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ORIGINAL ARTICLE

# The Impact of Sleep-Wake Behaviour on Tennis Match Performance in Junior State Grade Tennis Players

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## Abstract

**Purpose** To date, no study has investigated the extent to which sleep-wake behaviour (SWB) influences match performance in junior tennis players. This study aimed to assess the influence of SWB for the week and night before on match performance, particularly match analytics and activity.

**Methods** This study recruited 10 junior state grade tennis players who wore an actigraphy device and completed a sleep diary for the week before their match on two separate occasions throughout their competition season. Players wore a global positioning system device to track their movement during matches, and an experienced tennis coach recorded players' match analytics.

**Results** This study showed that the sleep fragmentation index was significantly lower the week before matches in females who had won than those who had lost. Additionally, the sleep fragmentation index was significantly lower the night before a given match than the week before. Only sleep fragmentation index and sleep latency significantly influenced match performance in junior tennis players. The percentage of second serves points won differed between match wins and losses for male players, while winners and forced errors differed for female players.

**Conclusion** These findings provide a detailed profile of tennis match play in junior state grade players. Despite individual differences, reduced restlessness the night before a match coincides with increased match performance.

**Keywords** Sleep fragmentation · Tennis analytics · Global positioning system · Sleep quality · Sleep duration

## Introduction

Emerging evidence indicates that sleep-wake behaviour (SWB) influences athletes' match play and physical performance [12, 16, 32, 46]. Sleep-wake behaviour encompasses the sleep timing (sleep onset time [SOT]), duration (total sleep time [TST]) and quality (sleep fragmentation index [SFI], wake after sleep onset [WASO]) of a player [16]. Despite the possible influence of sleep on specific performance variables, limited papers have investigated the impact of SWBs on tennis performance [13, 31, 41, 49]. One potential mechanism that has been shown to impair the performance of tennis skills (serve, forehand and backhand accuracy) is a night of sleep loss in junior and young adult players [41, 49]. However, sleep restriction protocols employed by these studies have only been done the night before testing [41, 49], which lacks ecological validity. Lever et al. [31] is the only study, to date, to investigate the influence sleep has on tennis match performance,finding that despite improved sleep duration following sleep hygiene education, tennis match results (games won/lost) did not significantly change.

Studies in professional and semi-professional basketball players have reported longer TST, time in bed (TIB), and superior subjective sleep quality are positively associated with basketball performance metrics [16, 46]. However, similar associations have not been observed between SWB and performance metrics in Australian football players [42], indicating that the influence of SWB may vary between sports.

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Furthermore, while the consequences of complete sleep deprivation on athletic performance are well known, the exact influence of sleep restriction, which is more prevalent in tennis players, is less clear [17]. It appears that detriments in sporting performance following sleep restriction may be attributed to declines in neurocognitive performance, but further studies are required to ascertain the exact impacts of sleep [17]

Existing literature indicates that sleep may be disrupted the night before competition due to performance anxiety [28]. Compensatory sleep (appropriate sleep duration and quality) the week before may reduce any adverse effects of one poor night of sleep [10, 12]; however, this needs to be more thoroughly investigated. In particular, there is a need to investigate further how uninterrupted SWB the night before a match and the week before a match impacts tennis match performance. These studies are especially important for teenagers, with current recommendations from the National Sleep Foundation that teenagers require 8 to 10 hours of sleep each night for optimal physical, cognitive and emotional health [22]. However, education, social and sporting commitments may negatively impact sleep duration, making it difficult for optimal tennis performance to be achieved [2, 4].

The dominant metric to assess tennis match play performance is player rankings [21, 47], predicated on the outcome of matches. However, this simple metric may not provide complete insight into performance as it does not explain technical, tactical (match analytics) or physical (match activity) outcomes. Therefore, match analytics are commonly undertaken and explored as they provide a more detailed insight into overall performance [15, 20]. Match analytics reveal performance trends, including serving percentages, the number of winners or unforced errors, and the percentage of points won of varying rally lengths (0–1 shots, 2–5 shots), which players and coaches can use to adapt training and match tactics. Furthermore, the identification of superior tennis performance through match analytics, such as higher percentage of serve and points won at various rally lengths can be used to predict current and future success of players [39, 51].

Tennis match activity profiles are vital when monitoring players' physical demands or designing training programs [18, 23, 36]. Furthermore, they may enable small variances in performance, perhaps due to fatigue, that is not reflected in the match result to be identified [25]. There is conflicting evidence around the use of global positioning system (GPS) devices to measure tennis activity. One of the initial studies conducted with GPS devices in tennis reported an underestimation of players' distance covered and movement speed [9]. Studies using newer GPS devices recording at higher frequencies have had equivocal findings with some, but not all [48], studies showing that they are reliable and valid over short distances when accelerations are < 4 $m/s^2$ [1, 5]. Nevertheless, numerous studies have employed GPS devices to measure activity during tennis matches in junior (< 18 years) tennis players, with conflicting findings [18, 23, 24, 36]. Higher-ranked players have been shown to cover more distance and attain higher max speed [18]. However, no difference in match activity has been observed between players who win or lose [23, 24]. While informative, these studies did not concurrently evaluate match analytics and activity, which may explain potential variation in speed reached or distance covered by a player. For example, if fewer winners and errors are made and longer rally lengths are observed, the distance covered by a player will be more.

