The influence of self-reported total sleep time and sleep quality on physical performance in junior tennis players

La influencia del tiempo de sueño total autorreportado y la calidad del sueño en el desempeño físico de jugadores júnior de tenis

Mitchell Turner [1*], Johnny Lo [2], Philipp Beranek[1], Ian C. Dunican [1,3] and Travis Cruickshank [1,4,5]

1 School of Medical and Health Sciences, Edith Cowan University, Perth, Australia
2 School of Science, Edith Cowan University, Perth, Australia
3 Centre for Sleep Science, School of Human Sciences, The University of Western Australia, Perth, Australia
4 Centre for Precision Health, School of Medical and Health Sciences, Edith Cowan University, Perth, Australia
5 Perron Institute for Neurological and Translational Sciences, Perth Australia

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Abstract

Studies have shown the importance of sleep on tennis skill execution; however, its influence on physical performance metrics is unclear. This study aimed to examine the extent to which sleep duration and sleep quality metrics influence physical performance metrics in junior tennis players. Thirty-six junior tennis players from Australia and Germany completed the Consensus Sleep Diary over seven nights. A novel total sleep score based on current National Sleep Foundation recommendations was generated (calculated as the percentage of the average standardised sleep metrics), for each player. Players physical performance was measured using a comprehensive tennis-specific testing battery. This included sit and reach test for flexibility, counter movement jump and overhead medicine ball throw for power, 5-, 10- and 20-metre sprints for speed, tennis agility test for agility and reaction time, grip strength for strength, repeat sprint ability for anaerobic capacity and the Hit and Turn Tennis Test for aerobic capacity. Teenage (14 to 17 years of age) players reported significantly lower sleep duration (471 ± 116 min versus 543 ± 72 min; $p < 0.001$, $d = 0.83$) and sleep efficiency (90% ± 11% versus 94 % ± 5%; $p = 0.011$, $d = 0.49$) metrics than school-aged players. Players with higher self-reported sleep quality had slower reaction times during a tennis agility test ($r = 0.604$, $p = 0.011$). However, players who reported feeling more rested and refreshed had faster reaction times during a tennis agility test ($r = -0.579$, $p = 0.020$). No other significant associations were present between self-reported sleep metrics and physical performance metrics. Nevertheless, feeling well-rested and refreshed, one of the primary outcomes of sleep, improves reaction time during a tennis-specific agility test. However, physical performance metrics are not significantly influenced by small variations in recommended sleep duration and sleep quality ranges.

Keywords: *Reaction time; Restfulness, Sleep efficiency; Teenager; Tennis agility.*

Resumen

Diversos estudios demuestran la importancia del sueño en la ejecución de las habilidades en el tenis, sin embargo, su influencia en las métricas del desempeño físico no es clara. El objetivo de este estudio es analizar hasta qué punto las métricas de la duración y calidad del sueño influencian las métricas del desempeño físico en jugadores júnior de tenis. Treinta y seis jugadores júnior de tenis de Australia y Alemania completaron el Diario de Sueño Consensuado durante siete noches. Para cada jugador se creó una nueva puntuación del sueño total basada en las recomendaciones actuales de la Fundación Nacional del Sueño (calculada como el porcentaje de la media

Corresponding author: Mitchell Turner, mitchel.turner@ecu.edu.au

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de las métricas de sueño estandarizadas). El desempeño físico de los jugadores fue medido con una batería integral de pruebas específicas para el tenis. Las pruebas incluidas fueron la prueba de sentarse y alcanzar para flexibilidad, el salto en contramovimiento y el lanzamiento de balón medicinal sobre la cabeza para la potencia, sprints de 5, 10 y 20 metros para la velocidad, la prueba de agilidad en tenis para la agilidad y el tiempo de reacción, fuerza de agarre para la fuerza, capacidad de repetir sprint para la capacidad anaeróbica y la prueba de golpear y girar en tenis para la capacidad aeróbica. Los jugadores adolescentes (de 14 a 17 años) reportaron métricas significativamente menores en la duración del sueño (471 ± 116 min frente a 543 ± 72 min; p <0,001, d = 0,83) y la eficiencia del sueño (90% ± 11% versus 94 % ± 5%; p = 0,011, d = 0,49) comparadas con las de jugadores en edad escolar. Los jugadores con mayor calidad de sueño autorreportada tuvieron tiempos de reacción más lentos durante la prueba de agilidad en tenis (r = 0,604, p = 0,011). Sin embargo, los jugadores que reportaron sentirse más descansados y renovados tuvieron tiempos de reacción más rápidos durante la prueba de agilidad en tenis (r = -0,579, p = 0,020). No se encontraron otras asociaciones significativas entre las métricas de sueño autorreportadas y las del desempeño físico. No obstante, sentirse descansado y renovado, uno de los resultados principales del sueño, mejora el tiempo de reacción en la prueba de agilidad específica para tenis. Por otra parte, las métricas del desempeño físico no están influenciadas significativamente por las pequeñas variaciones en la duración del sueño y los rangos de calidad del sueño recomendados.

