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Sleep profiles of elite swimmers during different training phases

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ABSTRACT

This study aims to describe the sleeping patterns during different training phases in competitive swimmers. Twelve national and international level swimmers (3 females, 9 males) were monitored during 4 different phases consisting of a preparation training phase, a taper phase, a competition phase and a rest phase. Sleep parameters were assessed using wrist activity monitors and self-report sleep diaries. There was a moderately higher (*d* = 0.70 – 1.00) sleep onset latency during the competition phase compared to taper, train and rest phase. Trivial to small differences were observed for total sleep time between phases (*d* = 0.05 – 0.40). Sleep efficiency was moderately higher (*d* = 0.60 – 0.75) in the training and taper phases compared to competition and rest. Restfulness and Fragmentation Index (FI) were lowest in the rest with differences between phases being small (*d* = 0.43 – 0.51) for restfulness and small to moderate (*d* = 0.43 – 0.62) for FI. Time in and out of bed was very largely later (*d* = 1.96 – 2.34) in rest compared to the other phases. Total nap time was moderately lower in rest (*d* = 1.13 – 1.18) compared to the training and competition phases whilst there was a small difference (*d* = 0.46) compared to taper. To conclude, whilst there were trivial to small differences in sleep quantity between phases, there are small to moderate differences in other sleep parameters. Specifically, sleep onset latency was higher during the competition phase. Additionally, this study highlights the substantial between-individual variations in sleep responses during different training phases.

Keywords: swimming, athlete, performance, recovery.

INTRODUCTION

Recovery from training and competition is an essential aspect of the training process of elite athletes. Sufficient recovery is needed to enhance and maintain training quality and readiness to perform at the competitions (18). Sufficient recovery is also required to reduce the risk of transitioning into a state of excessive fatigue (non-functional overreaching, overtraining syndrome) and also to reduce the risk of injury (18). One of the most important aspects of the recovery continuum for elite athletes is obtaining a sufficient quantity and quality of sleep. Indeed, athletes and coaches have ranked sleep as the most important recovery strategy (6). Since a variety of crucial immune and metabolic processes occur during sleep, it appears a conceptual relationship exists between the quantity and quality of sleep and the capacity of athletes to perform and recover (22). However, due to the variable individual requirement for sleep, complexity of sleep function and the numerous different athletic environments present in elite sport (19, 27), the interaction between sleep and markers of recovery and well-being in elite athletes remains largely unknown.

Various specific aspects and commitments of different sports (i.e. scheduling) may have an impact on sleep, making some sports more prone to potential sleep difficulties compared to others. For example, professional footballers incur significantly reduced (subjective) sleep durations following a night-match compared to training and day-matches (8). Comparatively, Sargent et al. (23) assessed the impact of training schedules on sleep and fatigue in swimmers. They found that early morning training sessions resulted in reduced sleep durations and increased pre-training fatigue levels. Disturbed sleep is critical to address because it can result in neurocognitive and physiological changes that may compromise performance (1, 3, 22). Using wristwatch actigraphy in triathletes with symptoms of overreaching, Hausswirth et al. (12) observed reductions in sleep duration, sleep efficiency and time spent immobile during time in bed. Other research has highlighted that the amount of sleep an elite athlete obtains is largely influenced by their training schedule and training phase (24). These studies provide valuable evidence on the potential relationship between the influence of different training phases (and resulting changes in training characteristics) on sleep. However, despite the anecdotal criticality of sleep to recovery, and the emphasis placed on regular athlete monitoring, there is little literature addressing the sleep profiles of competitive athletes such as swimmers during different training phases. The different training characteristics of different training phases may have an impact on the potential for sleep disturbances (16). However, field-based observational studies where variations in sleep volume and quality may occur due to changes in training characteristics or sport commitments are scarce in the current literature. Such knowledge would improve our understanding of the swimmers' typical sleep behaviour, how this behaviour shifts when faced with compromising situations (e.g. different training phases) and potentially how these changes impact aspects of the recovery continuum.

Whilst a range of data exists on the role of sleep in recovery, and on the impact of various interventions (competition, time of day training etc) on sleep quality/quantity, there is a lack of sleep data during different training phases in competitive swimmers. Therefore, obtaining descriptive data of how competitive swimmers sleep would assist in identifying normative sleep behavior. In doing so, such investigations may identify potential factors relating to disturbed sleep which could assist in defining and recommending appropriate sleeping strategies to coaches and athletes. Therefore, this paper aims to describe the potential changes in sleeping patterns during different training phases in competitive swimmers.

METHODS

Experimental Approach to the Problem

This study evaluates the potential changes in sleeping patterns during different training phases in competitive swimmers. The data were collected at 4 different training and competition phases consisting of a preparation training phase (TRAIN), a taper phase (TAP) a competition phase (COMP) and a REST phase (REST). Each phase was classified by the coach responsible for the planning and programming of all athletes. For TRAIN, TAP and REST, athletes were monitored in their home environment. For COMP, all participants were monitored in a hotel environment.

