measures with limited scope and poor sampling) that make it difficult to generalise these findings.

*7.3.1.2 Sleep Onset Latency*

In Chapter 3, esports athletes' median SOL measured using wrist activity monitors was 16 minutes in South Korea, 21 minutes in Australia and 26 minutes in the US (the total sample mean was 20 minutes with no significant difference between countries). Similarly, in Chapter 4, the sleep diary estimate of SOL was 28 minutes, while the wrist activity estimate was 31 minutes. These two chapters show that SOL was typically within normal limits (i.e. < 30 minutes; Ohayon et al., 2017), except for wrist activity monitor estimates in Chapter 4. However, SOL, in this instance, only exceeded the clinical cut-off by one minute, which is marginal and unlikely to be clinically remarkable. In the broader literature, two other studies comprising professional esports athletes have also found evidence of normal SOL (Gomes et al., 2021; S. Lee et al., 2020). In one study, Gomes et al. (2021) examined the sleep behaviour of 20 LoL esports athletes over a two-week period using wrist activity monitors. They reported a mean SOL of 13–16 minutes. In another study, S. Lee et al. (2020) used a sleep diary over a two-week period to measure the sleep of 34 LoL and Overwatch esports athletes and compared them with matched controls (i.e. non-esports athletes). They reported a SOL of 22 minutes for the esports athlete group and 13 minutes for the control group (this difference was non-significant).

In contrast, one study comprising professional esports athletes found excessive SOL. Sanz-Milone et al. (2021) measured sleep in a sample of 12 Counter-Strike: Global Offensive esports athletes over a seven-day period using wrist activity monitors. Splitting the sample based on chronotype, they found an average SOL for neither types and evening types of 35 and 41 minutes, respectively. Furthermore, taking a more nuanced approach, the study in Chapter 6 found that SOL lengthened in the days leading up to and across a competition, eventually exceeding the clinical cut-off for three days before quickly returning to normal limits post-competition. Overall, evidence from most studies (across several regions, games played and sleep measures used) suggests that SOL is non-problematic for esports athletes, although the nights preceding a competition may lead to longer SOL. This finding generally reflects the same pattern of SOL seen in traditional athletes, where average SOL measured over a period (e.g. two weeks) is typically normal (Lastella et al., 2015), while closer analysis in some studies (but not all) reveals longer SOL around competition schedules (e.g. Ehrlenspiel et al., 2018; Juliff et al., 2015).

#### *7.3.1.3 Wake After Sleep Onset*

Perhaps the most variable sleep characteristic finding reported in this thesis and the wider literature pertains to WASO. In Chapter 3, the median WASO using wrist activity monitors was 50 minutes in South Korea, 31 minutes in Australia and 55 minutes in the US (the total sample mean was 47 minutes, with no significant difference between countries). In Chapter 4, the mean WASO sleep diary estimate was 9 minutes, while the wrist activity monitor estimate was 44 minutes. In Chapter 6, mean WASO based on sleep diary ranged from 1–14 minutes leading up to competition, across competition and post-competition.

Varying estimates of WASO can be seen in other studies comprising professional esports athletes. In their study, Gomes et al. (2021) used wrist activity monitors in a sample of 20 LoL esports athletes and found that mean WASO ranged from 34–36 minutes. Meanwhile, S. Lee et al. (2020) used a sleep diary in a sample of 34 LoL and Overwatch esports athletes and compared them to matched controls. The authors reported a mean WASO of 12 minutes in the esports athlete group and 9 minutes in the control group. Taken together, evidence from this thesis and the wider literature shows a clear discrepancy in WASO based on the sleep measure used (i.e. wrist activity monitors may overestimate WASO relative to sleep diaries), which is a commonly reported bias in the sleep literature (Short et al., 2012). What we can conclude from this discrepancy is that the perception of esports athletes is that they experience minimal disruption to their sleep during the night after falling asleep.

However, objectively, wrist activity monitor estimates indicate they sleep worse during the night than they perceive. Evidence suggests that the wrist activity monitor used in the present thesis (i.e. the Readiband developed by Fatigue Science) has good agreement with PSG (Chinoy et al., 2021). Thus, based on this evidence, WASO may be an issue for some esports athletes, similar to traditional athletes (Gupta et al., 2017). In Chapter 3, we suggested that the observed excessive WASO might be due to insomnia or sleep-disordered breathing. We discuss these possibilities further in subsequent sections, but it is worth briefly noting that there is currently limited evidence to support either hypothesis. However, it should be highlighted that younger males have been shown to move more during the night but still be asleep (Short et al., 2012). Hence, we cannot discount the possibility that findings of excessive WASO may be overestimated. In summary, WASO estimates for esports athletes may be problematic and appear to vary as a function of the sleep measure used; while the effect of region and game played is less evident from the available research.

#### *7.3.1.4 Sleep Timing (Sleep Onset and Wake-Up Time)*

A notable finding from the present thesis was the consistent observation of delayed sleep timing in all studies that assessed the sleep patterns of esports athletes. In Chapter 3, median sleep onset and wake-up time was 2:00–9:51 am in the US, 3:40–10:51 am in Australia and 4:50 am–12:08 pm in South Korea. In Chapter 4, the mean sleep onset and wake-up time for all participants was 3:42–11:06 am based on sleep diary estimates and 4:00–11:36 am based on wrist activity monitor estimates. In Chapter 6, where we assessed sleep at pre-competition, across competition and post-competition, mean sleep onset varied between approximately 2:24 am and 3:30 am, while wake-up time varied between 10:24 am and 11:40 am. When considering the esports sleep literature more broadly, findings from the present thesis have been corroborated in other research.

In one study, Gomes et al. (2021) measured the sleep of Brazilian LoL esports athletes using wrist activity monitors. The authors reported sleep onset times that ranged from 1:38–2:17 am and wake-up times from 8:53–9:58 am. Similarly, Sanz-Milone et al. (2021) measured the sleep of Brazilian Counter-Strike: Global Offensive esports athletes using wrist activity monitors. Results revealed sleep onset times that ranged from 2:26 am to 2:35 am and wake-up times from 9:45 am to 10:03 am. In the most extreme example of delayed sleep timing to date, S. Lee et al. (2020) measured the sleep of South Korean LoL and Overwatch esports athletes using a sleep diary. They found a mean sleep onset of 5:04 am and a wake-up time of 12:13 pm. Based on the findings from Chapter 3 and Lee et al., esports athletes from South Korea seem to have more delayed sleep timing than their peers from other countries, which aligns with previous studies in the general sleep literature (e.g. Kuula et al., 2019).

In addition to direct measures of sleep (i.e. sleep diary and wrist activity monitors), two studies also implemented questionnaires (i.e. morningness-eveningness questionnaire) to assess the chronotype of esports athletes (Gomes et al., 2021; Sanz-Milone et al., 2021). Approximately 58–62% of participants were classified as evening types, while none were classified as morning types. Collectively, these findings indicate that delayed sleep timing appears to be a common experience for esports athletes, consistent with the sleep patterns of young people and casual gamers (De Rosa et al., 2023; Kuula et al., 2019). Furthermore, delayed sleep timing among esports athletes presents across several regions, games played and sleep measures used, but esports athletes from South Korea may have the biggest delay in their sleep timing.

#### *7.3.1.5 Total Sleep Time*

Most studies from the present thesis revealed evidence of inadequate TST among esports athletes. In Chapter 3, median wrist activity monitor estimates of TST ranged from

6.7 hours in the US to 6.8 hours in Australia and 6.8 hours in South Korea. Similarly, in Chapter 4, mean wrist activity monitor estimates for all participants as a group was 6.9 hours, while sleep diary estimates were 7.4 hours. Other studies in the literature have reported similar findings. Based on wrist activity monitor estimates, Gomes et al. (2021) observed that TST ranged from 6.5 to 6.6 hours per night in a group of Brazilian LoL esports athletes. Furthermore, based on sleep diary estimates, S. Lee et al. (2020) found that TST was 7.2 hours per night in a group of LoL and Overwatch esports athletes. However, in contrast to these findings, in Chapter 6, where we examined the sleep of Rocket League esports athletes at pre-competition, across competition and post-competition, we found that TST was generally higher and varied between 7.5 and 8.6 hours per night. Apart from the bias for sleep diaries to overestimate TST relative to wrist activity monitors, one plausible reason for the different findings in Chapter 6 is that competition games were scheduled for later in the day (i.e. 5:00 pm), meaning there may have been fewer reasons to wake up earlier. Together, these findings indicate that low TST may be an issue for many, but not all, esports athletes. Importantly, this finding was observed across several regions, games played and sleep measures used. Inadequate TST is common among both traditional athletes and young people (Kuula et al., 2019; Walsh et al., 2021); thus, some esports athletes appear to share this sleep characteristic.

#### *7.3.1.6 Sleep Questionnaires*

The ISI, which has a clinical cut-off of 10 (86.1% sensitivity, 87.7% specificity; Morin et al., 2011), was used in Chapters 3 and 4 to assess the presence and severity of insomnia symptoms in esports athletes. In Chapter 3, the median scores for esports athletes were 10.5 in South Korea, 10.5 in Australia and 9 in the US, with a total sample median score of 10 and no significant differences across countries. Similarly, in Chapter 4, the total sample mean score was 10.5. To the best of our knowledge, no other studies have implemented the

ISI specifically with professional esports athletes. Keeping in mind that the ISI has not been validated in an esports population, the results from this thesis revealed some mean scores that marginally exceeded the clinical cut-off. Thus, insomnia may be a risk factor for esports athletes, which we discuss further below.