Palabras clave: *Tiempo de reacción, descanso, eficiencia del sueño, adolescente, agilidad en tenis.*

INTRODUCTION

Current recommendations, by the National Sleep Foundation (NSF), suggest that school-aged children (6-13 years of age) and adolescents (14-17 years of age) should achieve 9-11 hours and 8-10 hours of sleep each night, respectively (Hirshkowitz et al., 2015). Junior (<18 years of age) athletes often receive less sleep than these recommendations (Riederer, 2020). Sleep quality has also been shown to be impaired in junior athletes (Suppiah et al., 2021). Sleep duration and sleep quality may be impaired by lifestyle factors, including school commencement times, homework, and potential social media and gaming (Hansen et al., 2017; Wahlstrom et al., 2017). Additionally, junior athletes' sporting commitments may impact their sleep opportunity, thus reducing their sleep duration and sleep quality (Dumortier et al., 2018; Kölling et al., 2016).

Studies in young adult tennis players have found that partial sleep deprivation (reduced sleep duration) negatively impacts serve, forehand and backhand accuracy (Reyner & Horne, 2013; Vitale et al., 2021). One week of sleep extension to nine hours per day has been shown to increase serve accuracy in college tennis players (Schwartz & Simon, 2015). These studies indicate a positive link between sleep duration and execution of tennis skills. However, increased sleep duration as part of a mixed-method recovery strategy (the use of multiple recovery strategies) did not positively impact tennis performance outcomes (Lever et al., 2021). Though, it did improve lower body power and reduce perceived muscle soreness in junior tennis players, indicating a link between increased sleep duration and improved physical performance (Duffield et al., 2014).

While there is a paucity of studies investigating the effects of sleep on physical performance in junior athletes (Riederer, 2020), numerous studies have been conducted in adult athletes from various sports, with equivocal findings (Watson, 2017). Specifically, reaction times have been shown to slow when partial (reduced sleep duration) or complete (maintain wakefulness) sleep deprivation occurs (Fullagar et al., 2015; Reilly & Edwards, 2007; Watson, 2017). Maximal strength appears to be unaffected by sleep duration (Reilly & Edwards, 2007; Sinnerton & Reilly, 1992; Watson, 2017). However, the effects of sleep duration on aerobic capacity and sprint performance are less clear, with some (Mah et al., 2011; Peacock et al., 2018; Watson, 2017), but not all (Reilly & Edwards, 2007; Sinnerton & Reilly, 1992), studies reporting decrements in performance following nights with reduced sleep duration.

Current studies have reported associations between physical factors and tennis performance (Fett et al., 2020; Ulbricht et al., 2016). Given these associations, aspiring junior tennis players must optimise their physical performance to ensure tennis success. Understanding the factors influencing physical performance, including sleep, is then of paramount importance. Therefore, we aimed to examine the extent to which sleep duration and sleep quality metrics influence physical performance metrics in Australian and German junior tennis players. We hypothesised that junior tennis players with sleep duration and sleep quality metrics that meet the NSF recommendations will have superior performance in physical tests.

METHODS

Players

Thirty-six junior tennis players volunteered for this study. Twenty-six were school-aged and 10 were considered teenagers. Players were recruited through local clubs and coaches in Perth, Australia and Cologne, Germany. Data presented in our study represent a subset from a more extensive study investigating predictors of performance in junior tennis players. Inclusion criteria for our study were as follows; be between 9 and 18 years of age, have a tennis ranking attained through competition, and currently perform at minimum one training session per week. All players and their guardians provided written informed consent before engaging in study testing procedures. Our study was approved by the Edith Cowan University Human Research Ethics Committee (ID: 00673).