Subjects

Twelve national and international level swimmers (3 females, 9 males) participated in this study (mean ± SD; age: 21 ± 2 years, height: 183 ± 8 cm, bodyweight: 74.3 ± 7.8 kg). The study was conducted during the 2015/2016 competitive swim season. At the time of the study four of the participants had previously competed at the Commonwealth Games (total of 6 silver medals) and four competed at previous World Championships (winning 1 gold medal). The data collection period commenced in November 2015 and concluded in May 2016 and this period included a competition phase for the 2016 Rio De Janeiro Olympic Games trials. Participants reported to be healthy and free of injury, and none of the participants reported to be taking medication known to influence sleep or had travelled across time zones in the 2 weeks prior to data collection commencing. All participants were informed of the purpose and procedures of the study and written informed consent was obtained prior to participation. Institutional ethics approval was granted and in agreement with the Helsinki Declaration.

Procedures

Training phases

Duration of each phase was 14 days for the TRAIN and TAP and varied between 3 to 7 days for the REST and COMP, depending on the individual. The breakdown for each individual's competition phase was 3 days (n=1), 5 days (n=5), 6 days (n=3) and 7 days (n=3). The breakdown for each individual's rest phase (REST) was 3 days (n=1), 4 days (n=4), 5 days (n=4), and 7 days rest (n=3). Athletes were asked to carry out their normal daily training programme, which was programmed and delivered by the respective coaching staff at a central campus, where all the athletes were based. During training phases, training consisted typically of 4-5 early sessions (start of training between 7.30 and 8.30 AM) and 3-4 afternoon sessions (3.30 PM). Training paces were prescribed based on field-based lactate assessments performed before conducting the study. Training intensity zones were classified as "Aerobic Capacity 1" (zone 1), "Aerobic Capacity 2" (zone 2), "Aerobic Capacity 3" (zone 3) which consisted of low to moderate intensity conducted at a pace that would elicit an (expected) lactate concentration of < 2 mmol·L^{-1}, 2 – 4 mmol·L^{-1} and 3 – 6 mmol·L^{-1}, respectively, based on the pre-study field-based lactate assessments. In addition, time spent at high intensity intervals were classified as either "Aerobic Power (zone 4)" , "Anaerobic Capacity (zone 5)" and "Anaerobic Power (zone 6)" and these consisted of a number of different interval formats consisting of intervals varying between 50 – 400 m at zone 4, 25 – 100 m for zone 5 and zone 6. Distance swam at each of these zones was collected and analysed for every training phase.

Sleep

Sleep parameters were monitored using wrist activity monitors and self-report sleep diaries. All participants were provided with an actigraph wristwatch (GeneActiv, Cambridgeshire, UK) for each of the four data collection periods and were instructed to wear the watch on the non-dominant hand at all times except when swimming or showering. Data from the actigraphy watches were sampled at 10 Hz and assessed at 60-second epochs (28). Participants were instructed to report; any naps they had during the day (min) and screen time after 5 PM (min) before going to sleep. Participants were also instructed to report subjective sleep quantity and quality upon awakening. Further sleep parameters were obtained through actigraphy assessment. These include total time in bed, total sleep time, sleep onset latency, sleep efficiency, restfulness and fragmentation index (FI). Total sleep time was calculated as:

[(Δ of sleep duration between bedtime and time of wake) – duration of sleep onset latency – total wake episode duration]

Sleep efficiency (%) was calculated as the ratio between total sleep time and total time in bed. Restfulness was calculated as the number minutes with epochs greater than 1 throughout total sleep time. FI (%) was calculated as the ratio between total sleep time and minutes classified as restfulness.

Statistical analyses

Prior to analysis the assumption of normality was verified by using Shapiro-Wilk W test and visual inspection of QQ plots. Sleep variables for every phase were compared to each other using a multilevel random intercept model using Tukey's method for pairwise comparisons in R (R: A Language and environment for statistical computing, Vienna, Austria). To account for individual differences in sleep parameters, random effect variability was modelled using a random intercept for each participant. Level of significance was established at $P < 0.05$. Magnitude based inferences was used to further evaluate and describe the magnitude of the effects observed (13). Standardised effect size is reported as Cohen's *d*, using the pooled standard deviation as the denominator. Qualitative interpretation of *d* was based on the guidelines provided by Hopkins et al. (13): 0 - 0.19 trivial; 0.20 – 0.59 small; 0.6 – 1.19 moderate; 1.20 – 1.99 large; ≥ 2.00 very large.