This study aimed to (i) describe the SWB before a competitive tennis match, including the week and night before the match, (ii) quantify the tennis match analytics and activity, and (iii) investigate the influence of SWBs, the week and night before a tennis match, on match performance. It was hypothesised that an increase in total sleep time, by way of an earlier sleep onset time (SOT), and low sleep disturbances will positively influence tennis match play performance (i.e., a greater percentage of points won) in junior state grade players.

## Methods

### Participants

Ten state grade adolescent players volunteered to participate in this study. Players competed in the junior state grade tennis competition, the highest grade of junior (16 and under) tennis in Western Australia and were required to train a minimum of once per week during the study period. Nine ($n = 9$) players completed the testing requirements, of which four were male. One player could not complete their second testing period due to unforeseen circumstances outside of the testing period. Player demographic information is presented in Table 1. Written informed consent was provided from their guardians on study enrolment. All research procedures were conducted in accordance with the Declaration of Helsinki.

**Table 1** Player demographic information presented as mean ± SD (range)

| Age (years) | Tennis experience (years) | Tennis training/play per week (hours) |
|---|---|---|
| 13.6 ± 1.1 (11–15) | 6.4 ± 2.4 (2–10) | 11.3 ± 2.2 (8–15) |

## Experimental Design

An observational study design over two analysis periods, each seven days/nights in duration, was employed to determine the influence of SWB on tennis match performance. During these analysis periods, the SWB of players were monitored, using a sleep diary and a wrist-worn activity monitor, for seven nights leading up to a state grade competition match. The analysis period commenced on a Sunday night; school was attended for five of the seven recorded nights (Monday to Friday), with all tennis matches taking place on the subsequent Sunday morning. Match performance was assessed via the match result, analytics (e.g., winners and unforced errors) and activity (e.g., distance covered and max speed). Additionally, the years of tennis experience and hours of tennis training performed during the week were also collected. Male competition matches were the best of three tie-break sets, while female matches were two tie-break sets with a match tie-break at one set all. Therefore, males and females were analyzed separately. The research team met with players one week before their competition match to provide them with a sleep diary and wrist-worn activity monitor. The research team then followed up with participants before their match to collect their sleep diary and wrist-worn activity monitor and provide them with their global positioning system (GPS) vest and unit for the match (see Fig. 1). The match was then video recorded so match analytics could be performed later by an experienced tennis coach.

## Measures

### Sleep–Wake Behaviour

Sleep-wake behaviours were monitored for seven days/nights leading up to the match. The Consensus Sleep Diary and a wrist-worn activity monitor (GT3X, Actigraph, FL, USA) were used to record SWB data [33].

The Consensus Sleep Diary consists of 21 questions designed to assess sleep-wake timings, subjective sleep quality and sleep influencing factors, such as alcohol, caffeine and medications, of the players [3, 8].

Players were asked to wear a wrist-worn activity monitor, on their non-dominant wrist, from 30 min before periods of sleep until 30 min after their final awakening. Data were recorded at 60 Hz and analyzed using the Actilife software (Actilife version 6.13.4, Actigraph, FL, USA). The Cole-Kripke sleep/wake algorithm calculated sleep metrics based on the recorded accelerometer data [7]. The sleep periods were identified from data attained from the Consensus Sleep Diary and manually entered into the Actilife software. This method of determining SWB has been validated against polysomnography (PSG) to use with adolescents [38]. The SWB metrics attained include time at lights out (TALO), sleep latency (SL), SOT, WASO, SFI, TST, TIB, sleep