Experimental Design

A cross-sectional study design was utilised to evaluate associations between sleep duration and sleep quality and physical performance outcomes in junior tennis players. Players' sleep duration and sleep quality were monitored for seven nights across weekdays and weekends, with a minimum of five nights needed for further analysis. Physical performance testing was conducted in one testing session on a tennis hard court surface; the testing sessions were conducted between 9:00 am and 5:00 pm and was administered by the same examiners. The experimental design and timings can be seen in Figure 1.

MEASURES

Sleep-wake behaviour

The Consensus Sleep Diary (CSD) measured players' sleep duration and sleep quality (Carney et al., 2012). This measure was developed by the Pittsburgh Assessment Conference in 2012 and has since been validated (Carney et al., 2012; Maich et al., 2018). When completing the diary, players were required to report the following information for each day/night: (i) what time did they go to bed (bedtime), (ii) what time they tried to sleep, (iii) how long it took them to fall asleep, (iv) how many times they woke during the night and for how long, (v) what time they woke for the day, and (vi) what time they got out of bed. Additionally, the CSD included 5-point Likert scales for players to rate their sleep quality and restfulness. The information derived by the CSD enables calculation of time in bed (TIB), sleep onset latency (SOL), wake after sleep onset (WASO), sleep duration, sleep efficiency (SE), sleep quality and restfulness. Sleep duration, SOL, WASO and SE, measured by the Consensus sleep diary, have been validated against actigraphy (Maich et al., 2018). The CSD can be seen in Figure S1 of the supplementary file.

Each player's total sleep score was calculated based on age-appropriate (school-aged: 9 to 13 years or teenager: 14 to 17 years) sleep duration and sleep quality (sleep latency, wake after sleep onset and sleep efficiency) recommendations from the NSF (Hirshkowitz et al., 2015; Ohayon et al., 2017). The recommended ranges for each sleep variable can be seen in Figure 2. A detailed description of how the total sleep score was determined can be seen in Figure S2. The total sleep scores, presented as a percentage, represent the level of adherence (no adherence 0% to complete adherence 100%) each player had to sleep duration and sleep quality recommendations outlined by the National Sleep Foundation (Hirshkowitz et al., 2015; Ohayon et al., 2017).

Physical and Mental Fatigue

The Chalder Fatigue Scale (CFS) evaluated fatigue, including physical and mental fatigue (Chalder et al., 1993). The CFS is an eleven-item validated questionnaire designed to indicate the current physical and mental fatigue. Scores are then totalled and range from 0-33, with higher scores indicating greater fatigue levels. A score of 22 indicates a player was feeling fatigued at the time of completion.

Anthropometrics

Standing heights were measured and recorded to the nearest centimetre (0.01 m) using a tape measure. Players stood tall with their back against a wall, the distance from the ground to the top of their heads recorded. Body mass was measured using a set of electronic scales and was recorded to the nearest gram (0.01 kg).

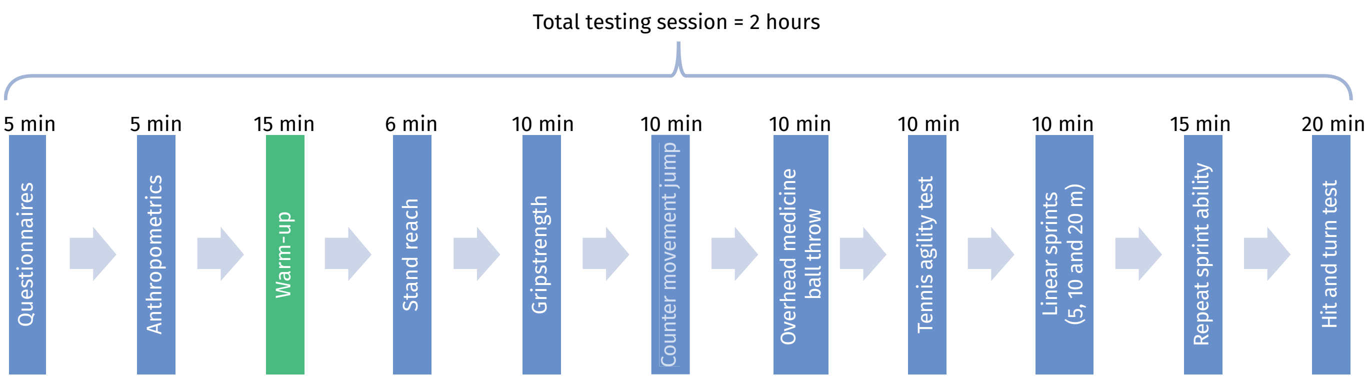

Figure 1. Experimental design, inclusive of order and timings of testing session.

