Graduate Journal of Sports Science, Coaching, Management, & Rehabilitation (GJSSCMR) – ISSN 2977-1579
Dawson & Burnie - 1587

https://www.northumbriajournals.co.uk/index.php/gjsscmr/article/view/1587

Published date: 14th February 2025

Research Article

The effect of sleep on swimming performance

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Abstract

There has been extensive research on sleep, including the stages, deprivation, and importance. However, there is limited research into the importance of sleep for athletes, especially swimmers. Therefore, the aim of the study was to investigate if quality of sleep affects swimming performance in university level swimmers. Eleven student-athletes from a university swimming team completed a timed 50 and 200 m freestyle swim in the morning and evening. Participants completed the Pittsburgh Sleep Quality Index questionnaire (PSQI) and Elite Performance Readiness Questionnaire (EPRQ) prior to the swims. Differences between AM and PM swims were analysed using either a paired t-test or Wilcoxon signed rank test, with Spearman's rank correlations used to assess strength of relationships. The 200 m swim was faster in the evening compared to morning ($P = 0.013$) with no difference observed for the 50 m swim ($P = 0.102$). There was no correlation between PSQI scores and swim time (rho [ρ] = -0.22). Eight out of the 11 swimmers (66%) were deemed to have poor quality sleep. The results highlight the importance of sleep and understanding the effects of sleep deprivation and reveal that athletes performed better in the evening compared to the morning. This is important when planning competitions and training programs, understanding that athletes perform better in the evening when they're potentially more motivated and alert. Our results could be considered for British Universities and Colleges Sport events, as performance standard seems to be greater, later in the day.

Keywords: EPRQ, PSQI, sleep deprivation, student athletes, university swimmers.

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Introduction

For overall wellness, sleep is essential (Brinkman et al., 2020), however, sleep is a very complex process, and the exact purpose of it is not clear (Brinkman et al., 2020). Numerous hypotheses have investigated the brain and tried to pinpoint a reason for why humans sleep. There is no exact reason as to why humans need sleep, but a combination of reasons explains the importance. Sleep is essential for many brain processes, including the communication between neurons (National Institute of Neurological Disorders and Stroke, 2022). There has been extensive research into the stages of sleep. There are two types of sleep: rapid eye movement (REM) sleep and non-REM (NREM) sleep. During REM sleep, brain activity increases, and the muscles become temporarily paralysed (Suni, 2021). Clusters of sleep-promoting neurons become more active, whilst neurotransmitters reduce the activity of cells (National Institute of Neurological Disorders and Stroke, 2022). REM sleep occurs around 90 minutes after initially falling asleep, and your eyes move rapidly behind closed eyelids (National Institute of Neurological Disorders and Stroke, 2022). For cognitive processes like memory, learning, and creativity, REM sleep is thought to be required (Suni, 2021). NREM sleep consists of 3 stages: N1, N2, and N3. N3 is the stage of deep sleep, also known as slow wave sleep (SWS). It is hard to awaken when in this state, and heart rate and breathing rate are at their lowest (National Institute of Neurological Disorders and Stroke, 2022). N3 is important for muscle and tissue repair, as well as memory consolidation (Wiginton, 2024).