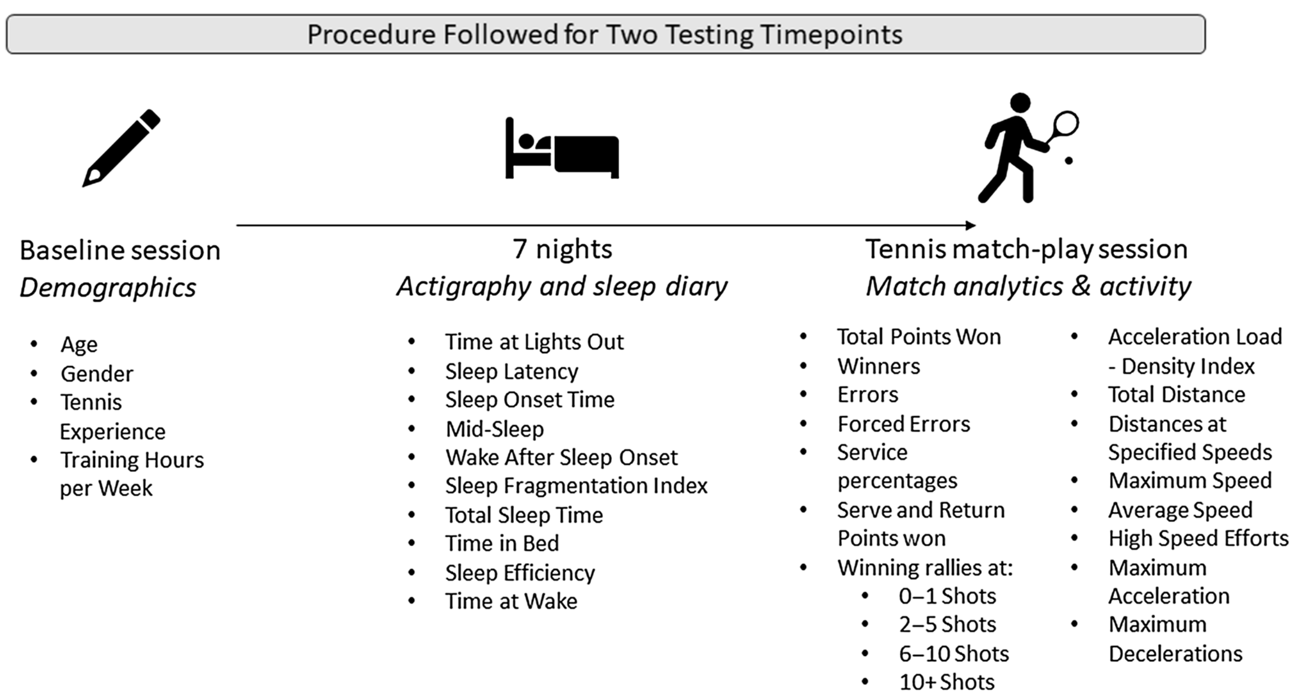


**Fig. 1** The experimental design of the research study, the procedure that each player performed at two-time points during their competition season

efficiency (SE) and TAW, with a detailed description of all variables provided in Table S1A. The GT3X Actigraph device has been shown to have an accuracy of 82% compared to PSG [6]. However, it should be noted that SL, WASO (total number of minutes awake after sleep onset) and SE have shown moderate reliability with PSG and should be interpreted with caution [6, 11].

### Chronotype

Chronotype was determined using the midsleep time of participants for the week leading up to match play. Midsleep on free days with a sleep correction (MSFscn) is a valid calculation for measuring chronotype and is outlined in Eq. (1) [26, 27, 43]. Players were grouped into one of the following chronotypes based on their MSFscn: extremely early (≤ 1:59), moderately early (2:00–2:59), slightly early (3:00–3:59), intermediate (4:00–4:59), slightly late (5:00–5:59), moderately late (6:00–6:59) or extremely late (≥ 7:00) [26].

$$Case1 : TST_f > TST_w \rightarrow MSF - \left( \frac{TST_f - TST}{2} \right)$$

$$Case2 : TST_f < TST_w \rightarrow MSF \quad (1)$$

### Match Analytics

Video recordings of the tennis matches were reviewed, and match analytics were scored by an experienced tennis coach with over ten years of coaching experience, using a tennis scoring and statistics tracker (Tennis Math, application version 3.1.0). Match analytics included for analysis, along with a description, are provided in Table S1B.

### Match Activity

Tennis match activity was assessed using GPS devices (EVO device, GPSports, ACT, Australia). GPS devices were recorded at a frequency of 10 Hz. These devices contain a tri-axial accelerometer which records at a frequency of 100 Hz. While the underestimation of distance covered and movement speed have been reported [48], similar devices and recording frequencies have previously been used and shown to be reliable and accurate with tennis-specific movements [18, 19]. The GPS device was placed in a GPS vest, positioned on the upper back between the scapulae. The GPS device was switched on at least 10 min before the match to obtain clear satellite signals [23, 24]. The duration of the match activity was from the start of the first point until the completion of the final point, with all points and rest periods included. The match activity variables included for analysis and a description of each can be seen in Table S1C. The following velocity categories were used when assessing the distance in each zone: 0–1 m/s; 1–2 m/s; 2–3 m/s; 3–4 m/s and ≥ 4 m/s, as per previous literature with adolescent players [23].

### Statistical Analysis

A Shapiro-Wilk test was used to check data distribution. Data were normally distributed and therefore reported as mean ± SD, effect sizes and ranges. An Independent Samples *T*-Test was used to identify within-sex differences in SWB, match analytics and match activity variables between match wins or losses. A Paired Samples *T*-Test was used to compare SWB metrics for the week and night before the tennis match. Effect sizes were estimated using Cohens *d* and interpreted as follows: trivial 0.0–0.2, small 0.2–0.6, moderate 0.6–1.2, large 1.2–2.0, and very large > 2.0 [49]. Within-sex linear regression analyses were performed to determine the influence of SWB metrics, the night prior and the week prior (as averages), on match performance metrics.

## Results

### Sleep

Overall, in the week leading up to matches, players TALO was 21:45 (± 40 min), with SOT occurring at 21:54 (± 44 min); thus, players had an average SL of 9 ± 7 min. Players TAW was 6:36 (± 31 min), and they had 64 ± 19 min of WASO. Players spent 530 ± 27 min in bed and had an average TST of 457 ± 26 min. Players had a SE of 86% ± 4% and an SFI of 28% ± 7% for the week. The MSFscn chronotype calculation resulted in five extreme morning types, three moderate morning types and one slight morning type.