Physical assessments

Flexibility

Flexibility was measured using a Sit and Reach test; players are required to sit on the ground with their legs extended and the soles of their feet against a sit and reach box (Flex tester, Novel Products Incorporated, Rockton, USA). Players had their hands on top of one another with palms facing down and reached forward as far as possible without their knees bending, holding this position for 2-3 seconds (Roetert et al., 1992). Players performed three trials, one after the other, with the best trial achieved recorded and analysed.

Linear speed

Linear speed was assessed over 5, 10 and 20-metre distances using timing light sensors (Speed light, Swift Performance, Queensland, Australia). The testing procedure was previously used with junior tennis players; it involves players beginning their linear sprint from a standing start, positioned 50 centimetres behind the first timing light sensor (Ulbricht et al., 2016). Players were allowed practice runs if required after the initial instructions were provided. Each player then performed two maximal 20-metre sprints with a two-minute passive recovery between sprints. Sprint times over 5-, 10- and 20-metre distances were recorded to the nearest millisecond (0.01 sec).

Tennis Agility Test

Agility was assessed using the Tennis Agility Test (TAT), which required players to start in a standing 'ready position', straddling the centre mark of the baseline. The tester initiated the test who performed a forehand or backhand swing, indicating that the player runs to their right or left, respectively. The player was required to run to the doubles sideline, perform a forehand or backswing, then run to the opposing doubles sideline, perform a forehand or backhand swing before running back to the centre mark to complete the test. The players were provided with a clear explanation of the test and allowed a practice run before three trials, interspersed with two-minute passive recovery periods. The three trials' best reaction time (the time between tester and player movements) and total time (time to complete the test) were included for analysis. Both times were recorded to the nearest 0.3 milliseconds (0.03 sec) using Kinovea (open-access video analysis software; https://www.kinovea.org).

Counter movement jump

Players jump height during a counter movement jump (CMJ) was used to determine lower body power. To reduce the involvement of arm-swing during the jump, players held a pole across their shoulders (Legg et al., 2017). A linear positional transducer (GymAware, Kinetic Performance Technology, Canberra, Australia) attached to the end of the pole was used to measure the jump height of players. Players were instructed to jump as high as possible whilst keeping the pole level; the trial was repeated if the player tilted the pole. Three maximal CMJs were performed with two-minute passive recovery periods between jumps. The maximal height of each jump was recorded to the nearest centimetre (0.01 m).

Overhead medicine ball throw

The upper body power of players was assessed using an overhead medicine ball throw; this test has previously been used with junior tennis players (Ulbricht et al., 2016). This test requires players to stand with their feet side by side and, using both hands, throw a two-kilogram medicine ball overhead as far as possible. Players were instructed not to step forward when throwing as the measurement was taken from their feet to the point where the ball landed; if a player stepped forward, the throw was retaken. A total of three throws were performed, with a two-minute passive recovery period between throws. The furthest horizontal distance from the thrower to the landing position of the medicine ball was recorded and used for analysis. All throws were recorded to the nearest five centimetres (0.05 m).

Grip strength

Upper body strength was assessed using a grip strength test, commonly used to measure strength in junior tennis players (Fett et al., 2020; Girard & Millet, 2009; Ulbricht et al., 2016). A hand dynamometer (Advanced Hand Dynamometer, TTM, Japan) was gripped by the player and positioned by the side of their body; it was then squeezed maximally for three seconds. The player's grip strength was measured in kilograms (kg), and the best of two trials on each hand, separated by two minutes of passive recovery, was used for further analysis.