Sleep is also a crucial component of both physical and mental well-being (Capezuti, 2016) and teenagers are recommended to aim for between 8 and 10 hours per night (Gudmundsdottir, 2019). A consistent and good quality sleep schedule comes with many benefits: improved immunity, mental and physical well-being, memory consolidation, hormone balance, and reproductive health are all facilitated by getting enough sleep (Baranwal et al., 2023). There are many people who suffer from sleep deprivation, and while the effects on the general population have been extensively studied, there are few research studies that specifically address the impact on athletes (Vitale et al., 2019). Many people experience sleeping difficulties or receive less sleep than is advised (Capezuti, 2016). Therefore, it is important to study sleep health and the consequences of poor sleep quality and deprivation. In addition, sleep disturbances are linked to high rates of daytime functioning impairment, poor job performance, crash rates, and increased pain perception (Baranwal et al., 2023). An increase in the rate of disease can result from sleep disorders such as insomnia, sleep apnoea, and circadian rhythm disorders, as well as disrupted sleep brought on by lifestyle decisions, environmental factors, or other medical diseases (Baranwal et al., 2023). These disorders can also worsen or cause other medical and psychiatric conditions (Baranwal et al., 2023). Intraindividual variability in sleep has also been linked to several physical and neurodevelopmental conditions in children and adolescents, as well as psychopathological symptoms, weight, stress, cognitive functioning, and poorer sleep habits (Gudmundsdottir, 2019). Consistency of sleep patterns (e.g., bedtime and sleep duration on weekdays vs. weekends or night-to-night variability) may also affect restitution and health in addition to average sleep duration (Gudmundsdottir, 2019). Lack of sleep has negative impacts on decision-making, affecting speed and accuracy, having a detrimental impact on overall task performance. Sleep loss heightens fatigue and negatively impacts cognitive performance, mood, and post-exercise recovery (Troynikov et al., 2018).

It has been suggested that adult elite athletes need more sleep than the 7–9 hours advised each night to meet prolonged training loads in the best possible health. But prior research has shown that elite adult athletes frequently get inadequate sleep (Gudmundsdottir, 2019). According to a study conducted on tennis players, serve accuracy increased from around 36 to 42% when sleep was raised to at least 9 hours per night (Fry & Rehman, 2021). Ochoa-Lácar et al.'s (2022) systematic review also revealed that basketball players who had increased sleep quality and duration had better performance and a lower chance of injury. There is limited research on swimmers; however, current literature shows the majority have extremely short total sleep time prior to early morning sessions, and total sleep time variability increases with more early morning sessions (Gudmundsdottir, 2019). A study showed that when sleep was increased to a 10-hour period, performance was improved in both male and female elite swimmers (Fry & Rehman, 2021); kick strokes increased, turn times decreased, and reaction times off diving blocks were quicker along with a 15-meter sprint swim time improvement. These athletes also reported feeling happier, less tired, and sleepy during the day (Fry & Rehman, 2021). A study by Nunes et al. (2021) investigated the impact of time of day on swimming performance (50, 200 and 400 m). It was found that 50 and 200 m swimming performance in boys was similar at both times, but overall performance improved in the evening in the 400 m swim. There are very few studies on student athletes. University student athletes differ from other populations due to the unique lifestyle of socialising and studying, and a greater sense of freedom. Previous research on sleep has been undertaken on adults and other groups of athletes such as football and basketball players (Ochoa-Lácar et al., 2022). As noted, literature has shown the importance of sleep for overall health and wellbeing but there are few existing studies focusing on the importance of sleep for general athletic performance. The present study aims to investigate if sleep quality affects swimming performance in university level swimmers. The hypothesis was that lower quality of sleep leads to lower swimming performance. It was also hypothesised that swimmers would perform better in the evening than the morning.

Methods

Participants

Eleven student-athletes (age 19 ± 1 years, stature 170 ± 11 cm, body mass 67 ± 12 kg; 3 males, 8 females) from a University Swimming Team gave written informed consent to the study. The study received ethical approval from the Northumbria University Faculty of Health and Life Science Ethics committee. A sample size of 19 was determined by the following three studies; Nunes et al. (2021; 33 participants), Mah et al. (2011; 11 participants), and Schwartz and Simon, (2015; 12 participants). However, due to the amount of people willing to participate, only 11 were recruited. The following inclusion criteria were considered prior to testing: (1) all participants train two to three times a week for 60–90 minutes, (2) have at least two years' competitive experience. The exclusion criteria included the following: (1) participants who consumed alcohol 24 hours prior to the study, (2) participants who took place in strenuous physical activity for the study's duration or 24 hours prior to the study. The study took place two weeks after the competitive season, to ensure all participants were in a good competitive condition and familiar with the distances. Before collecting data, participants were informed of the potential risks (normal training risks, e.g., cramps, stitches) and potential benefits along with providing written informed consent.