When comparing the SWB metrics for the night before matches with the average of the week before (nights 1–7) matches, there were no statistical differences found for any measure, except for SFI, which was lower by 19% ± 2% ($P < 0.001$, $d = 2.683$) the night before matches.

As presented in Fig. 2, no significant differences were observed in SWB before matches regardless of the match result in male junior state grade players. The average SFI for the week before matches was lower by 9% ± 3% ($P = 0.01$, $d = 2.122$) in females who won, compared to females who lost.

### Match Analytics

The differences in tennis match analytics for males and females who won and lost are displayed in Table 2. The

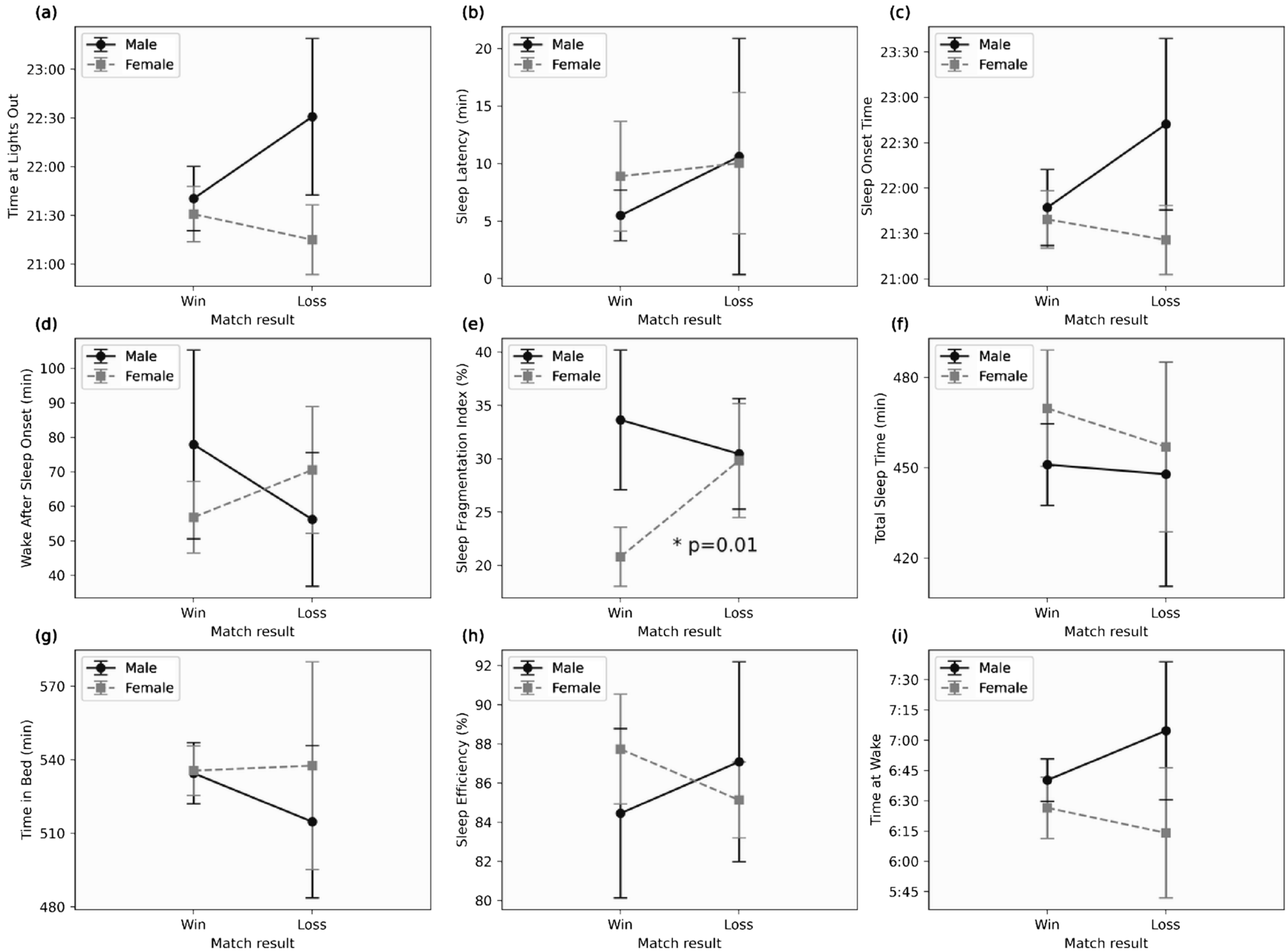


**Fig. 2** The differences in sleep-wake behaviour between match wins and losses for male and female players. The means are indicated by a circle for males and a square for females, with standard deviations provided with capped error bars. Females' data are illustrated in grey with a dashed line for clarity. *Significance ($P<0.05$)

percentage of total points won differed between matches won and lost for both males and females. Males who won their match won more second serve points ($P=0.013$, $d=2.467$) and rallies between two and five strokes ($P=0.012$, $d=2.163$). Females who won hit more winners ($P=0.033$, $d=1.633$), made less forced errors ($P=0.012$, $d=2.042$) and won a greater percentage of rallies with one stroke ($P=0.013$, $d=1.997$).