Repeat Sprint Ability

The anaerobic capacity of players was assessed using the repeat sprint ability test; this test has recently been performed with junior tennis players (Vitale et al., 2021). The test required players to sprint 20 metres as fast as possible every 20 seconds for ten repetitions. The sprint times of players were measured using timing gates (Speed light, Swift Performance, Queensland, Australia) placed one metre above ground level. The anaerobic capacity was determined by the fatigue decrement score, calculated using the following formula (Chapman & Sheppard, 2011; Vitale et al., 2021).

Fatigue decrement (%) = ((total sprint time – ideal time) / total sprint time) x 100

Hit and Turn Tennis Test

The aerobic capacity of players was assessed using a tennis-specific endurance test called the Hit and Turn Tennis Test; this test is reliable and valid (Ferrauti et al., 2011). The test was delivered by a standardised audio file that dictates the direction and speed players move. Players were required to run and sidestep in the indicated direction and perform forehand and backhand swings until they could not make the time or voluntarily withdrew.

Statistical analysis

As determined by the Shapiro-Wilk test, data were normally distributed and presented as mean ± standard deviation (range). A T-test was conducted to identify if the sleep latency, wake after sleep onset, sleep duration or sleep efficiency differed between school-aged children and teenagers. General linear modelling was also used to determine the influence of sleep duration and sleep quality on each of the physical performance metrics. All models were adjusted for sex, age and nationality. False discovery rate (FDR) correction was applied to account for multiple models and to mitigate false positive results. The effect sizes were reported as Cohen's *d* or *r* (partial correlations). Cohen's *d* thresholds were identified as small = 0.2, medium = 0.5 and large = 0.8 (Cohen, 2013). While Cohen's *r* thresholds were identified as small = 0.1, medium = 0.3 and large = 0.5 (Cohen, 2013). Analysis was conducted using R Studio software package, Version 1.1 (RStudio Team, 2020). A p-value <0.05 was considered statistically significant.

Overall, there were 36 players in our study, n=22 players from Australia and n=14 players from Germany. Of these players, 25 were male, and 26 were categorised as school-aged (9 to 13 years). Demographic information for players is presented in Table 1.

Table 1.
Brief advices on management of lateral elbow tendinopathy.

	M ± SD	Range
Age (years)	12 ± 2	(9, 17)
Tennis experience (years)	6 ± 2	(1, 11)
Hours played per week	8 ± 4	(1, 17)
Height (centimetres)	162.1 ± 11.1	(139, 179.5)
Body mass (kilogram)	50.0 ± 11.6	(29.8, 81.5)

Note. M, Mean; SD, standard deviation.

Consensus Sleep Diary

Teenagers had 72 minutes (p <0.001, d = 0.83) less sleep duration than school-aged children for each night across the seven nights. Additionally, Teenagers had a 4% (p = 0.011, d = 0.49) lower sleep efficiency than school-aged children each night across the seven nights (Figure 3).

Players average sleep quality score was 3 ± 1 (2, 5), which is indicative of 'fair' sleep quality. The average score for how well-rested or refreshed players felt was 3 ± 1 (1, 5), indicative of 'somewhat rested'. Players average total sleep score was 67% ± 9% (46%, 86%). The descriptive data for the physical performance metrics are presented in Table 2.