Protocol

Participants completed the Pittsburgh Sleep Quality Index (PSQI), which evaluates sleep quality over one month. The questionnaire consists of 19 items, which combine to form 7 components (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disruptions, usage of sleeping medication, and daytime dysfunction), which together produce an overall score (0-21). Participants scoring 0-4 indicates good sleep, between 5-10 points indicates poor quality sleep, and points 11-21 presents a sleeping disorder (Nunes et al., 2021). Backhaus et al. (2002) found that the PSQI questionnaire has high test-retest reliability and good validity, along with been validated with many clinical populations (Shahid et al., 2011).

This study was a repeated measures design. Participants completed the Elite Performance Readiness Questionnaire (EPRQ) prior to training. The EPRQ consists of 10 items, giving a quick assessment of performance readiness. Each question is answered by marking a vertical line on a 10 point (100 mm) visual analogue scale. The questionnaire is made up of two components. The first component is the Brief Assessment of Mood (BAM) (a shortened version of the Profile of Mood States [McNair et al., 1971] created by Dean et al., 1990). The BAM includes 6 adjectives (Angry, Alert, Fatigued, Depressed, Confused, and Tense) for the participant to indicate how they feel about each mood at that current time. A study by Shearer et al. (2017) showed the effectiveness and reliability of the questionnaire to measure and monitor recovery in footballers. The original BAM questionnaire had limitations, and by extending it (adding confidence, motivation, muscle soreness and sleep quality) allowed athletes to broaden and give more in-depth responses. In addition to other more invasive techniques, mood-based assessments of perceptual fatigue offer a non-invasive way to gauge recovery status. Participants completed the questionnaire (using pen and paper) before training on a morning (0700 hrs), and the following day in the evening (1800 hrs). Participant times were compared between morning and evening for both 50 and 200m. The 50 m sprint was performed first, as it predominately uses the anaerobic energy system and on average only lasts 25-35 seconds. The 200 m swim predominately uses the aerobic system and lasts from 2-3 minutes. By doing the 50 m sprint first, it will not affect the performance of the 200 m. The method used was informed by Nunes et al. (2021) study that examined the impact of time of day on performance in adolescent swimmers. In their study, the athletes performed a timed 50 and 400 m, both in the morning and evening. However, in the present study, only the 200 m was used due to the time available and the athletes being more inclined to participate in a 200 m swim, rather than 400 m.

The swims took place in a 25 m pool with a water temperature between 27-28°C (Sport Central, Northumbria University). Participants completed a standardised warm-up, consisting of 400 m freestyle, 100 m backstroke, 100 m medley (butterfly, backstroke, breaststroke, and freestyle) and 4 × 50 m kick. They then performed a timed 50 and 200 m freestyle swim from a dive start which was timed by a handheld stopwatch. Rate of Perceived Exertion (RPE) was also recorded after each swim using the Borg scale (Williams, 2017). The scale is a valid measure of exertion and has a very large correlation with % heart rate (Arney et al., 2019).

Data Collection and Analysis

Statistical tests for discrete variables were performed using IBM SPSS Statistics (v28, IBM UK Ltd, Portsmouth, UK). The data were tested for normality and analysed using either a t-test or Wilcoxon signed rank test depending on normality. A paired t-test was used to compare 200 m swim times between AM and PM, and a Wilcoxon matched pairs test was used to compare 50 m swim times between AM and PM. A Spearman's rho test was used to assess the correlation between PSQI scores and swim times. A Wilcoxon test was used to analyse the correlation between RPE and PSQI scores. Correlation of swim times and sleep quality were analysed using Spearman's correlation coefficients. The correlation coefficients were interpreted according to Batterham and Hopkins (2006) as trivial (0.0), small (>0.1), moderate (>0.3), large (>0.5), very large >0.7), nearly perfect (>0.9) and perfect

(1.0). EPQR scores were analysed using a paired t-test. The level of statistical significance was P ≤ 0.05. The data was also analysed using multiple linear regression to the EPRQ questions predicted swimming performance. The dependent variable was the swimming times, and the independent variables (predictors) were the EPRQ questions. There were too many variables to analyse once, therefore this was repeated multiple times to find the strongest predictors for swimming performance.