Sleepiness levels in esports athletes were also measured. In Chapters 3 and 4, a modified version of the PDSS was used, which has a clinical cut-off for excessive sleepiness of 15 (Meyer et al., 2018). In Chapter 3, the mean scores for esports athletes were 16.5 in South Korea, 14 in Australia and 13 in the US. The total sample mean was 15, with no significant difference between countries. In Chapter 4, the total sample mean score was 14.75. These findings show that despite estimates of low TST, not all esports athletes from the present thesis reported subjective estimates of excessive sleepiness, though scores from Australia and the US were approaching the clinical cut-off. This finding aligns with other studies. For example, Gomes et al. (2021) found in a group of Brazilian LoL esports athletes that the mean daytime sleepiness score (measured via the Epworth Sleepiness Scale) was below the clinical cut-off. Likewise, Sanz-Milone et al. (2021) found in a group of Brazilian Counter-Strike: Global Offensive esports athletes that the mean daytime sleepiness score (measured via the Epworth Sleepiness Scale) was below the clinical cut-off. However, S. Lee et al. (2020) found in a group of South Korean LoL and Overwatch esports athletes that mean daytime sleepiness scores (measured via the PDSS) exceeded the clinical cut-off. Collectively, these findings highlight potential regional variations in sleepiness levels among esports athletes and generally lower levels of sleepiness than might have been predicted based on low TST estimates.

#### *7.3.1.7 Sleep and Mood (Depression and Anxiety)*

As described in Chapter 1, sleep has a well-established relationship with mood (i.e. depression and anxiety). Hence, we sought to examine whether this relationship presented among esports athletes, particularly in light of our findings regarding low TST estimates. However, several methodological challenges were presented over the course of the present thesis, making this task difficult. In Chapter 3, we found that some aspects of sleep (i.e. time in bed, the number of awakenings, wake-up time and WASO but not TST) correlated with depression scores but not with anxiety scores. In this Chapter, we were limited to more rudimentary statistical analysis owing to our small sample size, making it difficult to ascertain anything other than the presence of a relationship between these variables.

Likewise, in Chapter 6, where we examined the relationship between sleep and depression (among other things) in pre-competition, across competition and post-competition, we were again restricted to correlations owing to a similarly small sample size. In this instance, we observed no relationship between sleep (SOL, WASO and TST) and depression scores. However, it is worth noting that TST, WASO and SOL (apart from three nights) were within normal limits, decreasing the likelihood of observing a relationship. In Chapter 4, we implemented a brief sleep intervention designed to improve not only sleep but also potentially mood (i.e. depression and anxiety) and cognitive performance. However, apart from some modest benefits, sleep was largely unchanged. Hence, because we were unable to manipulate sleep, there was no change in mood, as has been seen in other research that extended the TST of sleep-deprived adolescents (e.g. Dewald-Kaufmann et al., 2014).

Together, all three studies were restricted in their ability to observe the effect of sleep on mood. Furthermore, outside of the present thesis, no other research of which we are aware has examined the relationship between sleep and mood in professional esports athletes. Thus, findings from the present thesis provide limited insight regarding this relationship. In a recent perspective paper, Kegelaers et al. (2024) highlighted the need for researchers to focus on mental health in esports athletes, given their exposure to a range of stressors (e.g. expectations, interpersonal conflict and external criticism) and lack of mental health support systems within esports. To this end, further investigation into the potential influence of sleep on mood disturbances is warranted.

#### *7.3.1.8 Sleep and Cognitive Performance*

Similar to mood, there is a well-known relationship between sleep and cognitive functioning (Smithies et al., 2021). In Chapter 1, we outlined how sleep restriction can deleteriously affect multiple domains of cognitive functioning, particularly rudimentary tasks such as vigilant attention (Van Dongen et al., 2003). Given that there is a strong cognitive emphasis in esports (Pedraza-Ramirez et al., 2020), we attempted to explore the potential association between sleep behaviour and cognitive functioning specific to the esports context. With this objective in mind, we included the PVT in two studies, focusing on reaction time, one of the main outcome metrics generated by this test. However, similar to mood, we were hampered by methodological challenges in both studies.

In the study in Chapter 4, where we implemented a brief sleep intervention, we failed to improve sleep meaningfully; therefore, as expected, we did not see any subsequent change in reaction time. Likewise, in Chapter 6, esports athletes obtained subjective TST over 8 hours on most nights pre-competition, across competition and post-competition. With TST in this range, we were unlikely to see any effect on reaction time, which we did not (based on correlations). As with mood, no other studies have investigated the relationship between sleep and cognitive functioning. According to Smithies et al. (2021), esports athletes can be classified as elite cognitive performers. Thus, despite the aforementioned methodological challenges experienced in the present thesis, the relationship between sleep and cognitive functioning remains an important domain of esports research. Indeed, we note that other researchers have started investigating the potential role of nutrition (Goulart et al., 2023; Szot et al., 2022) and exercise (McNulty et al., 2023; Toth et al., 2020) for improving cognitive functioning in esports athletes, highlighting the importance being placed on this aspect of esports performance.

#### *7.3.1.9 Summary of Sleep Behaviour, Mood and Cognitive Performance in Esports*

Although initial studies found acceptable estimates of TST and sleep quality among esports athletes (Rudolf et al., 2020; Thomas et al., 2019), this was most likely a function of methodological shortcomings rather than a true reflection of sleep behaviour. In contrast, findings from this thesis (which forms the bulk of published studies) and several other studies paint a contrasting picture. Across several regions and games played, sleep diary and wrist activity monitor estimates strongly suggest that esports athletes have very delayed sleep patterns. Most studies indicate esports athletes obtain insufficient TST (close to or < 7 hours per night), with the possible exception being Rocket League esports athletes from the Oceanic region. SOL is typically adequate (although possibly worsens around competition), whereas WASO may be problematic and differs based on the measure used (i.e. objective measures exceed subjective measures). Overall, many, but not all, of these findings are consistent with the sleep characteristics of the related populations outlined in Chapter 1, namely, young people, traditional athletes and casual gamers. In terms of other sleep-related aspects, preliminary evidence suggests that despite low TST estimates, excessive daytime sleepiness may not be widespread, although some regional variation was noted. Furthermore, initial screening for insomnia symptoms shows that further investigation is warranted. With respect to sleep and mood, there is some indication of a relationship; however, methodological challenges limit our ability to draw meaningful conclusions. Likewise, we also faced methodological challenges examining the relationship between sleep and cognitive performance (i.e. PVT and reaction time). Further research on both fronts is required.

### 7.3.2 Aim 2: Risk Factors for Poor Sleep in Esports

A number of risk factors for poor sleep in esports were initially proposed by Bonnar, Castine et al. (2019), including caffeine use, air travel, elevated arousal on pre-competition and competition nights, evening technology use, sleep disorders and performance-enhancing substances (e.g. Adderall). In Chapter 2, game genre and gaming culture were also proposed as potential risk factors. Over the past few years, evidence has emerged supporting some of these risk factors, while others previously not considered have been identified as research has progressed over time.

#### *7.3.2.1 Delayed Sleep Timing*

As mentioned earlier, evidence from this thesis (Chapters 3, 4 and 6) and the wider literature (Gomes et al., 2021; S. Lee et al., 2020; Sanz-Milone et al., 2021) demonstrates that many esports athletes have delayed sleep patterns (i.e. late sleep onset and wake-up times), with some likely even meeting criteria for delayed sleep-wake phase disorder (Sateia, 2014). Furthermore, this evidence was observed across multiple regions (i.e. North America, South Korea, Oceania and South America), which suggests delayed sleep timing may be a widespread risk factor for poor sleep among esports athletes. It is worth noting that in addition to the natural delay in sleep timing seen in young people, findings from Chapters 2, 3 and 5 and S. Lee et al. (2020) suggest that late training schedules might also contribute to esports athletes' decision to delay going to sleep (noting there may be other reasons as well which are discussed later). However, delayed circadian timing is not inherently a problem or harmful. Research shows that when individuals with delayed sleep timing are allowed to sleep when they desire and without interruption, they can achieve adequate TST (Sateia, 2014).

However, in light of our findings and other research indicating many esports athletes are sleep restricted (e.g. Gomes et al., 2021; S. Lee et al., 2020), it would seem that participants in these studies were not being provided the opportunity to sleep in until their desired wake-up time. Although we cannot specifically determine what compelled them to wake up, it is plausible that their professional obligations (e.g. training) may have curtailed their ability to sleep in. This phenomenon is similar to what happens to young people attending school. Many school students experience delayed sleep timing, but inflexible school start times necessitate an early wake-up time, resulting in insufficient TST (Gariepy et al., 2020; Gradisar et al., 2011). Thus, findings from this thesis and the broader literature suggest that delayed sleep timing may be a potentially prominent risk factor for suboptimal sleep among esports athletes.

#### *7.3.2.2 Sleep Disorders*

There is currently minimal evidence available regarding the presence of sleep disorders in esports. Bonnar, Castine et al. (2019) originally proposed that the sedentary nature of esports participation may lead to negative health outcomes (e.g. overweight) and increased risk of associated sleep disturbances (i.e. obstructive sleep apnoea). Indeed, meta-analytic evidence from casual gamers suggests that non-active video games are related to increased BMI (Marker et al., 2022). Likewise, increased screen time is linked to unhealthy lifestyle behaviours and the risk of being overweight in adults (Arnaez et al., 2018). However, despite the apparent relationship between playing video games and higher weight status, findings from the last few years regarding esports athletes are mixed. For example, in the study in Chapter 3, we found that the overall average BMI of esports athletes from South Korea, Australia and the US was in the healthy weight range but approaching the pre-obesity range (i.e. BMI = 24.7); South Korean participants were in the pre-obesity range (i.e. BMI = 25.2). In the study in Chapter 5, we found similar but slightly different results. That is, once again, the overall average BMI of participants from South Korea, Australia and the US was in the healthy weight range, yet this time it was US participants who were in the pre-obesity range. In the study in Chapter 6, participants were in the healthy weight range (i.e. BMI = 23.8). Looking more broadly at the literature, evidence from a sample of 1,772 esports athletes from 65 countries demonstrated that participants were more likely (~10%) to be in the healthy weight range compared with the general population but were also more likely to be in the morbidly obese range (~4%; Trotter et al., 2020). This finding aligns with recent research, which shows that professional esports athletes report less sedentary behaviour and more physical activity than casual gamers (Dowdell et al., 2024). Taken together, current evidence from this thesis and other studies indicates that weight as a risk for sleep-disordered breathing (sleep apnoea) in esports is marginal. However, a small proportion of esports athletes may be at risk.