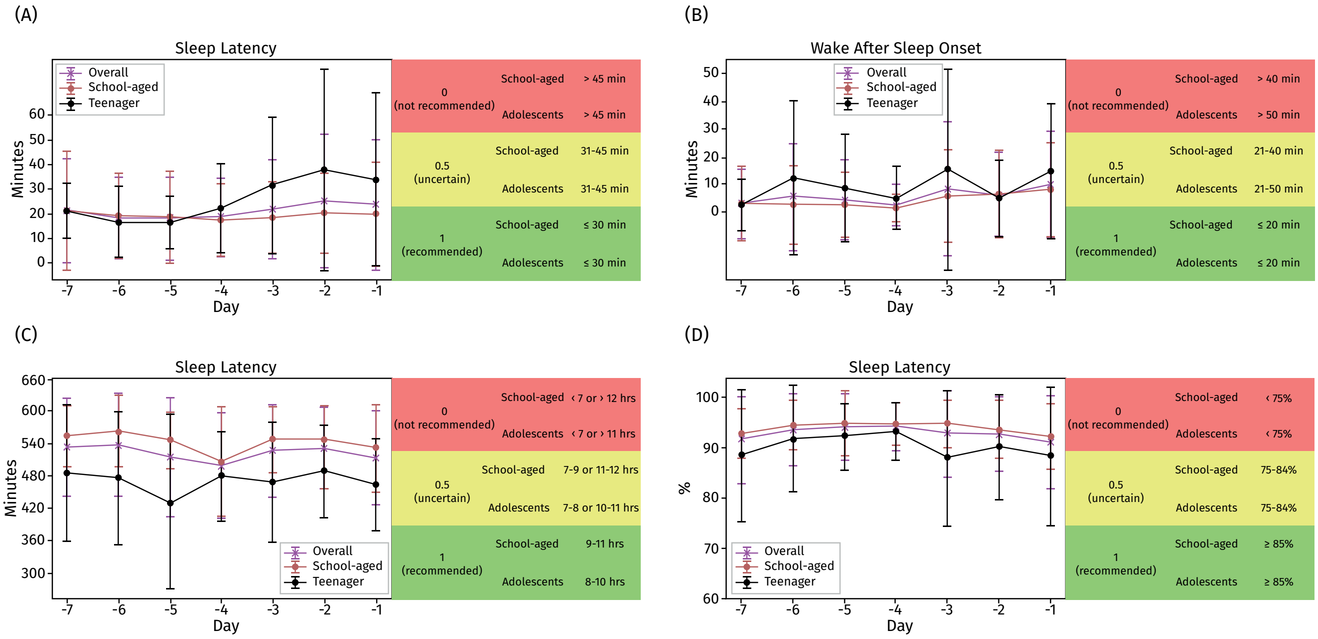

Figure 2. The mean and standard deviations of self-reported scores of the seven-day sleep diary for overall, school-aged and teenage players. The recommended ranges from the National Sleep Foundation for each age category are also provided for each sleep metric. Green indicates recommended, yellow indicates uncertain and red indicates not recommended. Sleep metrics include: Sleep latency (A), wake after sleep onset (B), sleep duration (C) and sleep efficiency (D).

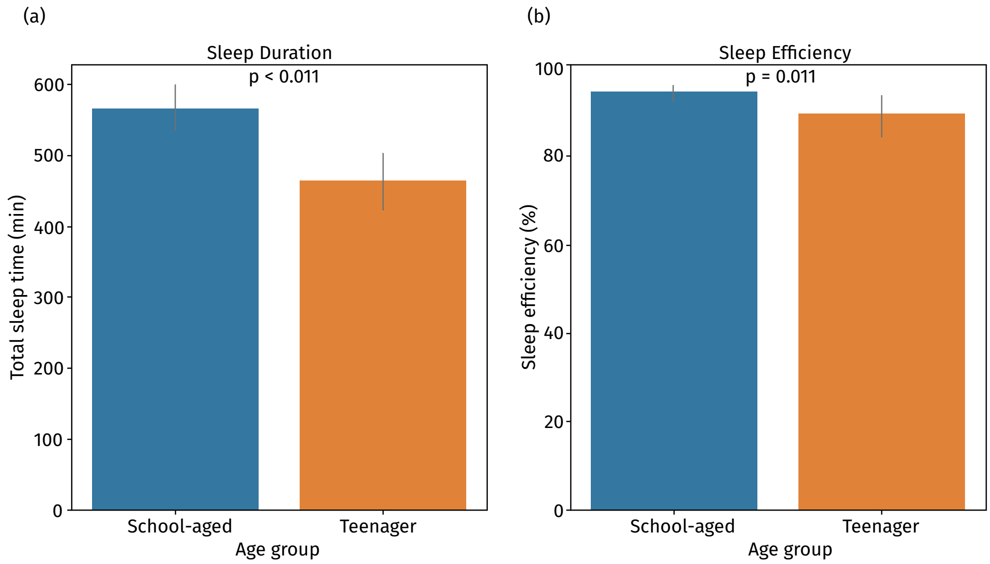

Figure 3. Bar plot of the mean sleep duration (a) and sleep efficiency (b) of school-aged and teenage players. Standard deviation for each group is indicated by the black error bars.

Table 2.
Physical performance tests presented as mean, standard deviation and range.