Results

For the 50 m swim, there was no difference between morning and evening performance (32.64 ± 4.63 vs. 31.46 ± 4.60 s; P = 0.102). Mean RPE was also comparable, showing participants found both performances equally as hard (Table 1). For the 200 m swim, performance was greater in the evening compared to the morning (160.27 ± 34.78 vs. 162.31 ± 35.37 s; P = 0.013). However, mean RPE was comparable (P = 0.192, Table 1).

Table 1. RPE values for 50 and 200 m swims, during AM and PM.

Distance (m)	Mean (SD)		P value
	AM	PM	
50	15 ± 1.03	15 ± 0.98	0.192
200	14 ± 1.12	15 ± 1.0	0.132

Values are mean (± SD).

The PSQI readings ranged from 2 to 13. Three participants were considered to have good sleep, seven deemed poor-quality sleep, and one with a sleeping disorder (Table 2). The PSQI scores showed no correlation between either the AM 200 m (rho [ρ] = −0.13) or the PM 200 m (rho [ρ] = −0.22). Sleep quality showed a weak correlation with the AM 200 m, and the PM 200 m showed a stronger correlation coefficient. RPE was correlated to PSQI scores (P = 0.003). Perceptual responses (Table 3) in the Elite Performance readiness questionnaire show that fatigue decreased prior to the PM session (P = 0.006). Alertness was also higher in the PM session compared to the AM session (P = 0.002).

Table 2. 200 m swim times for good and poor-quality sleep

Sleep Quality	Mean (SD)		P value
	AM	PM	
Good	156 ± 17.79	153 ± 17.35	0.242
Poor	164 ± 40.95	162 ± 40.16	0.111

Values are mean (± SD).

Table 3. Perceptual responses measured using EPRQ, during AM and PM.

Variable	Units 0-10	Mean (SD) AM	PM	Mean difference	P value
Angry		1.26 ± 0.91	1.95 ± 1.97	0.68	0.279
Confused		3.04 ± 2.29	2.39 ± 2.34	-0.65	0.402
Depressed		1.9 ± 1.83	1.74 ± 2.01	-0.16	0.693
Fatigued		5.84 ± 1.49	4.08 ± 1.65	-1.75	0.006*
Tense		4.45 ± 2.05	3.57 ± 1.64	-0.87	0.135
Alert		2.54 ± 2.02	6.22 ± 1.63	3.68	0.002*
Confident		4.15 ± 2.14	5.81 ± 1.73	1.65	0.042
Sore		5.35 ± 1.41	4.95 ± 1.89	-0.39	0.581
Motivated		3.07 ± 2.41	6.01 ± 1.91	2.94	0.010
Sleep		5.12 ± 2.27	5.19 ± 1.7	0.07	0.922

*Values are mean (± SD). Significant differences between AM and PM indicated by * P ≤ 0.05*

Multiple linear regression (Table 4) shows all R values are >0.9, showing a 'nearly perfect' correlation between EPRQ and swim performance (Batterham & Hopkins, 2006). The R^2 values show that the variables from the EPRQ questionnaire are good predictors (91 to 99%) of swimming performance (different variables were used for each analysis) of the independent variables (EPRQ questions), only one showed significance: confidence for the AM 50 m (P = 0.048).

Table 4. Multiple linear regression values for 50 and 200 m, during AM and PM.