Insomnia, a common sleep disorder in the general population (Cunnington et al., 2013), is another potential sleep disorder that could affect the sleep of esports athletes. Insomnia is defined as a persistent sleep complaint characterised by difficulty falling asleep, staying asleep or waking too early (Morin et al., 2015). It must occur at least three times a week for more than three months, be associated with daytime impairments (e.g. fatigue, attention or concentration issues) and cannot be better accounted for by another sleep or psychiatric disorder (Morin et al., 2015). Sleep is sensitive to the hyperarousal effects of stress, which is why insomnia is often precipitated by stressful life events (Harvey, 2002).

The relationship between sleep and stress is pertinent, given that current research in esports indicates that high stress is common because of factors such as performance expectations and a desire to win (Leis et al., 2022; Poulus et al., 2022a). To date, no research has specifically investigated the prevalence of insomnia in esports. However, in the studies in Chapters 3 and 4 of this thesis, the ISI, a commonly used insomnia screening questionnaire, was used to measure symptoms of sleep disturbance. Results indicate that, on average, participants from the study in Chapter 3 equalled the clinical cut-off of 10, while participants from the study in Chapter 4 exceeded it, albeit to a small degree. Based on this evidence, some esports athletes may experience symptoms of insomnia. Findings from the sports science literature show a high prevalence of insomnia symptoms in traditional athletes (Gupta et al., 2017), but it is too soon to say whether this is also the case in esports. However, given the range of consequences associated with insomnia (e.g. daytime impairments; Cameron et al., 2017), there is a need to understand whether this is an issue for esports athletes. Hence, further research is warranted to determine the prevalence rates of esports athletes who meet the full insomnia diagnostic criteria.

#### *7.3.2.3 Competition-Related Anxiety*

Several studies in the sports science literature have reported that competition-related anxiety is linked with suboptimal sleep outcomes around competition (Ehrlenspiel et al., 2018; Juliff et al., 2015). Theoretically, sleep is affected by anxiety owing to the activation of the sympathetic nervous system and an associated increase in physiological arousal (Harvey, 2002). To probe whether this also occurred in esports, in the studies in Chapters 3 and 4, we used a retrospective single-item question to assess in the last 12 months whether participants had experienced a sleep disturbance (i.e. sleep initiation, maintenance or early awakening) the night before a competition. Results revealed that 49–53% of participants indicated they had.

Subsequently, to explore this line of inquiry further, we prospectively measured the sleep behaviour and evening anxiety of 16 Rocket League esports athletes' pre-competition (i.e. the week leading up to competition) and across competition (i.e. three days and two nights). First, using the same retrospective single-item question from studies in Chapters 3 and 4, we found further evidence that sleep disturbances may be common (68%) among esports athletes, with SOL being the most frequently affected, followed by WASO. Sleep diary estimates corroborated this finding. Both SOL and WASO increased relative to the pre-competition period, although only SOL reached clinically significant levels. Notably, impaired SOL is the most often-cited problem for traditional athletes around competition (Juliff et al., 2015).

However, despite the finding of deterioration in SOL and WASO, the correlational analysis showed no relationship between anxiety and sleep (SOL, WASO and TST). Because of our small sample size, we were limited to rudimentary statistical analyses, which decreased the strength of our conclusions. Furthermore, the relationship between sleep and anxiety needs to be examined in other esports populations and at higher levels of competition. Hence, additional research is required to examine whether competition-related anxiety is a risk factor for poor sleep in esports. Especially in light of research showing that stress around competition appears common in esports (Leis et al., 2022; Poulus et al., 2022b; Smith et al., 2019).

#### *7.3.2.4 Competition Schedules*

In the Chapter 5 study, evidence from coaches and support staff indicated that night competitions and congested competitions can both affect the sleep of esports athletes. However, we were unable to determine the exact cause of this impact from the available data given the study's design. Furthermore, to our knowledge, no other studies have investigated this relationship since the Chapter 5 study was published. Thus, at this time, no further clarity has emerged from the literature. However, examining the sports science literature, evidence suggests that competition-related effects can lead to inadequate TST due to a delay in bedtime and reduced sleep opportunity. First, the nature of competition itself can have this effect because of post-competition factors, such as muscle soreness, increased circulating cortisol, sympathetic hyperactivity and lingering high caffeine levels (Roberts et al., 2019). Presumably, the later a competition (and therefore closer to typical bedtime), the more these factors will affect subsequent sleep.

Likewise, congested competition schedules can also contribute to shorter TST via reduced sleep opportunity owing to factors such as sustained competition anticipation, travel and simply being busy (Fullagar, Duffield et al., 2015; Saidi et al., 2022). Relating these findings to esports, some factors may be more relevant to esports athletes than others. For example, it could be speculated that muscle soreness may be unlikely to be as pertinent in esports as it is in traditional sports. In contrast, factors such as increased sympathetic hyperactivity, competition anticipation and simply being busy could plausibly affect esports athletes. Additionally, we speculated in the Chapter 5 study that there could be esports-specific factors associated with competition that could also affect their sleep. For example, we outlined the possible role of 'grinding' (i.e. training for excessive hours), whereby esports athletes feel the pressure to restrict sleep opportunity to obtain extra practice during multi-day competitions. Although this hypothesis remains to be tested, grind culture is prevalent in esports and is considered an effective practice model for success by esports athletes (McGee, 2021). Overall, a significant volume of research is required to elucidate the impact and mechanistic relationship of competition on the sleep patterns of esports athletes.

#### *7.3.2.5 Caffeine*

Caffeine is likely the most widely consumed psychoactive substance in the world (Ahluwalia et al., 2014; Fulgoni et al., 2015; Heckman et al., 2010) and a common ergogenic aid used by traditional athletes (Del Coso et al., 2011). However, caffeine can negatively affect sleep because it influences the homeostatic process (Process S) of sleep-wake regulation (Gardiner et al., 2023). Specifically, caffeine is an adenosine-receptor antagonist that blocks the action of adenosine, resulting in stimulation of the central nervous system and an associated decrease in perceived fatigue and sleepiness (Gardiner et al., 2023; O'Callaghan et al., 2018). Thus, given the variability in caffeine half-life (i.e. 3–5 hours;

McLellan et al., 2016), poorly timed caffeine consumption can lead to longer SOL, shorter TST and reduced sleep efficiency (Gardiner et al., 2023).

In the Bonnar, Castine et al. (2019) opinion piece, it was suggested that caffeine use may be high among esports athletes owing to the prominence of major energy drink brands (i.e. Redbull and Monster Energy) within the esports industry. Indeed, higher frequency exposure to energy drink advertisements and sponsorship has been found to increase the purchasing likelihood of featured products in US university-level esports athletes (Roscoe et al., 2023). However, findings from this thesis suggest that caffeine consumption by professional esports athletes in some regions and games may be non-problematic. In the Chapter 4 study, we found using a single-item retrospective question that 76% of esports athletes from South Korea, Australia and the US consumed less than 200 mg of caffeine per day. This finding is consistent with other studies showing low levels of caffeine consumption using prospective measures of nutrient intake, although samples in these studies contained a mix of non-professionals and professionals (Goulart et al., 2023; Ribeiro et al., 2023). Importantly, caffeine consumption under 400 mg per day is considered safe (Verster & Koenig, 2018). Additionally, we observed in the Chapter 6 study that the average timing of last caffeine consumption was 7.5–9 hours before lights-out time. Overall, despite the initial proposal by Bonnar et al., preliminary evidence to date suggests that caffeine may be consumed by esports athletes (in some regions and games) in a non-harmful manner (i.e. amount and timing) with respect to sleep.

#### *7.3.2.6 Gaming Culture*

In Chapter 2, we proposed that gaming culture may serve as a risk factor for poor sleep in esports. Specifically, we outlined how, in esports, there is a largely unstructured pathway from amateur to professional, although this has slowly improved. During these formative years, aspiring professional esports athletes may be exposed to a gaming culture that does not value sleep. This exposure may inadvertently contribute to dysfunctional beliefs about sleep (e.g. grinding is more important than sleep) that are then carried into professional environments, negatively influencing sleep-related behaviour. Since the study in Chapter 2 was published, no research has examined this idea further. Thus, as it currently stands, no empirical evidence supports this hypothesis. However, other authors have echoed the idea that gaming culture can influence behaviour in esports and expanded on it in other ways.

In a book regarding esports medicine, McGee (2021) highlights that in addition to gaming culture influencing behaviour, it may also breed a level of scepticism among esports athletes that makes them averse to accepting assistance from healthcare professionals. The authors sum up the attitude of esports athletes as, 'I got to a professional level without you, why do I need you now?' (McGee, 2021, p. 244). While not all esports athletes would share this attitude, the author's observation highlights the possibility that gaming culture may have a pervasive influence on health behaviour (including sleep) and engagement with healthcare providers. From a sleep perspective, resistance to engagement with healthcare professionals is pertinent, given research showing that young people find it particularly difficult to engage in sleep-related behavioural changes (Micic et al., 2019). Together, further research is needed to elucidate the influence gaming culture has on the beliefs and behaviour of aspiring esports athletes and current professionals.

#### *7.3.2.7 Game Title*

Another possible risk factor for poor sleep in esports that we outlined in Chapter 2 was game genre (e.g. FPS, MOBA and sports). This proposal was based on evidence from the sports science literature demonstrating differences based on the type of sport played. For example, traditional athletes who play individual sports obtain less TST than those from team sports (Lastella et al., 2015), while high-intensity traditional athletes have better sleep quality compared with low-intensity traditional athletes (Suppiah et al., 2015). No research has yet investigated whether these kinds of differences exist in esports. However, in addition to game genre, individual game titles may also potentially influence sleep outcomes (i.e. even games within the same genre). In the literature, there is a tendency for studies to conflate esports athletes from different games when discussing findings (e.g. Bányai et al., 2019) or samples are made up of esports athletes from different games (e.g. Giakoni-Ramírez et al., 2022). To be clear, this is not a criticism of these studies. For example, it is understandable that given the difficulty of recruiting professional esports athletes, researchers may seek to increase the sample size by mixing esports athletes together (which is the approach taken in the Chapter 4 study). However, some authors have raised mixed samples as an issue and recommended not assuming that all esports athletes are the same, similar to how not all traditional athletes are the same (e.g. Poulus et al., 2020). Importantly, this assertion has implications for sleep research in esports.