	Physical performance tests	
	M ± SD	Range
Chalder Fatigue Scale (#)	11 ± 3	(4, 21)
Sit and reach (#)	22 ± 11	(1, 50)
Counter movement jump (metres)	0.32 ± 0.06	(0.20, 0.49)
Overhead medicine ball throw (metres)	5.6 ± 1.3	(2.6, 8.5)
Sprints		
5 metres (seconds)	1.12 ± 0.21	(0.71, 1.51)
10 metres (seconds)	2.04 ± 0.23	(1.48, 2.60)
20 metres (seconds)	3.63 ± 0.35	(2.81, 4.55)
Tennis Agility Test		
Reaction time (seconds)	0.41 ± 0.14	(0.20, 0.80)
Total time (seconds)	6.83 ± 0.52	(6.13, 8.50)
Grip strength		
Dominant side (kilograms)	27.4 ± 9.8	(13.8, 48.0)
Non-dominant side (kilograms)	24.0 ± 8.7	(11.5, 44.0)
Repeat Sprint Ability (%)	6.34 ± 2.64	(1.63, 14.18)
Hit and Turn Tennis Test (#)	9.9 ± 4.1	(2.3, 18.0)

Note. M, Mean; SD, standard deviation.

Associations

Sleep and physical

Sleep duration did not significantly impact any physical performance tests. No significant impact was found between sleep quality metrics, including SOL, WASO, and SE, or the overall sleep score and any of the physical performance tests. Higher self-reported sleep quality scores (r = 0.604, p = 0.011) resulted in slower TAT reaction times. While higher self-reported restfulness scores (r = -0.579, p = 0.020) resulted in faster TAT reaction times (Figure 4).

DISCUSSION

The primary aim of this study was to explore associations between physical performance metrics and sleep duration and sleep quality in junior tennis players. The results from our study indicate that sleep quality, as measured by self-reported restfulness, had a significant positive impact on the reaction time of players undertaking the TAT. This finding aligns with previous literature showing the significant influence of sleep quality on athlete reaction times (Fullagar et al., 2015; Reilly & Edwards, 2007; Watson, 2017). Specifically, slower reaction times were reported after one night of partial sleep deprivation in athletes across various sports (Fullagar et al., 2015). Sleep deprivation is thought to negatively affect non-executive functions (automatic processes) utilised during reaction time tasks (Tucker et al., 2010). Thus, players who felt well-rested and refreshed, one of the primary outcomes of sleep, may have had improved automatic processes when reacting to the stimulus during the tennis-specific agility test.

Players who reported better subjective sleep quality were found to have slower TAT reaction times. This result contradicts the positive relationship observed between self-reported restfulness and reaction time from our study. This unexpected finding may be due to ceiling effects for our study's subjective sleep quality measure. In particular, the majority of players in our study scored above fair for subjective sleep quality (indicated in Figure 4); thus subjective sleep quality scores may not have been low enough to compromise reaction times. Further research is required to ascertain the self-reported sleep quality threshold needed to instigate a change in physical performance.

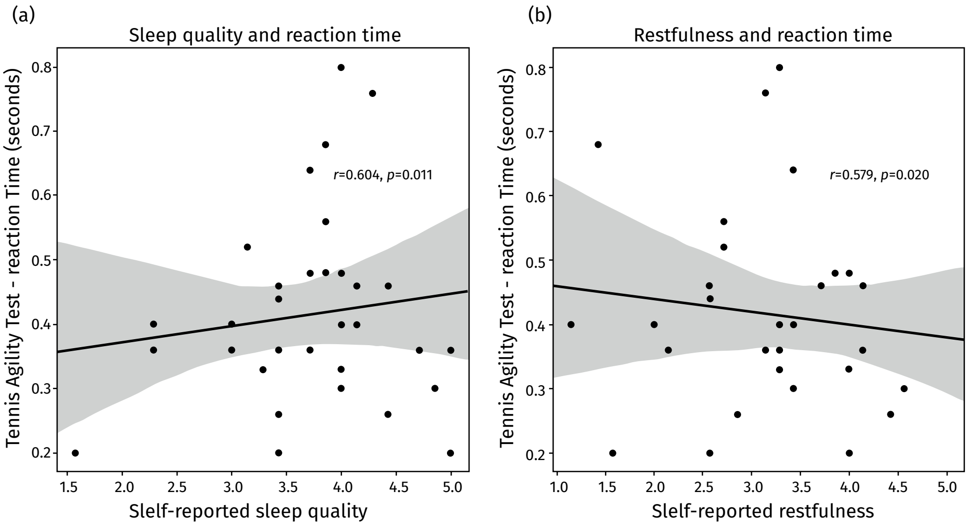

Figure 4. Scatterplots with regression model fit (black line) and 95% confidence intervals (shaded grey area) of the Tennis Agility Test reaction times and (A) self-reported sleep quality and (B) self-reported restfulness.