## Match Activity

The differences in tennis match activity metrics for males and females who won and lost are presented in Table 3. Males who won covered less ($P=0.049$, $d=1.481$) distance in zone 4 (3–4 m/s) compared to males who lost. Females who won had a higher max speed ($P=0.049$, $d=1.460$) than those who lost.

## Associations

As seen in Fig. 3, males who have a one percent increase in SFI for the night before their tennis matches increased the percentage of second serve points won by 0.68% (SE=0.23, $P=0.030$). Females who have a one-minute increase in SL for the night before their tennis matches increased the percentage of total points by 0.9% (SE=0.35, $P=0.034$), second serve points by 1.47% (SE=0.6, $P=0.041$) and second serve receiving points won by 1.48% (SE=0.59, $P=0.037$), which can be seen in Fig. 3.

## Individual Player Reports

Individual player reports, including match performance and SWB metrics and specific descriptions and recommendations, are presented in Fig. S1A–S1I of the supplementary file. The player reports show that only two players (players

**Table 2** Match analytics for the tennis match wins and losses

| Parameters | Wins | Losses | 95% CI | *P*-value | Effect size | |
|---|---|---|---|---|---|---|
| **Males** | | | | | | |
| TPW (%) | 57.77 ± 2.2 | 45.81 ± 2.09 | [ 7.64 to 16.27] | 0.001 | 5.617 | Very Large |
| W (%) | 7.63 ± 1.16 | 9.88 ± 4.03 | [−7.19 to 2.7] | 0.295 | 0.670 | Moderate |
| UE (%) | 18.91 ± 8.74 | 17.65 ± 8.64 | [−15.92 to 18.44] | 0.852 | 0.145 | Trivial |
| FE (%) | 11.06 ± 2.51 | 17.17 ± 4.99 | [−12.64 to 0.4] | 0.061 | 1.414 | Large |
| FSIP (%) | 71.0 ± 4.36 | 62.8 ± 7.16 | [−1.79 to 18.19] | 0.091 | 1.289 | Large |
| Aces (#) | 0.33 ± 0.58 | 0.2 ± 0.45 | [−1.01 to 1.28] | 0.751 | 0.270 | Small |
| DF (#) | 2.33 ± 2.52 | 6.2 ± 4.09 | [−9.6 to 1.86] | 0.149 | 1.062 | Moderate |
| FSPW (%) | 61.0 ± 3.61 | 54.2 ± 2.59 | [−0.44 to 14.04] | 0.059 | 2.292 | Very Large |
| SSPW (%) | 60.0 ± 4.0 | 48.0 ± 5.24 | [ 3.72 to 20.28] | 0.013 | 2.467 | Very Large |
| SSRPW (%) | 53.0 ± 10.44 | 44.6 ± 9.15 | [−12.12 to 28.92] | 0.315 | 0.875 | Moderate |
| 0–1 (%) | 64.29 ± 5.95 | 51.42 ± 11.45 | [−2.22 to 27.96] | 0.082 | 1.293 | Large |
| 2–5 (%) | 54.53 ± 2.81 | 43.02 ± 6.21 | [ 3.59 to 19.43] | 0.012 | 2.163 | Very Large |
| 6–10 (%) | 49.52 ± 8.28 | 47.19 ± 10.64 | [−14.7 to 19.36] | 0.743 | 0.235 | Small |
| 10 + (%) | 53.33 ± 41.63 | 35.17 ± 35.45 | [−63.81 to 100.14] | 0.564 | 0.483 | Small |
| **Females** | | | | | | |
| TPW (%) | 58.25 ± 4.79 | 45.29 ± 9.1 | [ 2.36 to 23.57] | 0.022 | 1.783 | Large |
| W (%) | 14.11 ± 6.24 | 6.61 ± 1.81 | [ 0.8 to 14.2] | 0.033 | 1.633 | Large |
| UE (%) | 25.09 ± 5.57 | 27.94 ± 8.88 | [−13.66 to 7.96] | 0.560 | 0.384 | Small |
| FE (%) | 10.82 ± 4.31 | 17.52 ± 1.71 | [−11.48 to −1.92] | 0.012 | 2.042 | Very Large |
| FSIP (%) | 63.0 ± 7.75 | 61.0 ± 8.8 | [−10.09 to 14.09] | 0.713 | 0.241 | Small |
| Aces (#) | 0.8 ± 0.84 | 0.2 ± 0.45 | [−0.38 to 1.58] | 0.195 | 0.894 | Moderate |
| DF (#) | 5.0 ± 2.35 | 7.8 ± 1.79 | [−5.84 to 0.24] | 0.067 | 1.342 | Large |
| FSPW (%) | 62.2 ± 5.17 | 53.8 ± 10.28 | [−3.47 to 20.27] | 0.141 | 1.032 | Moderate |
| SSPW (%) | 67.4 ± 16.89 | 55.2 ± 14.81 | [−10.96 to 35.36] | 0.259 | 0.768 | Moderate |
| SSRPW (%) | 55.4 ± 17.37 | 44.6 ± 9.15 | [−4.08 to 37.68] | 0.101 | 1.173 | Moderate |
| 0–1 (%) | 59.09 ± 5.73 | 45.23 ± 7.97 | [ 3.74 to 23.98] | 0.013 | 1.997 | Large |
| 2–5 (%) | 58.38 ± 8.56 | 46.74 ± 10.41 | [−2.26 to 25.54] | 0.090 | 1.222 | Large |
| 6–10 (%) | 56.03 ± 7.31 | 44.62 ± 8.54 | [−0.18 to 23.01] | 0.053 | 1.436 | Large |
| 10 + (%) | 52.0 ± 50.2 | 35.56 ± 41.13 | [−50.48 to 83.37] | 0.587 | 0.358 | Small |