If esports athletes from different games do experience variable sleep outcomes, then sleep interventions would need to be adapted accordingly. Currently, the available evidence provides little insight regarding this question owing to confounding factors such as regional variation (e.g. Chapter 3) and the use of different sleep measures (Chapter 3 v. Chapter 6). However, Gomes et al.'s (2021) and Sanz-Milone et al.'s (2021) studies were both conducted in Brazil using wrist activity monitors with esports athletes from separate games, namely, Counter-Strike: Global Offensive and LoL. Although we cannot infer whether the results reported in these studies are significantly different, there appears to be a notable difference between SOL, sleep onset and wake-up times on face value. Clearly, further research is required to explore potential differences in sleep outcomes based on the game played.

#### *7.3.2.8 A Conceptual Model for Explaining Risk Factors*

As suggested in Chapter 2, it may be useful to have a conceptual model that aims to provide a comprehensive understanding of the multifaceted factors influencing sleep problems in esports, facilitating targeted interventions and strategies to optimise sleep health, enhance performance and promote the overall wellbeing of esports athletes. To this end, we proposed that Spielman's 3-P model, used to understand and treat insomnia, could be adapted for use in an esports context. To provide a brief overview, the 3-P model refers to three factors that contribute to the development and maintenance of insomnia: *predisposing* factors (i.e. vulnerabilities that increase the risk of developing insomnia), *precipitating* factors (i.e. events that trigger an initial sleep problem) and *perpetuating* factors (i.e. maladaptive cognitions and behaviours that are intended to help manage the sleep disturbance but instead contribute to its maintenance; Perlis et al., 2011). Chapter 2 outlined examples of esports-specific risk factors under these categories. However, we now believe further research is required to increase certainty and depth in our understanding of these factors and how they interact with sleep in an esports context. Nevertheless, the 3-P model remains a potentially viable framework for guiding future investigations.

#### *7.3.2.9 Summary of Risk Factors for Poor Sleep in Esports*

Findings from this thesis have contributed to the collective understanding of the risk factors associated with suboptimal sleep in esports. Based on the available data, evidence supporting the risk factors described above varies in quantity and strength. Delayed sleep timing has emerged as a consistent risk factor, with converging lines of evidence from multiple studies showing similar findings, using different sleep measures and across several geographical regions and games played. Based on preliminary evidence, some risk factors appear less impactful (i.e. sleep-disordered breathing and caffeine use). However, most potential risk factors (i.e. insomnia, competition-related anxiety, competition schedules, gaming culture and game title) require further investigation before firm conclusions can be drawn. Lastly, Spielman's 3P model may be a useful conceptual model that could be used to explain the relationship between risk factors and suboptimal sleep in esports.

### 7.3.3 Aim 3: Sleep Interventions

Of all our aims, Aim 3 is perhaps the most difficult to discuss in relation to the wider literature, as to the best of our knowledge, the studies presented in this thesis are the only ones to explore sleep interventions in an esports population directly. On the one hand, this highlights the pioneering nature of our research. However, the absence of comparable studies limits our ability to contextualise our findings within the broader esports literature. Accordingly, while it is difficult to add anything new over and above what we have already described in previous chapters, in this section, we try to establish a foundational understanding of the current evidence regarding sleep interventions in esports.

In Chapter 2, along with Spielman's 3-P model (discussed above), we made several theoretically grounded sleep intervention suggestions. These related to genre-related effects (reconceptualised as game-related effects), unconventional training schedules, wind-down time, basic cognitive therapy techniques, jet lag, motivational content and early intervention. Since then, some of these interventions have been trialled (i.e. wind-down time, unconventional training schedules and motivational interviewing in Chapter 4). However, the effect of these interventions cannot be isolated, while the others remain untested. Although these intervention suggestions likely have merit, further research is required to better understand their potential clinical utility and application in an esports context.

In Chapter 4, we implemented the first and only sleep intervention to date, with 56 participants from South Korea, Australia and the US. The intervention was brief (i.e. two weeks), was low intensity and had multiple components. More specifically, the intervention included a group sleep education class, daily biofeedback from a wrist activity monitor, and a 30-minute individual session with a clinical psychologist, which covered the four rules of brief behavioural therapy for insomnia, a relaxation task and motivational interviewing questions to enhance treatment compliance. This intervention design was influenced by some of the considerations outlined in Chapter 2 and generally used a cognitive behavioural framework. Overall, there were only modest sleep benefits, with slight changes for subjective and objective sleep onset time, and subjective SOL and sleep efficiency. Notably, sleep did not improve enough to affect change in mood (i.e. depression and anxiety) or cognitive performance (i.e. reaction time measured via the PVT).

Examining the sports science literature, findings from Chapter 4 align with similar brief sleep interventions for traditional athletes that are not individualised (Van Ryswyk et al., 2017). That is, brief interventions may be effective if they are more targeted. Furthermore, because it was a multi-component intervention, we cannot isolate the effect of individual components. Based on the lack of improvement, we outlined several considerations for future interventions. These included creating a stepped-care model to meet the idiosyncratic sleep needs of esports athletes (i.e. matching the dose to individual sleep needs), gamifying intervention content, including coaches and support staff in intervention delivery, better understanding poor sleep risk factors in esports and incorporating more motivational content.

In the Chapter 5 study, our focus shifted towards an exploration of the role coaches and support staff play in supporting the sleep health of esports athletes, building upon the suggestion outlined in Chapter 4. We found that many coaches and support staff already play an active role in supporting the sleep health of their esports athletes at both a professional and semi-professional level. While rates of sleep monitoring were low (48%), implementation of sleep hygiene practices was higher (66%). The primary barrier to sleep monitoring and sleep hygiene practices was esports athletes' dislike of the process, which demonstrates the importance of developing engaging interventions. Speaking more broadly, we suggested that with appropriate education, coaches and support staff could potentially be leveraged to provide entry-level sleep health support to esports athletes in a stepped-care model. Of course, this idea remains to be tested, although it appears conceptually and pragmatically promising.

#### *7.3.3.1 Summary of Sleep Interventions*

Thus far, only studies from the present thesis have investigated sleep interventions in an esports population, making this part of the literature the least developed of those discussed. The one sleep intervention trialled to date only produced modest sleep benefits and no mood or cognitive performance benefits. A range of sleep intervention components have been proposed, but many of them are yet to be thoroughly explored before their clinical utility can be determined. Furthermore, a new framework (i.e. a stepped-care model) has been suggested, but this also needs to be investigated. Overall, although the scarcity of direct research in this space limits the conclusions that can be drawn, our contributions help lay a foundation for future investigations.

## 7.4 Methodological Implications

Throughout this thesis, several noteworthy methodological limitations have emerged. These limitations encompass various methodological aspects, including the selection of measurement tools, sampling methods and manipulation of variables. Considering these limitations in future investigations will contribute to the ongoing development of rigorous, insightful and pragmatic research practices within esports.

#### *7.4.1.1 Selection of Measurement Tools*

Despite significant logistical challenges, we managed to use wrist activity monitors in the studies in Chapters 3 and 4. However, in the Chapter 6 study, we were restricted to using a sleep diary. Online sleep diaries are cheap and easy to disseminate (Walsh et al., 2021) and are particularly useful for geographically spread participants (Mallinson et al., 2019), as is often the case in esports. Furthermore, they provide additional information about other sleep-related behaviours, such as caffeine and alcohol use (Carney et al., 2012). This makes them an obvious choice in esports sleep research. However, without a concurrent objective sleep measure, sleep diaries can only provide insight into a participant's perception of their sleep (Carney et al., 2012). In contrast, objective measures provide accurate and impartial information about an individual's sleep that is free of bias (Martin & Hakim, 2011). Thus, there is a strong rationale for incorporating objective sleep measures into esports sleep research.

In the future, nearables (i.e. radar and microphone based) may offer an alternative to wrist activity monitors. This type of nearable technology encompasses phone applications that can be downloaded from mobile application stores (Hathorn et al., 2023). Although they currently lack the necessary validation, the major benefit of mobile applications is that they can be easily downloaded and are completely unobtrusive, only needing to be placed close to the user while sleeping (T. Lee et al., 2023). Thus, nearable phone applications could potentially solve the dissemination problem associated with wrist activity monitors. However, time will tell whether their performance can reach a research-grade level.

#### *7.4.1.2 Sampling*

Throughout this thesis, we have mentioned several times that recruiting professional esports athletes poses significant challenges owing to their busy schedules and focus on training and competition. Consequently, despite the rapid increase in esports publications since this thesis commenced in 2019, relatively few studies have samples comprising professional esports athletes. When browsing the literature, it would appear that these recruitment challenges have prompted researchers to explore alternatives such as working with easier-to-recruit populations (e.g. ranked esports athletes or casual gamers) or conducting various types of reviews (e.g. perspective, narrative or systematic), which do not require participants. Unfortunately, the scarcity of empirical studies involving professional esports athletes limits the availability of data necessary for making evidence-based decisions regarding optimising performance, health and welfare.

Essentially, professional esports athletes and those working with them (e.g. coaches, support staff and managers) remain largely empirically uninformed. This situation emphasises the need for solutions to enhance recruitment in the esports field, benefitting both the esports industry and researchers alike. Taking a broad approach, this could include researchers and universities establishing collaborative relationships with game publishers, esports organisations and their esports athletes. This type of partnership offers several advantages for both parties. It would increase access to potential participants and ensure that research aligns with industry needs, producing more applicable findings that increase the practical impact of scientific discoveries (Harman, 2001). Furthermore, collaborative efforts would foster mutual learning while also encouraging resource optimisation and utilisation (Harman, 2001). Ultimately, this is only one idea, and there are likely a multitude that will be required to overcome the issue of recruitment.