This study found that sleep duration and sleep quality were not significantly associated with repeat sprint ability. This result is in agreement with findings from Vitale et al. (2021), which reported no impact of sleep restriction on repeat sprint ability. Contrary to our expectations, our results revealed that sleep duration and sleep quality were not associated with aerobic performance (Hit and Turn Tennis Test). This finding was unexpected as reduced sleep duration has been linked with increased perceived exertion and declines in pre-exercise muscle glycogen stores, both essential for aerobic performance (Skein et al., 2011; Temesi et al., 2013; Watson, 2017). Further research using objective sleep measures is required to determine the effects of sleep duration and quality on aerobic performance in junior tennis players.

The findings of our study show no effect of sleep duration or sleep quality on speed, power and strength metrics. These findings align with previous literature where maximal speed, power, and strength have been found to not be negatively impacted by acute sleep deprivation (Blumert et al., 2007; Fullagar et al., 2015; Reilly & Edwards, 2007; Watson, 2017). Interestingly, sustained partial sleep deprivation of three hours' sleep per night over three nights has negatively impacted strength performance in weightlifting athletes (Reilly & Piercy, 1994), suggesting that performance decrements may only arise with sustained sleep deprivation. Sleep deprivation was not observed in the seven nights recorded (Figure 2), as all nights met the recommended sleep durations (Hirshkowitz et al., 2015). Therefore, further research is required to ascertain if partial sleep deprivation impacts physical performance in junior tennis players.

Potential limitations

This study did not control time of day when conducting performance testing, which may have impacted player performance. Testing was conducted during daylight hours between 9:00 am and 5:00 pm. Given that these were young amateur tennis players, we were required to comply with their schedules, including school, training, and family commitments thus representing a "real life" situation for coaches and players. The sample size calculation performed for this study indicated a required sample of 55 (α = 0.05, power = 0.80). Unfortunately, this study was only able to recruit 36 junior tennis players. While lower than the calculated sample size, the included sample is larger than previous studies undertaken in this area (Jarraya et al., 2014; Lever et al., 2021; Reyner & Horne, 2013; Vitale et al., 2021). Players' sleep duration and sleep quality were recorded subjectively using a sleep diary. This method is subject to memory bias as it relies on the recollection of players and cannot identify unconscious awakenings. It is, however, more ecologically valid than lab-based measures as it allows players to sleep in their natural environment and engage in their everyday routines. The benefit of this is we collected over 2,000 data points of sleep and had high participation due to the ease of use. Finally, sleep diaries were completed over weekdays and weekends, potentially biasing the data due to social commitments, such as school start times. However, all participants completed a sleep diary over weekdays and weekends to reduce any bias. This approach is also ecologically valid as it is reflective of data collection in the 'real life' setting, where such factors are not controlled.

Future research

While our study results indicate that physical performance is unaffected by sleep duration and sleep quality in junior tennis players, further studies using objective sleep monitoring are required. Furthermore, future studies should aim to control the time of day when testing occurs, as this has been shown to influence physical performance outcomes (Knowles et al., 2018). In addition to the testing time, future studies should also measure players chronotype to determine if the influence of sleep on physical performance differs for morning versus evening chronotypes. Finally, future studies should also aim to investigate the effects of sleep duration and sleep quality on tennis match performance as the decline in reaction time speed found in our study may have a large influence on tennis match outcomes.

CONCLUSION

Our study investigated the effects of sleep duration and sleep quality on physical performance metrics in junior tennis players for the first time. The main finding from our study was that if players felt more rested and refreshed, their reaction time during a tennis agility test was faster. Additionally, sleep duration and sleep quality had no significant impact on any physical performance variable, which may have been due to the recorded sleep duration and sleep quality metrics being within the recommended ranges (Hirshkowitz et al., 2015; Ohayon et al., 2017). Nevertheless, the findings from our study support the notion that physical performance metrics are not significantly influenced by small variations in sleep duration and sleep quality.

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