one and four) had matches where their sleep scores for the week were below 50% (indicative of poor sleep). While two players (players three and nine) had matches where their sleep score for the week was above 75% (indicative of very good sleep).

## Discussion

This is the first study to investigate the influence of SWB on tennis match performance. Furthermore, it is the first study to simultaneously quantify junior state grade players' match analytics and activity. This study found a relationship between SFI for the night before a match and the percentage of second serve points won in male junior players. The direction of this relationship was unexpected, with greater sleep disruption for the night before a match being related to an increase in the percentage of second serve points won. This finding aligns with previously reported associations between movement and fragmentation indices and basketball analytics. The authors surmised that the observed restlessness might not be associated with actual sleep disturbances [16]. Alternatively, the recorded SFI for the night before the matches were not high enough to impact performance. Specifically, even though higher SFI values were related to a greater percentage of second serve points won, the SFI for all players for the night before the matches were still very low. The relationship found between sleep latency and match performance in female junior players should be interpreted with caution due to the known limitations of actigraphy in recording sleep latency, as it relies on subjective reporting of TALO via a sleep diary [6, 11].

Interestingly, SFI was the only SWB metric to differ significantly the night before the match, and between match wins and losses in female junior players, with players who won having a lower SFI percentage. Existing research with adolescents has reported poor sleep quality and duration as a result of increases in school homework (potentially excessive

**Table 3** Match activity metrics for the tennis match wins and losses

| Parameters | Wins | Losses | 95% CI | *P*-value | Effect size | |
|---|---|---|---|---|---|---|
| **Males** | | | | | | |
| ALDI (#) | 5.16 ± 0.3 | 5.03 ± 0.17 | [−0.5 to 0.76] | 0.544 | 0.586 | Small |
| TD (m) | 3845.11 ± 362.97 | 4792.17 ± 1436.24 | [−2707.16 to 813.03] | 0.222 | 0.795 | Moderate |
| DZ1 (%) | 63.93 ± 7.69 | 71.93 ± 8.89 | [−23.4 to 7.39] | 0.238 | 0.941 | Moderate |
| DZ2 (%) | 20.58 ± 7.36 | 12.23 ± 7.01 | [−6.11 to 22.8] | 0.187 | 1.170 | Moderate |
| DZ3 (%) | 10.78 ± 1.03 | 9.32 ± 1.3 | [−0.65 to 3.56] | 0.137 | 1.196 | Moderate |
| DZ4 (%) | 4.22 ± 0.26 | 5.53 ± 1.07 | [−2.62 to 0] | 0.049 | 1.481 | Large |
| DZ5 (%) | 0.42 ± 0.28 | 0.71 ± 0.44 | [−0.92 to 0.35] | 0.310 | 0.721 | Moderate |
| MS (m/s) | 5.15 ± 0.09 | 5.65 ± 0.74 | [−1.41 to 0.42] | 0.211 | 0.815 | Moderate |
| AS (m/s) | 0.86 ± 0.05 | 0.82 ± 0.07 | [−0.06 to 0.14] | 0.354 | 0.650 | Moderate |
| HSE (#) | 60.0 ± 5.29 | 88.0 ± 33.32 | [−69.01 to 13.01] | 0.134 | 1.023 | Moderate |
| MA (m/s$^2$) | 2.94 ± 0.24 | 3.41 ± 0 | – | – | – | – |
| MD (m/s$^2$) | −3.29 ± 0.62 | −3.69 ± 0 | – | – | – | – |
| **Females** | | | | | | |
| ALDI (#) | 5.48 ± 0.23 | 5.18 ± 0.51 | [−0.28 to 0.87] | 0.269 | 0.751 | Moderate |
| TD (m) | 3040.94 ± 1142.63 | 3418.35 ± 928.51 | [−1895.77 to 1140.96] | 0.582 | 0.363 | Small |
| DZ1 (%) | 69.11 ± 4.98 | 76.37 ± 9.37 | [−18.19 to 3.69] | 0.165 | 0.967 | Moderate |
| DZ2 (%) | 19.93 ± 4.21 | 14.07 ± 9.22 | [−4.59 to 16.31] | 0.232 | 0.818 | Moderate |
| DZ3 (%) | 7.97 ± 0.79 | 7.29 ± 1.22 | [−0.83 to 2.17] | 0.332 | 0.653 | Moderate |
| DZ4 (%) | 2.81 ± 0.73 | 2.24 ± 0.9 | [−0.62 to 1.77] | 0.300 | 0.701 | Moderate |
| DZ5 (%) | 0.16 ± 0.14 | 0.03 ± 0.07 | [−0.03 to 0.29] | 0.104 | 1.158 | Moderate |
| MS (m/s) | 4.52 ± 0.39 | 4.0 ± 0.31 | [0 to 1.04] | 0.049 | 1.460 | Large |
| AS (m/s) | 0.69 ± 0.04 | 0.64 ± 0.09 | [−0.05 to 0.15] | 0.288 | 0.719 | Moderate |
| HSE (#) | 29.2 ± 8.79 | 30.2 ± 11.52 | [−15.94 to 13.94] | 0.881 | 0.098 | Trivial |
| MA (m/s$^2$) | 2.79 ± 0.28 | 2.71 ± 0.2 | [−0.3 to 0.46] | 0.634 | 0.321 | Small |
| MD (m/s$^2$) | −3.14 ± 0.23 | −2.94 ± 0.31 | [−0.67 to 0.26] | 0.323 | 0.760 | Moderate |