Moreover, a primary consequence of the challenge in recruiting professional esports athletes is that sample sizes are inevitably smaller, consistent with the sports science literature where small sample sizes are common (see Bonnar et al., 2018). However, the esports research community's approach to small sample sizes remains to be seen. From our perspective, we encourage reviewers to engage in open and constructive dialogue with authors around the use of small sample sizes while equally keeping in mind the context-specific challenges of conducting research with professional esports athletes. With appropriate methodology design, well-considered statistical analysis and clear communication to the reader, some limitations associated with smaller sample sizes can be mitigated. Another approach to addressing small samples is to collect more rich data, whether it be measures designed to triangulate and thus validate each other or even the combination of quantitative and qualitative measures. Furthermore, if researchers are transparent about the limitations of their studies, this enables the reader to consider how they may affect the interpretation of results. Overall, in the broader context, for the esports research field to advance, there needs to be some level of understanding and acceptance of the practical constraints that may necessitate smaller sample sizes when conducting research with professional esports athletes.

The final point concerning sampling regards external validity constraints. As noted earlier, it has been proposed in this thesis and by other authors (Poulus et al., 2020) that esports athletes should not be considered homogenous. The unique dynamics, demands and nuances inherent in different games and regions may affect sleep patterns and other sleep-related variables. Therefore, when considering the research findings comprising esports athletes from a particular game and region, caution should be used before extrapolating findings to esports athletes who play other games and live in different regions. For example, in the study in Chapter 6, we recruited Oceanic Rocket League esports athletes. Ideally, the study conducted in that chapter should be replicated in other games and regions. To be clear, we acknowledge there may be some research that can be generalised across games and regions. However, we believe there is a need for deliberate replication of sleep research across various games and regions. This process will ensure that findings represent the diverse array of esports athletes competing in different games around the world.

#### *7.4.1.3 Manipulation of Variables*

As noted throughout this thesis, owing to methodological limitations (e.g. study design and rudimentary statistical analysis), we were largely unable to discern the relationship between sleep, mood and cognitive functioning. Despite this, we encourage researchers to continue integrating mood and cognitive functioning measures into esports sleep research where feasible. However, it would appear that study designs that allow direct manipulation of sleep (e.g. sleep dose-response studies) are required to explore these relationships more comprehensively. Notably, previous studies in the general population (e.g. Van Dongen et al., 2003) and traditional athletes (Fullagar, Skorski et al., 2015) have successfully employed such methodologies, providing valuable insights into the impact of sleep restriction on multiple domains of cognitive, emotional and physical functioning. By leveraging a similar approach in esports research, we can begin to elucidate the relationship between sleep, mood and cognitive functioning in esports.

#### *7.4.1.4 Summary of Methodological Implications*

As with any research, there are methodological implications that should be considered for future research. In terms of the selection of measurement tools, although sleep diaries are pragmatically useful, the potential incorporation of nearables (an objective measure of sleep) like radar and microphone-based phone applications in the future presents an avenue for addressing dissemination challenges associated with wrist activity monitors. Sampling challenges related to the recruitment of professional esports athletes have contributed to small sample sizes and external validity constraints. Innovative solutions, including closer collaborative ties between research institutions and industry, acceptance of small sample sizes and wider replication of studies, appear to be needed to address sampling concerns. Lastly, to untangle the potential relationships between sleep and other variables (i.e. mood and cognitive functioning), study designs that enable the direct manipulation of sleep may be necessary.

## 7.5 Clinical Implications

Throughout this thesis, several clinical recommendations have been provided. This section attempts to synthesise these recommendations and explore how they relate to future intervention planning and delivery for professional esports athletes. However, although this discussion is grounded in current knowledge, we acknowledge there is still much we need to learn about the sleep behaviour of esports athletes, which will ultimately influence the way in which their sleep health is supported moving forward.

### 7.5.1 Intervention Aims

The most common problematic sleep characteristics for esports athletes appear to be delayed sleep timing, possible long WASO, restricted TST and long SOL around competitions. While it is important to be mindful of these characteristics, esports athletes may likely encounter a spectrum of sleep-related challenges. Thus, an effective sleep intervention for esports athletes would need the capacity and responsiveness to accommodate these idiosyncratic sleep needs. The general aim of an intervention would be both to protect sleep (for esports athletes who are already sleeping well) and improve sleep (for esports athletes who experience suboptimal sleep).

### 7.5.2 The Need for Brevity

Professional esports athletes are known to lead very busy lives (Paravizo & de Souza, 2021) with a focus on training and competition. Additionally, in our experience, professional esports organisations face many competing operational demands. Accordingly, interventions, whether focused on sleep or other health behaviours, must be brief and targeted to fit within the demanding schedules of esports athletes and the broader operational dynamics of esports organisations. Keeping this need in mind when designing and delivering a sleep intervention for esports athletes should increase the likelihood that they will be viable at an individual and organisational level.

### 7.5.3 Intervention Framework: A Stepped-Care Model

Considering the requirements outlined above, a stepped-care model might be a suitable framework for use in esports (as outlined in Chapters 4 and 5). This model allows precise and adaptable care, ensuring that the treatment received aligns with individual sleep needs (Cheung et al., 2019). Thus, not only would a stepped-care model be able to address a range of sleep needs, but it would also minimise the burden on esports athletes and organisations. In other words, rather than a ‘one-size fits all’ approach, esports athletes would receive the sleep health support necessary to generate the best outcome for their sleep. Stepped-care models have gained popularity recently and have also been recommended for traditional athletes (Walsh et al., 2021).

Initially, at the start of a season, esports athletes should complete a needs-based assessment to determine the appropriate level of intervention required. This assessment would include sleep monitoring, likely using a combination of subjective and objective sleep measures and questionnaires. In the interests of simplicity, we propose only having two levels. In the Chapter 4 study, we suggested ‘at-risk’ and ‘high-risk’ classifications. However, this suggestion has been revised, and instead, ‘basic sleep needs’ and ‘diverse sleep needs’ classifications are recommended. In terms of classification, diverse sleep needs would be those esports athletes who have a suspected sleep disorder (e.g. insomnia), experience acute sleep disturbances (e.g. pre-competition) or report chronic sleep restriction (e.g. < 7 hours per night).

The entry level of a sleep stepped-care model in esports should include a combination of sleep education and sleep hygiene. We suggest that all esports athletes complete this step in a group format, regardless of their sleep need classification. Education content would be pertinent to esports athletes to increase relevance but generally include information related to sleep processes, the risk factors for poor sleep in esports, and the impact of poor sleep on performance and wellbeing. This content would also be gamified where appropriate to aid contextual learning. In addition, sleep hygiene recommendations would be individualised based on information gathered during the sleep needs assessment. With appropriate training, coaches and support staff could potentially be trained to deliver this content.

The second level of a sleep stepped-care model in esports would specifically support esports athletes with more diverse sleep needs. These individuals could be identified through the sleep needs assessment at the start of a season or self-refer as needed during the season. Considering the increased complexity of managing these types of sleep issues, this level of care should be delivered by a clinical psychologist trained in behavioural sleep medicine. Sessions would occur weekly until the issue is resolved but aim to be brief. Examples of possible treatments include bright light therapy to re-time delayed sleep timing (Richardson et al., 2018), MBSR strategies to manage competition-related anxiety (Zhou et al., 2020) and motivational interviewing to reduce ambivalence to making sleep-related behavioural change (Gradisar et al., 2014).

### 7.5.4 Other Sleep Intervention Considerations

Naturally, certain intervention considerations may fall outside the scope of the stepped-care model outlined above. A notable example is the management of jet lag for teams travelling to a major competition (see Janse van Rensburg et al., 2021). Given that not all teams qualify for majors, it would be inefficient to allocate time and resources to cover this content universally. Rather, it should be provided on an as-needed basis (i.e. when a team has qualified and is required to travel) by a trained professional, such as a clinical psychologist. Realistically, there are likely few of these types of examples, with the stepped-care model adequately addressing most esports athletes' sleep needs.

### 7.5.5 Summary of Clinical Implications

A sleep intervention for esports athletes must be able to address a multitude of sleep needs but also be brief and targeted to be viable within the constraints of a professional esports organisation. We recommend a stepped-care model as a plausible solution that meets both criteria. Accordingly, we suggest a two-level stepped-care model, servicing esports athletes with basic sleep needs and those with more diverse sleep needs. The aim of such an intervention would be to protect sleep and improve sleep. The first intervention level would include sleep education and sleep hygiene, possibly delivered by coaches and support staff. Moreover, the second intervention level would include more advanced treatments delivered by a clinical psychologist trained in behavioural sleep medicine. In summary, we propose a comprehensive sleep intervention that balances the sleep needs of esports athletes with pragmatism and viability.

## 7.6 Limitations and Future Research Directions

It is important to acknowledge the limitations that shape the findings from the present thesis and the broader literature to advance the sleep and esports field of research. This section highlights these limitations and how they contribute to gaps in the knowledge base. Moreover, it then focuses on the future and extends on the aims of the present thesis by discussing and integrating potential lines of inquiry that could be explored moving forward.

### 7.6.1 Aim 1: Sleep Behaviour, Mood and Cognitive Performance in Esports

In esports research, studies have grouped esports athletes from different games together or examined games in isolation, across some regions, with a mix of subjective and objective sleep measures. Consequently, as noted earlier in this chapter, there are gaps in the knowledge about the sleep behaviour of professional esports athletes from different regions (i.e. Europe and North America) and who play different games (e.g. LoL v. Rocket League within the Oceanic region). In other words, it is currently unknown whether sleep behaviour varies based on the game played (e.g. LoL v. Rocket League) or region of competition (e.g. Oceania v. North America). Hence, future research should seek to fill this gap in knowledge by examining sleep behaviour in more games and across all esports regions, with subjective and objective sleep measures. This information would enable a more nuanced understanding of sleep behaviour in esports, which in turn may inform more personalised sleep intervention design and delivery.

Additionally, most studies have not examined whether there are sleep differences at different phases of the competition schedule during a regular season. Instead, researchers have typically collected data over a specified period (e.g. two weeks) and calculated averages for sleep variables such as TST, SOL and WASO (e.g. as we did the study in Chapter 3). Although this approach is understandable, given that it was in the early stages of the research process, it does not enable a closer examination of sleep behaviour around competition. In the Chapter 6 study, we sought to take a more fine-grained approach by looking at daily variation in sleep outcomes at pre-competition, across competition and post-competition. While this was a good starting point, findings were limited, in part, by external validity constraints. Thus, further research is required to quantify daily variation in sleep behaviour around competition using subjective and objective sleep measures. Furthermore, this should be conducted across various games and regions and at varying levels of competition (e.g. a regular season v. a major). Once again, this will enable esports athletes to receive more tailored sleep health support.