Time of day	Distance (m)	R	R^2
AM	50*	0.993	0.985
	200	0.980	0.960
PM	50	0.975	0.951
	200	0.954	0.910

*Values are mean (± SD). Significant differences between AM and PM indicated by * P ≤ 0.05*

Discussion

This study aimed to assess if sleep quality affected swimming performance and established a difference in swimming performance between the morning and evening. However, as there was no difference between good and poor-quality sleep on swimming performance, other factors may influence performance other than sleep. A difference was found in the 200 m swim between morning and evening, with most swimmers performing better in the evening, supporting the initial hypothesis. However, there was no difference in the 50 m swim between the morning and evening sessions and RPE was similar for both 50 and 200 m swims. No differences in 200 m performance were based on

sleep quality. Participants felt more fatigued in the morning and more alert in the evening, which may have had an influence on performance.
An increase in 200 m performance was found in the evening, a result in line with previous research by Nunes et al. (2021), where increased performance was found in 400 m performance. Their finding was driven by boys performing better in the evening and not girls, signifying that sex may have an impact on swimming performance in the evening. Madge (2014) analysed data to determine if a 200 m swim was classified as a sprint or a distance event. The results of the analysis showed 200 m is a distance event, as the top swimmers for 400 m were closer to the fastest 200 m mean swim times compared to the fastest 50 m swim times. Therefore, as 200 m is a distance event, it is easier to see the difference in performance (time) due to factors such as fatigue. Research shows that sleep deprivation affects endurance performance, as participants may be less motivated to endure discomfort (Thun et al., 2015). It is also shown that sleep deprivation reduces the time to exhaustion (Thun et al., 2015).

Results of the present study are also in line with research by di Cagno et al. (2013), where elite gymnasts performed better in the evening in coordination tests and reactive strength. Another study by Pullinger et al. (2019) showed that repeated sprint performance was greater, later in the day (1700 – 1900 hrs) than in the morning (0600 – 1000 hrs). A study by Klaus-Karwisch et al. (2023) found an increase in sprint and jump performance in the evening, in female sports students. It has also been suggested that an increase in body temperature correlates with a higher activation of fast twitch fibres, possibly explaining an increase in performance later in the day (Klaus-Karwisch et al., 2023). The body temperature follows the circadian rhythm, with its lowest values in the morning and its highest values in the afternoon and evening (Harding et al., 2020). It is important to understand and apply this knowledge to training regimens and competitions, to receive the best results from athletes. This may impact coaches' decisions when deciding what type of training is best for swimmers in the morning and evening. From this study's results, swimmers should complete more high intensity distance work in the evening. This is in line with finals usually taking place in the evening, at major events such as the Championships and Olympic games.

EPRQ variables were found to predict swimming performance (>91%). Owens et al. (1998) also suggested that alertness (an EPRQ variable) can be used to predict time-of-day effect on performance (di Cagno et al., 2013). Research shows that sleep deprivation can reduce performance by decreasing motivation (Thun et al., 2015) and this is in line with the present data where increased performance was found in the PM 200 m swim, where alertness and motivation increased. There was no difference found in the 50 m swim between the morning and evening sessions. This also reflects the results of

Nunes' study, showing no time-of-day effect for 50 m. As 50 m is a sprint event, it is considered easier to stay consistent. Therefore, it is not surprising that differences were not found due to the short distance. Research suggests that short-term high-power tasks are unaffected by one or several nights of sleep deprivation (Thun et al., 2015). In sprint events (50 and 100 m), most of the race is down to skill. The first 15 meters relies on the dive and underwater; the 5 m into the wall and 5 m out of the wall are determined by turn technique, wall power and underwater, and the last 5 m is dependent on finishing skills (Goldsmith, 2018). Therefore, for a 50 m sprint, 30 m of it is down to skill. As the participants were all experienced swimmers, the level of skill is unlikely to change throughout the study period. However, shown by previous research (Bonnar et al., 2018), sleep can affect sport specific skill execution. Thun et al. (2013) reported a series of technical skills that improved in the evening for various sports. This included an increase in swimming velocity, improved accuracy of badminton serves, dribbling speed and chipping accuracy in football. However, no difference in technical skill was seen in my study due to the short distance.