screen time) or after school sport (high-intensity exercise near bedtime or change in regular time bedtime [TALO]) [2, 4]. The absence of school the day before the matches may have resulted in the decrease in SFI, with players able to follow better sleep hygiene practices [50]. This supposition does, however, require further investigation. Nevertheless, increased restlessness, indicated by higher SFI, significantly impacts the match result, which is the primary performance outcome in female junior players.

The sleep duration reported in this study was, on average, 7 h 37 min. Previous studies on tennis players have reported equivalent or higher sleep durations than those from this study [31, 41, 49]. Sleep duration is of interest given that longer TST has been shown to improve tennis serve accuracy [44], which is vital given the known importance of the serve on match performance [39, 51]. This study observed no difference in TST between match wins and losses. Similarly, a recent study on junior tennis players found TST did not improve the number of games won and lost or the subjective player ratings [31]. This finding was also observed in semi-professional basketball players, with TST not influencing performance [16]. The reported findings from this and previous studies may be due to players receiving, on average, greater than seven hours of sleep per night, which according to the National Sleep Foundation (NSF), may be appropriate for the age groups included [22].

To date, research on the match analytics of players has predominately focused on professional level players [35, 40]. While intriguing, these metrics are not applicable for the younger generation of players who are not yet full-time athletes [14, 30]. As expected in junior state grade players, the percentage of total points won was significantly higher for match wins for males and females. In agreement with previous research in professional male players [39], the percentage of second serve points won was significantly higher for match wins in male junior players, emphasising the importance of the serve in male tennis. Winning a higher percentage of rallies that last two to five strokes was also significantly higher for match wins in male junior players. This is of great importance as most rallies will be in this bracket, with the average rally length reported in junior and senior (professional) men's tennis being 4.7 and 3.4 strokes, respectively [14]. Interestingly, this was not the case for female junior players. Our results show the percentage of rallies won that were one stroke in length were the most significant despite previous findings that females