As discussed earlier in this chapter, the interaction between sleep, mood and cognitive functioning was hindered by circumstances outside our control. However, based on evidence from the wider literature (e.g. Firth et al., 2020; Smithies et al., 2021), both relationships remain key areas of research interest. To evaluate these relationships, sleep dose-response study designs are likely required. This type of study design examines the relationship between different amounts of sleep (e.g. 8 hours v. 6 hours. v. 4 hours per night) and outcomes (e.g. mood and cognitive functioning) over a specified period such as two weeks (see Van Dongen et al., 2003 for an example). In esports, sleep restriction protocols would offer high ecological validity. However, there are several considerations for using sleep dose-response studies. Most notably, they are expensive, resource-intensive and time-consuming (Smithies et al., 2021). Moreover, it is extremely unlikely that professionals will be able to be recruited, meaning alternative samples may need to be considered (e.g. semi-professionals). Despite these challenges, untangling these relationships could potentially help optimise mental health and performance.

Prior to the onset of the pandemic, we had plans to investigate the impact of jet lag on sleep among professional esports athletes. However, these plans were abandoned once the pandemic emerged because of travel restrictions and other impediments. However, with a resurgence in live esports events as the pandemic subsided, esports athletes travel regularly for majors and other events again. In the sports science literature, increased research into the impact of jet lag on traditional athletes and their performance/welfare has led to greater awareness of the need for jet lag management (Janse van Rensburg et al., 2021). Likewise, esports athletes are likely also prone to the deleterious effect of jet lag. Although outside the scope of this thesis, esports researchers are encouraged to begin exploring how the sleep of esports athletes is affected when travelling and how it may influence their performance and welfare. Objective measures of sleep (e.g. wrist activity monitors) may be the easiest sleep measure to use in these circumstances owing to their ability to adjust to new time zones automatically, whereas sleep diaries may be confusing for participants as they require manual input, which could be challenging when travelling across time zones.

### 7.6.2 Aim 2: Risk Factors for Poor Sleep in Esports

In the Chapter 5 study, we identified night competitions and congested competitions as risk factors for poor sleep in esports. Of note, this evidence came from coaches and support staff, and not directly from esports athletes. In addition to quantifying actual sleep behaviour (as mentioned above), other study designs should be used to explore the interaction between competition and sleep. For example, future research could use a qualitative study design to elucidate the views of esports athletes. Qualitative designs have been used in other studies with professional esports athletes, which indicates they are an acceptable research approach (e.g. Leis et al., 2022; Poulus et al., 2022c). A notable benefit of qualitative study designs is that they provide information-rich data that enable insight into an individual's subjective experience (Aspers & Corte, 2019). Essentially, a qualitative approach would allow esports athletes to express in their own words how their sleep behaviour interacts with competition schedules. Furthermore, qualitative designs can be useful when dealing with small sample sizes as they do not rely on statistical power (compared with quantitative study designs) and instead rely on data saturation, a threshold whereby new data ceases to emerge, indicating understanding has been achieved (Hennink & Kaiser, 2022).

Although preliminary evidence suggests esports athletes' caffeine use is non-problematic, data from games within various regions (e.g. Europe and North America) is missing. Future research should seek to gather data from these regions across different games to determine whether caffeine use is being consumed in a healthy and non-harmful manner with respect to sleep. As an aside, I worked with a North American team competing in the Call of Duty League while the present thesis was being completed. Anecdotal evidence from this experience suggests that caffeine use may be being consumed at higher levels in this population than has been found in previous research. Preferably, validated dietary assessment tools, such as the caffeine food frequency questionnaire, which prospectively measures average daily caffeine consumption, would be used instead of a single-item retrospective question like what was used in the present thesis (Watson et al., 2017). Furthermore, like sleep diaries, digital versions of caffeine measurement tools are recommended (Meigs et al., 2022).

As noted earlier in this chapter, based on scores from the ISI, some esports athletes may experience insomnia symptoms. However, the prevalence of esports athletes who meet the full criteria for insomnia remains unknown. Broadly speaking, insomnia-related epidemiological research aims to investigate the occurrence and distribution of insomnia within a population (Frérot et al., 2018). This approach provides information regarding the scope of the problem, which in turn informs resource allocation and intervention planning and delivery (Zeng et al., 2020). Cross-sectional study designs are commonly used in this type of research. They are likely practical in esports as they provide a snapshot of insomnia rates at a particular point in time (Zeng et al., 2020). As an example of how this type of research could be conducted in esports, participants could initially be screened with a validated screening tool such as the ISI. Subsequently, those who exceed the clinical cut-off could complete a structured assessment (i.e. clinical interview) in addition to a two-week sleep diary to determine whether they meet sufficient criteria (i.e. based on a diagnostic manual such as the *International Classification for Sleep Disorders: Third Edition*) to warrant a diagnosis of insomnia.

In the Chapter 6 study, we examined the potential link between competition-related anxiety (i.e. cognitive anxiety) and subsequent sleep and found no relationship. However, there were several limitations in Chapter 6 that indicate further research is required before ruling out anxiety as an influencing factor on the sleep of esports athletes. First, participants in the sample did not experience a clinically remarkable increase in anxiety around competition, meaning an impact on sleep was unlikely. Second, it was a small sample size of 16, which meant it was constrained to more rudimentary statistical analysis (i.e. correlational analysis), preventing exploration of the daily interaction between these variables. Third, the presence of cognitive anxiety was measured, and not the direction of anxiety (an individual's interpretation), which can influence how anxiety is experienced. Future research should consider replicating our study at higher levels of competition (which may induce stronger anxiety symptoms), measuring additional anxiety symptoms (i.e. physiological) and the direction of anxiety, and if possible, having larger sample sizes, to address these limitations and further explore the role competition-related anxiety may have on esports athlete sleep. Moreover, this should be done across games and regions.

Delayed sleep timing was a consistent sleep characteristic found across all published studies thus far. However, the reasons for this delay in sleep timing, over and above the normal biological shift experienced by young people (Carskadon, 2002), largely remain unknown. In the Chapter 3 study, we observed that training times appeared to displace sleep timing, supported by qualitative evidence from S. Lee et al. (2020). Although training times may influence sleep timing, it is plausible that there are other things happening between the end of training and sleep that may also have an effect. For example, based on the S. Lee et al. study (2020), we speculated in the Chapter 4 study that bedtime procrastination may play a role in delaying sleep onset. Evidence suggests that bedtime procrastination is related to delayed sleep timing, poor mood, and insomnia symptoms (Chung et al., 2020). Another example is that some esports athletes may have dysfunctional beliefs about sleep (e.g. intense exercise right before bed will help me sleep) that lead to unhelpful behaviour (S. Lee et al., 2020). Moreover, anecdotally, professional esports athletes in games like LoL are very busy and, therefore, attempt to create personal time after training. Together, future research should aim to better understand what happens between the end of training and sleep to ascertain contributing factors to the delay in sleep timing and inform possible treatment targets.

Further to the point raised above about unhelpful beliefs about sleep, in the Chapter 2 study, we suggested that unhelpful beliefs about sleep may develop during the formative years of professional esports athletes owing to gaming culture. Of note, our proposal was not based on empirical data and was speculative in nature (although this idea has been echoed by other researchers; McGee, 2021). Since Chapter 2 was published, no research has empirically examined this proposal. Thus, further research is required to determine if and when unhelpful beliefs about sleep develop and whether aspiring professional esports athletes carry these beliefs into their careers. A cross-sectional design is likely the most pragmatic and viable type of study to answer this research question. From an intervention perspective, this is a particularly important area of research. If our proposal were empirically supported, it would strongly suggest that early intervention is critical in positively shaping the beliefs of esports athletes, which, in turn, would promote good sleep health.

### 7.6.3 Aim 3: Sleep Interventions

Research examining sleep interventions in esports is primarily limited by the few studies in this space. There are several potential avenues that should be explored to expand on this area of research moving forward. Broadly speaking, a stepped-care model should be trialled. For example, future research should seek to investigate the development of assessment tools that could be used to identify and classify the sleep needs of esports athletes. Sleep assessment tools have been created for use with traditional athletes (e.g. Athlete Sleep Behaviour Questionnaire; Driller et al., 2018), and thus, the same could be done with esports athletes. Subsequently, the first level of the stepped-care model (i.e. sleep education and sleep hygiene delivered by coaches and support staff) should be established and evaluated.

In terms of education content, further research is required to determine what information is most pertinent for esports athletes. While some sleep education content may be universal, other content may vary based on factors such as the game being played. Furthermore, in the Chapter 4 study, we suggested education materials could be gamified as they might aid contextual learning and increase engagement with the education process. A process like that employed by Sharpe et al. (2023) should be considered to determine what information should be gamified. In this study, the authors incorporated a panel of experts, including esports athletes, coaches and researchers, to identify performance indicators. Likewise, education content could be similarly shaped. As discussed in Chapter 5, with appropriate training, coaches and support staff may be suitable to deliver sleep education and sleep hygiene content. Thus, once the content for the first level of the stepped-care model has been established, whether sleep-trained coaches and support staff can deliver this type of intervention effectively should be tested. To summarise, future research should examine whether gamified sleep education and sleep hygiene delivered by coaches and support staff is an effective entry-level intervention on a stepped-care model.

The second level of the stepped-care model (i.e. diverse sleep needs) would likely be difficult to evaluate given the variety of sleep needs that would be serviced. Thus, assuming that the first level of the sleep stepped-care model has been developed and evaluated, the entire stepped-care model could then be implemented and assessed. In addition to sleep outcomes, this process should also assess the experience of esports athletes and esports organisations within the stepped-care model to determine its viability.

Overall, we encourage researchers to build sleep interventions for esports athletes from the ground up. Each stepped-care model component should be carefully evaluated before proceeding to the next step. Although it will take time, this approach may increase the likelihood of developing an effective sleep intervention for esports athletes.