There was a decrease in fatigue in the evening, compared to the morning (P = 0.006). Fatigue is also influenced by sleep, and the significant difference could be a result of a lack of sleep. A study by Grandner et al. (2020), looked at how sleep (duration and quality) and fatigue influenced mental health in student athletes. The results showed that the higher the PSQI scores, the higher the scores for depression and anxiety. A shorter sleep duration was also associated with higher levels of stress, anxiety and depression. The overall finding that sleep plays an important role in student athlete's mental health should be addressed more in practice. The National Collegiate Athletics Association (NCAA) included sleep screening as part of their published 'Mental Health Best Practices' guidelines, highlighting the importance of sleep quality and duration (Grandner et al., 2020).

Partial sleep deprivation has been studied, and results show that maximal measures of strength and single bouts of aerobic exercise are minimally affected (Bonnar et al., 2018). However, sports specific skill execution, submaximal exercise bouts, and muscular and anaerobic power are more affected by sleep deprivation (Bonnar et al., 2018). The results of the PSQI showed that eight out of the 11 (66%) had poor quality sleep, including one with a sleeping disorder. Therefore, it is more likely than not that the swimming performance of these participants were affected by poor quality sleep. As a result of the findings by Bonnar et al. (2018) sleep interventions have been studied to try to minimise these effects. These interventions can be categorised into sleep extension (and napping) and sleep hygiene. The results from a systematic review by Bonnar et al. (2018) show that improvements in sleep hygiene increase sleep duration but have no effect of performance. However, sleep extension was found to improve sport- specific skill execution and cognitive related tasks such as reaction time (Bonnar et al., 2018).

There are a variety of limitations to this study including the small sample size (n= 11). It is hard to establish differences in sleep quality due to the small sample size, as there were three participants deemed to have good quality sleep and eight deemed to have poor quality sleep (including one with a sleeping disorder). Although the PSQI questionnaire is a valid measure of sleep quality, it is subjective, making it difficult to know the accuracy of the results. It would be necessary to examine sleep quality through a more objective and scientific measure, such as a polysomnography (PSG). However, this is expensive, time consuming, and unavailable to most people. Another option would be to record sleep using smart watches, however not all participants had access to this. Another improvement to be made would be recording sleep quality the night before the swims, as this was done as an overall assessment of their sleep. This study could also be improved by participants wearing a heart rate monitor and recording their heart rate at the end of each swim, to help improve the accuracy of RPE. Future research may be continued with a larger sample size to consolidate and add to the findings of this study. It could be improved using more scientific measures for sleep to confirm the results. It could also be repeated using different distances such as 100 m to see if the same results are found.

Conclusion

For distance events, swimming performance is found to be better in the evening rather than in the morning, but sprinting is not significantly impacted by the time of day. This should be taken into account when organising tournaments like Nationals, Championships, and British Universities and Colleges Sport (BUCS) events. It should also be considered when planning training sessions, as athletes will perform better at training in the evening. As a result, intense sprint training can be performed at any time of the day and long-distance aerobic exercise should be done in the evening. Although it is not a direct predictor of performance, sleep quality is still a major factor. It is a reliable indicator of performance, along with a host of other factors like alertness and fatigue. In order to optimise performance, student athletes should practice good sleep hygiene and maintain a regular sleep schedule. If further research on this topic was to be conducted, participants should wear smart watches to more accurately monitor their sleep and swims repeated at several times using different distances and events.

Acknowledgments

Firstly, I would like to thank my supervisor, Louise Burnie, for all the help and support she has given me throughout my project. I feel very grateful that I was given the opportunity to work with Louise and it would not have been possible without her support.

I would also like to thank all my participants for their time and effort to take part in my dissertation research; it would not have been possible without you all.

Lastly, I would like to thank my family for their continued support throughout my time at university.

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