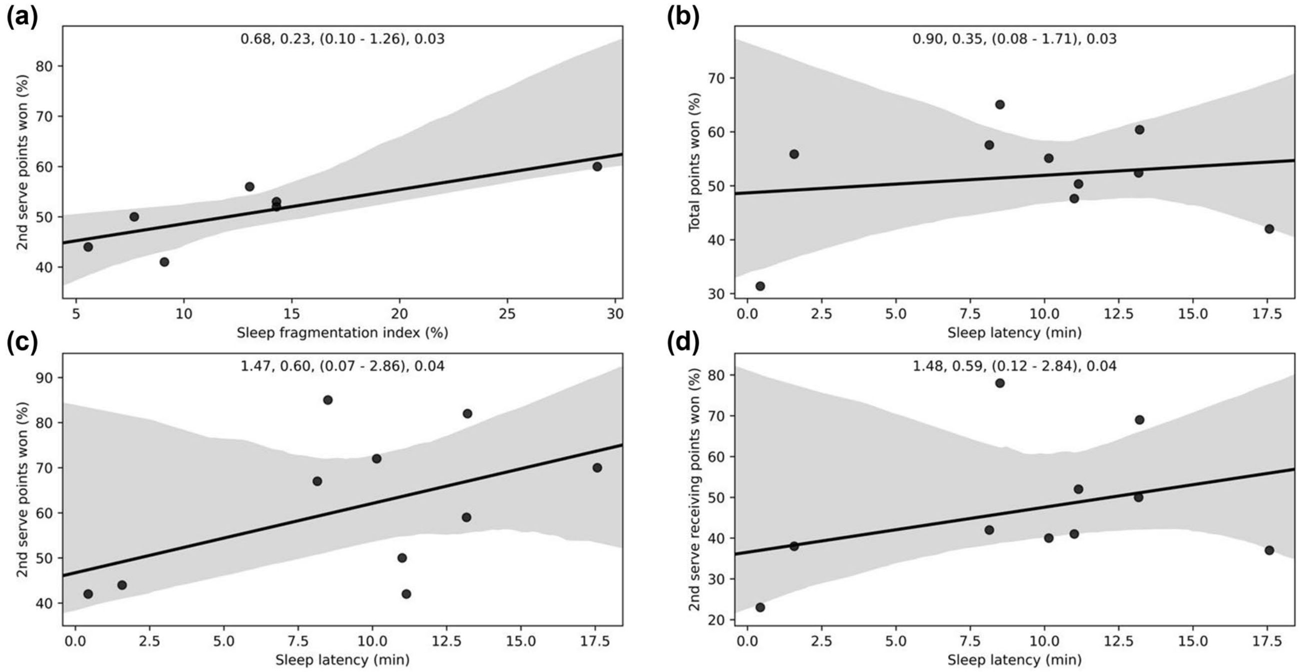


**Fig. 3** Relationship between sleep fragmentation index the night before the match and 2nd serve points won in males (**A**), sleep latency the night before the match and total points won (**B**), 2nd serve points won (**C**), and 2nd serve receiving points won (**D**) in females. Data presented as $\beta$, SE, (95% CI), *P*-value

have longer rallies than males [35]. The number of winners hit and forced errors made were also higher and lower, respectively, in junior female players who won, indicating an aggressive style of play.

Previous work investigating the match activity of male junior players found no significant differences in any match activity variables between match wins and losses [23, 29]. Our results contrast this earlier finding. In particular, our results show that match wins were associated with a lower percentage of distance covered between 3 and 4 m/s for male junior players. This conflict in findings may be attributed to the difference in court surfaces, with previous studies being played on clay and not hard court [23, 29]. Differences in players' playing style (aggressive vs. defensive) or that data in this study were collected during state league competitions and not simulated match play could explain the discrepancy in findings [34].

Furthermore, match wins were associated with a significantly greater maximal running speed in female junior players. This finding aligns with previous research by Galé-Ansodi et al. [18], who reported significantly higher maximal running speed in higher, compared to lower, ranked male and female players. While not significant, it is worth noting that the total distance covered was lower for male and female players that won their match. This finding is of interest given recent results from Filipcic et al. [14], showing that professional level players cover less distance than junior players due to increased shot speeds and shorter distances between the two players. These findings may aid coaches and players when planning training sessions. However, further research is still required to determine the most influential match activity metrics for successful tennis match performance.

The individual player reports developed in this study are a novel approach that demonstrates how the collected SWB data can be communicated in a practical setting. While group-level statistics are warranted and relevant for the advancement of science, they do not always accurately represent SWB at an individual or player level, which is relevant to coaches [45]. Individual player reports provide greater insight into the collected data, and studies should aim to report both individual and group level data in the future. Additionally, the player reports, including the NSF recommendations and calculated sleep scores, can be used as a practical tool for coaches to quickly and easily check a player's SWB leading up to or following a match.

While similar to previous studies [36, 37], this study included a relatively small sample of players. However, it is noteworthy that players in this study undertook multiple matches, which improves the reliability of these findings. Second, while all players shared a similar ranking, players' technical and physical attributes likely differed, which could have influenced match analytics and activity profiles. The level of the players in this sample may impact the transferability of the results to other players of a higher standard and who have greater training demands. Third, the court surface and environmental conditions could not be controlled; however, the matches followed the league rules and regulations, including suspension of play in extreme heat or rain. Additionally, players collected their tennis balls between points during the match, which may have increased the distance covered and decreased the average player's speed. Fourth, seven nights of sleep monitoring were conducted on two separate occasions during the season for each player, with match data collected for 18 matches (eight male and ten female). It is noteworthy that the collected sleep data may not be enough of a sample to demonstrate a behaviour but rather just an indication of sleep-wake activities leading up to competitive tennis matches. Finally, SL, WASO and SE measured with actigraphy have only shown moderate reliability compared to PSG, and therefore should be interpreted with caution.

Despite these limitations, this study showed sleep quality, specifically lower SFI, was the only metric to differ the night before matches and that it positively impacts the match result in female junior players. Future research is needed to confirm these preliminary findings and determine how increased sleep restlessness impacts tennis match play performance. Additionally, future research should explore the influence of individuals chronotypes and the time of the match on the relationship between sleep and tennis performance.

## Conclusion

This study provides preliminary evidence that tennis match play performance is affected by sleep quality, particularly the level of restlessness the night before the match. The percentage of restlessness indicated by the SFI was also the only SWB metric to improve the night before matches compared to the average of the week. These findings suggest that players should reduce potential disturbances and optimise their sleep hygiene to achieve the best sleep quality possible, especially the night before their matches.

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**Data availability** All data generated or analysed during this study are included in this published article and its supplementary information files.

## Declarations

**Competing interests** The authors have no relevant financial or non-financial interests to disclose.

**Ethics approval** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Edith Cowan University Human Research Ethics Committee (ID: 00673).

**Consent to participate** Informed consent was obtained from all participants included in the study and their parents.



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