## 7.7 Conclusion

When this thesis commenced in 2019, esports research was in its infancy, and there was minimal research that had investigated the sleep behaviour of professional esports athletes. Importantly, over the last five years, research has begun to shed some light on this aspect of professional esports. Broadly speaking, evidence suggests that many (but not all) esports athletes have delayed sleep timing, possible long WASO, restricted TST (close to or < 7 hours per night) and possible long SOL around competitions. Some of these sleep characteristics are consistent with those of traditional athletes, young people and casual gamers. Unfortunately, in contrast to emergent sleep findings, the relationship between sleep, mood and cognitive functioning remains largely unknown because of factors outside of our control. In terms of an explanation for these sleep characteristics, there appear to be several potential risk factors for poor sleep in esports. However, current evidence varies in terms of quantity and strength. Given the finding of suboptimal sleep, we also sought to improve the sleep of esports athletes. Despite an increased understanding of professional esports athletes and their sleep, the sleep intervention implemented was ineffective, highlighting this as an area for further exploration.

In summary, this thesis has meaningfully contributed to the knowledge base regarding the sleep behaviour of professional esports athletes. However, although more is known now than prior to beginning this thesis, it is readily acknowledged that the esports literature is still in its early days, with much more research required to develop a comprehensive understanding of esports athletes' sleep behaviour. Accordingly, this thesis has outlined several methodological considerations and potential lines of inquiry that will help advance the field of esports research. To this end, I wish future esports researchers the best of luck in this endeavour.

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# Appendix A: Opinion Piece Published Prior to the Commencement of the Present Thesis

## Sleep and Performance in Eathletes: For the Win!

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## Abstract

Over the last decade, esports, defined as a form of organised video game competition, has emerged as a global phenomenon. The professional players who compete in esports, namely, Eathletes, share many similarities with their traditional athlete counterparts. However, in sharp contrast to traditional athletes, there is a paucity of research investigating the factors that influence the performance of Eathletes. This gap in the literature is problematic because Eathletes are unable to make informed and empirically supported decisions about their performance management, unlike traditional athletes. Sleep is an important factor that influences athletic performance in traditional sports, particularly those that require a high level of cognitive demand. Research is yet to examine whether sleep also plays an important function in optimal performance and success of Eathletes in esports. Accordingly, the aim of this opinion piece is to review the broader sleep and sports medicine literature and provide theoretically grounded suggestions as to how existing findings may apply to Eathletes competing professionally in esports. Overall, it appears that Eathlete performance may be vulnerable to the deleterious effects of sleep restriction. Furthermore, Eathletes are likely at risk of sleep disturbances owing to the unique situations and conditions that characterise esports.



**Keywords:** Eathletes, sleep, performance, video games, cognition

**Sleep and Performance in Eathletes: For the Win!**

Over the last decade, esports, defined as a form of organised video game competition, has emerged as a global phenomenon. Once considered a niche subculture within the broader video gaming industry, esports now has an annual viewership of 380 million and is expected to reach a market value of 1.4 billion by 2021 (Newzoo, 2018). Professional leagues have been established globally in a variety of formats, with a particularly strong presence in Asia, Europe, and North America (Taylor, 2012). Concurrently, the number and scope of esports tournaments have increased significantly, with 588 major esports events in 2017 (Newzoo, 2018). In the context of accelerating business, consumer, and professional growth and development, esports is legitimising itself as a true form of sporting competition (Taylor, 2012).

The professional players who compete in esports, namely, Eathletes, share many similarities with their traditional athlete counterparts (Taylor, 2012). For example, Eathletes train rigorously; compete in tournaments; must abide by competition, association, and governing body rules; and can receive salaries and sponsorship (Taylor, 2012). However, in sharp contrast to traditional athletes, there is a paucity of research investigating the factors that influence the performance of Eathletes. This gap in the literature is problematic because Eathletes are unable to make informed and empirically supported decisions about their performance management, unlike traditional athletes. Furthermore, empirical research focusing on performance management research is critical given the importance of constant performance improvement for success and the high stakes (e.g. prize money, prestige) for which Eathletes now compete.

Sleep is an important factor that influences athletic performance in traditional sports (Kirschen et al., 2020), particularly those that require a high level of cognitive demand, such as basketball and baseball (Fullagar et al., 2015). Recently, there has been a surge of interest from athletes, coaches, and trainers regarding the importance of sleep in sport and the implementation of sleep enhancing strategies (Bonnar et al., 2018). Research is yet to examine whether sleep also plays an important function in optimal performance and success of Eathletes in esports. Accordingly, the aim in this opinion piece is to review the broader sleep and sports medicine literature and provide theoretically grounded suggestions as to how existing findings may apply to Eathletes competing professionally in esports.

## Sleep and Performance in Esports

Whereas athletic performance in traditional sports is determined by a variable combination of physical and cognitive abilities (Fullagar et al., 2015), Eathlete performance is more heavily reliant on cognitive abilities (Taylor, 2012). This reliance implicates sleep as a potential key determinant of Eathlete performance given that cognitive deficits are common following sleep restriction (i.e. reduced sleep duration; Lowe et al., 2017). In this section, we discuss the conceivable relationship between sleep and the cognitive abilities that underpin Eathlete performance.

In terms of more rudimentary cognitive processes, esports involve rapid presentation of new information, and competitive performance depends upon the ability to process this information quickly (i.e. intact information processing speed). For example, esports can involve rapidly changing information from multiple other human players, together with other in-game elements (e.g. game controlled players/bots). Relatedly, players need to make quick motor movements (which depend upon processing speed) in response to this rapidly changing information. Movements are enacted through visuomotor functioning, the processing of visual information and subsequent enactment of an Eathlete's on-screen avatar movement via physical movements (i.e. keyboard and mouse or console controller). An important component of visuomotor functioning for Eathletes is fine motor control, which involves precise manipulation of the smaller muscles in the hands to manage a complex array of buttons/keys and joystick/mouse manipulations. Furthermore, these manipulations need to be executed with correct timing, in varying sequences and with no room for error. In other words, Eathletes need to be able to quickly and efficiently process information and then respond appropriately, often with precise, fine motor movements. Importantly, the impact of sleep restriction on more basic cognitive domains is well documented within the literature. There is a broad consensus that sleep restriction results in decreased reaction times (Bonnar et al., 2018; Fullagar et al., 2015; Killgore, 2010; Lowe et al., 2017), reduced processing speed (Goel, 2017), and slower processing of visual information (Chee, 2015), leading to impaired visuomotor performance (Alhola & Polo-Kantola, 2007). Taken together, sleep restriction could essentially 'slow down' Eathletes, putting them at a competitive disadvantage in the fast-paced world of esports.

Two additional key cognitive processes involved in esports are attention and working memory. Given that many esports matches often go for upwards of 40 minutes (Schubert et al., 2016), Eathletes are required to sustain their attention for extended periods of time. Thus, effective sustained attention is necessary for competitive esports performance. Furthermore, to maintain focus on important in-game aspects, Eathletes also need to use efficient selective attention strategies. Selective attention is needed to focus on both relevant in-game elements and to reduce the impact of out-of-game environmental distractions (e.g. spectator noise at arena events). Further complicating gameplay, Eathletes must build a mental model of their opponent to determine and respond to opposing strategies and tactics. Mental models require efficient working memory, as multiple pieces of information need to be stored and analysed in real time. Working memory is also needed to effectively manage goals in both the short term (e.g. I must retreat from the current battle as I'll die otherwise) and the long term (e.g. playing consistent with a predefined battle plan). Sleep restriction appears to result in performance decrements in selective (Chee, 2015) and sustained attention, as well as working memory (Lowe et al., 2017). The resultant errors from brief attentional lapses and distractions, and impaired tactical awareness, may mean the difference between success and failure in esports, particularly for close matches or comparably skilled Eathletes.

In addition to more rudimentary cognitive processes, Eathlete performance also depends upon higher-order executive functioning. Executive functioning is a broad term describing a constellation of separable but related cognitive skills, including cognitive flexibility, problem solving, decision-making, and metacognition (Friedman & Miyake, 2017). These skills are often used in service of goal-directed behaviour, such as competing to win in esports. For example, cognitive flexibility is needed because Eathletes are required to anticipate and adapt to continuously changing variables during esports gameplay. Moreover, Eathletes must organise, plan, decide, and then implement strategies and tactics to achieve their respective objectives, and often coordinate effectively within the context of a team. Simultaneous to all of these cognitive processes, Eathletes need to monitor their own performance (i.e. metacognition) and regulate their emotions (e.g. if performing poorly). Parallel to the effect of sleep restriction on impairments in lower-order cognitive domains, evidence suggests that executive functioning is also adversely affected. A recent meta-analysis demonstrated that sleep restriction consistently negatively affected executive functioning (Lowe et al., 2017). Thus, sleep restriction may compromise Eathletes' ability to effectively engage and modulate aspects of performance related to the aforementioned complex elements of esports participation, once again highlighting that adequate sleep may be particularly important for optimal Eathlete performance.

## Potential Risk Factors for Sleep Disturbance in Eathletes

Despite the need for adequate sleep, sleep disturbances among traditional athletes are common, with a range of possible contributing risk factors (Roberts et al., 2019). Eathletes are likely exposed to many of the same risk factors as traditional athletes, although others may be unique to the situations and conditions that characterise esports. In the following section, we outline risk factors for suboptimal sleep that may be pertinent to Eathletes.

**Caffeine Use**

Caffeine is a well-known ergogenic aid (Grgic et al., 2018) used by traditional athletes across a wide range of sports (Del Coso et al., 2011). However, increased caffeine levels postmatch have been correlated with longer sleep latency and decreased sleep efficiency (Dunican et al., 2018). Hence, athletes need to take a strategic approach to caffeine use and regulate consumption appropriately to maximise performance gains while minimising harm to subsequent sleep. Although it currently remains unknown to what extent Eathletes consume caffeine, major energy drink brands such as Red Bull and Monster Energy have been prominent sponsors within the esports industry for some time (Cooke, 2018; Fitch, 2018). Thus, Eathlete exposure to marketing of caffeinated products may be high, but evidence is needed to support this idea.

**Air Travel**

Sleep disturbances related to air travel can occur because of the effects of jet lag, conflicting habitual sleep-wake schedules and travel times (Roberts et al., 2019), and travel fatigue caused by being confined, restricted in movement, and possibly dehydrated by dry cabin air (Lastella et al., 2019). Importantly, for athletes, sleep disturbances related to air travel have been found to compromise athletic performance (Lemmer et al., 2002; Waterhouse et al., 2002). With the continued growth of the esports industry, competitions have become more widespread around the world. Although esports competitions are unique in that it is not always necessary for Eathletes to travel to compete (i.e. they can compete remotely via the internet), major competitions are centralised and require competitors to be physically present (Taylor, 2012). Hence, many Eathletes are forced to travel long distances to compete, often by plane across multiple time zones.

## Pre-competition and Competition Nights

In their recent meta-analysis, Roberts et al. (2019) found evidence of reduced sleep duration and efficiency on competition nights. This finding was largely attributed to a delay in bedtime owing to a range of potential factors such as elevated cortisol and sympathetic hyperactivity. In comparison, equivocal findings were observed on pre-competition nights, although the authors noted that individual and female athletes might be more prone to pre-competition sleep disturbances owing to anxiety. Although esports are male dominated, policies to increase female participation are being implemented (Keiper et al., 2017). Furthermore, tournaments involving individual competitors are common (Taylor, 2012). Thus, some Eathletes may be susceptible to similar issues experienced by traditional athletes on pre-competition and competition nights, resulting in sleep disturbances.

## Evening Use of Light-Emitting Devices

Evidence from the general population suggests that evening use of light-emitting devices can interfere with melatonin secretion and consequently negatively affect sleep and daytime performance (Green et al., 2017). In contrast, preliminary results from studies comprising traditional athletes do not reflect these findings (Jones et al., 2018; Roberts et al., 2019). However, further research with larger sample sizes and a broader range of cognitive measures is needed before firm conclusions are drawn. Given that light-emitting devices are a core component of esports, Eathletes may be at an increased risk of sleep disturbances compared with traditional athletes, especially if training or competitive matches occur in the evening.

## Sleep Disorders

Sleep disorders, such as sleep apnoea and insomnia, can significantly degrade sleep quality and quantity (Dunican et al., 2019). The prevalence of sleep disorders among traditional athletes varies between sports, although athletes with particular physical characteristics (e.g. American footballers with high BMI) may be at increased risk of developing a sleep disorder (Roberts et al., 2019). Interestingly, given that Eathlete performance is minimally influenced by physical ability, the physical characteristics of the Eathlete population are likely more heterogeneous than traditional athletes. Thus, Eathletes may be less at risk of sleep disorders with specific physical risk factors that arise as a function of competing in esports. However, there may be physical risk factors for poor sleep that arise as a result of participating in esports. For example, the sedentary nature of esports, if managed poorly, could contribute to negative health outcomes (e.g. weight gain, neck pain; Happonen & Minashkina, 2019) and subsequent impaired sleep. Furthermore, given the broad range of diagnosable sleep disorders and their diverse etiologies (Sateia, 2014), sleep disorders remain a plausible issue for Eathletes.

**Performance-Enhancing Substances**

A report by the Esport Integrity Coalition (ESIC, 2016) determined that doping was a moderate threat to the integrity of esports. The report noted that Adderall and Ritalin, both stimulant medications used to treat attention deficit hyperactivity disorder, have instead been used by some Eathletes in an attempt to enhance performance. Although the Esport Integrity Coalition has developed an anti-doping policy (Anti-Doping Code), there is no systematic detection and enforcement regimen currently in place (EIC, 2018). Hence, no empirical data exist that can provide further insight with respect to doping prevalence or the types of substances used. From a sleep perspective, some performance-enhancing substances, particularly stimulants, could lead to sleep disturbances (Alamir et al., 2017).

**Other Risk Factors**

There are likely other additional risk factors for suboptimal sleep outcomes in the Eathlete population. Informal evidence suggests that this could include inadequate professional support and knowledge about the importance of sleep, competing demands such as work commitments that lead to training at night (particularly for semi-professionals), and overtraining. However, future empirical research is required to examine these potential risk factors in Eathletes.

## Conclusions and Future Research Directions

This opinion piece is the first to highlight the potential importance of adequate sleep for Eathlete performance. It is well established that sleep restriction impairs cognitive functioning, which may not be conducive for optimal Eathlete performance and therefore compromise the likelihood of competitive success. Indeed, cognitive deficits following sleep restriction may occur across the full spectrum of cognitive abilities that underpin Eathlete performance. Concerningly, similar to traditional athletes, Eathletes likely experience a high level of risk for sleep disturbances owing to the unique situations and conditions that characterise esports. From a practical perspective, these provisional findings have implications for the performance management of Eathletes at all stages of their training and competition schedule.

Our conclusions are limited in that they are based on existing findings drawn from the broader sleep and sports medicine literature. Hence, rigorous scientific research is required to investigate and test our propositions with Eathletes specifically. However, at a time when the esports industry is experiencing significant growth and popularity, research is notably lagging. We strongly encourage researchers in the field of sleep and sports medicine to invest the time and energy needed to further develop this emerging area of the literature. As a logical next step, future research should focus on the following three areas: (1) evaluation of Eathlete sleep patterns, (2) identification of risk factors for suboptimal sleep in Eathletes, and (3) understanding the consequences of sleep restriction on the cognitive abilities that underpin Eathlete performance. Conducting such research would further align Eathletes with traditional athletes professionally, helping them to perform at their peak potential, thereby providing spectators with the best viewing experience possible and enhancing the public profile of esports on the whole.

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# Appendix B: Demographic/General Questionnaire Used in Chapters 3, 4 and 6

Please read through the following questions carefully and answer to the best of your ability.

**Demographics**

Date of birth: ………………………… Height (in cm): ………………………

Weight (in kg): ……………………… Country of residence: ……………………

Sex:

❍ Male

❍ Female

**Esports background**

1. How many years have you been competing professionally in esports? …………….........
2. What is the primary game you currently compete in?…………………………………......
3. How many hours do you train approx. each day? ……………………..............................
4. a) When do you typically train (e.g. between 9am-4pm)? ……………………………..

   b) Please describe why you train at this time.………………………………….................
5. a) Do you compete in professional tournaments/competitions? ❍ Yes ❍ No

   b) If yes, how do you compete? ❍ Online ❍ In person ❍ Both

   c) Please specify approximately how many hours are spent competing in each domain annually:

   - Online: …………………hours - In-person: …………... hours
6. a) Do you work/study in addition to competing in esports? ❍ Yes ❍ No

   b) If yes, how many hours per week do you work and/or study?……………………........

**Sleep behaviour**

7. a) Have you ever been diagnosed with a sleep disorder/had trouble sleeping previously?

   ❍ Yes ❍ No

   b) If yes, please describe: ………………………………………………………………..
8. a) Are you currently using sleep medication?

   ❍ Yes ❍ No

b) If yes, please list the type of medication and dosage: ………………………………

9. a) Have you experienced a sleep disturbance the night before a competitive match within the last year?

❍ Yes ❍ No

b) If yes, did you: *Please note you may select more than one option.*

❍ Have trouble getting to sleep?

❍ Have trouble staying asleep?

❍ Wake too early?

c) How often does this happen before a match?

❍ Rarely

❍ Sometimes

❍ Often

❍ Almost always

10. a) Do you travel across time zones to compete in tournaments? ❍ Yes ❍ No

b) If yes, have you ever experienced disturbed sleep when travelling across time zones to a tournament? ❍ Yes ❍ No

c) If yes, please provide details about how your sleep was impacted:

………………………………. ………………………………………………………

11. a) Do you currently do anything to try and improve your sleep? ❍ Yes ❍ No

b) If yes, please describe what you do:

…………………………………………………………………………………… ………

12. a) Do you consume caffeinated drinks, foods or other caffeinated products to enhance your performance in esports? ❍ Yes ❍ No

b) If yes, which type of caffeinated product you usually consume:

❍ Beverage

❍ Food

❍ Other (please specify) ……………………………………………

c) Approx. how much caffeine (in total) do you consume daily (mg)?

❍ < 100 mg

❍ 100–200 mg

❍ 201–300 mg

❍ 301–400 mg

❍ 401–500 mg

❍ 501 mg

Note: In a standard cup of coffee there is 100 mg.

d) On average, what time do you consume your last caffeinated product for the day:………………

# Appendix C: Sleep Knowledge Quiz Used in Chapter 4

Please read through each question and circle the correct answer.

1. Sleep is a time when your body and brain shut down for rest and relaxation.

   True | False | Don't Know

2. Most young adults (18–25) need between 7–9 hrs of sleep each night.

   True | False | Don't Know

3. Getting one hour less sleep per night than I need will not have any effect on esports performance.

   True | False | Don't Know

4. Taking up to 30 mins to get to sleep is normal.

   True | False | Don't Know

5. Some technology use at night is ok as long as I try to fall asleep around the same time each night.

   True | False | Don't Know

6. Caffeine should be used as the primary strategy to manage sleep loss and sleepiness in Esports.

   True | False | Don't Know

7. 6hrs of sleep or less per night over a few weeks has the equivalent effect on performance as going 48 hrs without sleep.

   True | False | Don't Know

8. Deep sleep is the best type of sleep related to learning and memory.

   True | False | Don't Know

9. Unlike traditional sports, esports has very few risk factors that can lead to poor sleep.

   True | False | Don't Know

10. One process that controls when I sleep and wake-up is called the body clock.

    True | False | Don't Know

11. An esports athlete will always know if their performance is being affected by sleep loss.

    True | False | Don't Know

12. Tactical awareness (i.e. executing a game plan, making effective decisions, reacting to changes in-game plans) is unaffected by sleep loss.

    True    False    Don't Know

13. I should prioritise healthy sleep habits but I shouldn't stress about my sleep.

    True    False    Don't Know

14. Getting more sleep after being sleep deprived will improve my reaction time, mood and reduce fatigue.

    True    False    Don't Know

15. One consequence of sleep loss on performance is persevering with a strategy even though it is not working.

    True    False    Don't Know

16. Waking up during the night is abnormal.

    True    False    Don't Know