RESULTS

Mean swimming distance per day during REST was 645 ± 580 m, 3854 ± 1620 m during COMP, 4746 ± 1523 m during TAP and 5393 ± 1103 m during TRAIN. Mean daily swimming distance in the lower intensity zones (zone 1 – zone 3) was 4619 ± 1448 m during TAP, 5279 ± 1038 m during TRAIN, 3971 ± 1654 m during COMP and 645 ± 580 m during REST. Daily swimming distance in the higher intensity zones (zone 4 - 6) was 0 during REST, 124 ± 68 m during COMP, 114 ± 80 m during TRAIN and 127 ± 168 during TAP. Descriptive sleep data parameters for the athletes is presented in Table 1. Mean individual participant sleep variable data displayed for each testing phase (REST, COMP, TRAIN and TAPER) for sleep onset latency, total sleep time, sleep efficiency, FI, daily nap time and screen time exposure before bed are presented in Figure 1.

There was a moderately higher (d = 0.70 – 1.00) sleep onset latency during COMP compared to TAP, TRAIN and REST whilst other between-phase differences were trivial to small (d = 0.00 – 0.27). Trivial to small differences were observed in terms of total sleep time between phases (d = 0.05 – 0.40) with total sleep time being highest in COMP followed by TAP, REST and TRAIN. Sleep efficiency was moderately higher (d = 0.60 – 0.75) in TRAIN and TAP compared to COMP and REST. Restfulness and FI were lowest in REST with differences between phases being small (d = 0.43 – 0.51) for restfulness and small to moderate (d = 0.43 – 0.62) for FI. Bedtime was very largely later (d = 2.00 – 2.27) in REST compared to the other phases. Subsequently, get-up time was large to very largely (d = 1.96 – 2.34) later in REST compared to the other phases as well ($P < 0.01$). Total nap time was moderately lower in REST (d = 1.13 – 1.18) compared to TRAIN and COMP whilst there was a small difference (d = 0.46) compared to TAP. Subjective sleep quality was moderately lower in COMP compared to TAP whilst all other differences were trivial to small (d = 0.00

– 0.47). Screen time before bed was moderately lower (*d* = 0.64 – 0.80) in REST and COMP compared to TAP and TRAIN.

DISCUSSION

The aim of this study was to examine whether there were any differences in sleep characteristics of elite swimmers during different training phases. In alignment with normative values and healthy adult ranges (20), the athletes achieved a grouped average of 7.9 h sleep during REST, 7.9 h during COMP, 7.7 h during TRAIN and 7.9 h of sleep during TAP. Despite small to moderate differences in sleep quality and sleep onset latency, limited differences were observed in terms of sleep quantity between phases. To our knowledge this is the first comprehensive analysis of sleep quantity and quality during a complete training cycle in elite level swimmers.

Sleep is considered paramount for enhanced recovery and athletic performance (22). Despite this, studies in athletic populations have shown that some athletes do not always meet the recommendations for adequate sleep in healthy adults (7-9h, National Sleep Foundation, (20)). For instance, Leeder et al. (17) showed an average sleep duration of ~7 h in Olympic athletes. It appears that the swimmers in this study slept longer than previously reported sleep quantities in athletes (17, 26). In addition, limited between-phase differences in sleep quantity are observed. Small to moderate differences were observed in terms of total sleep time with total sleep time being lowest in the TRAIN phase compared to the other phases. However, taking in to account the magnitude of the difference (~ 15 min lower total sleep time in TRAIN compared to the other phases), any practical effects of these differences are most likely small. In addition, only small differences in sleep efficiency were observed when comparing phases. Since previous studies have shown that sleep duration and efficiency can be reduced in athletes whom are displaying symptoms of functional overreaching during a period of increased training load (12), a possible explanation for the limited differences observed is that the training load wasn't substantial enough to induce a state of overreaching (and thereby potential sleep disturbances). For example, deteriorated sleep latency, quantity and efficiency measured with actigraphy has been observed with high training loads in athletes (15). In addition, the relatively short data collection periods for each phase (3 – 14 days) might not have been long enough to discern any noticeable changes in sleep.

Sargent et al. (23) previously showed that early-morning training severely restricts the amount of sleep obtained by elite swimmers. They showed a mean total sleep time of 5.4 h during training days and 7.1 h on rest days. The authors mainly attributed the reduced time in bed to early wake times for 06:00 training start time and the inability to go to sleep any earlier in the evening prior to training. The total sleep time during training days observed by Sargent et al. (23) is substantially lower compared to the total sleep time observed in this study across all training and competition phases (7.7 – 7.9 h). Within this study we observed later wake times with the mean times of 07:25, 07:46 and 07:16 in TRAIN, TAP and COMP phases respectively. This was mainly made possible due to the later start times of morning swim sessions (between 07:30 – 08:30). Hence, it is suggested that the later wake times of the swimmers in the present study in comparison to the study by Sargent et al. (23) are the main contributor to the differences in sleep durations between the two studies. This is in line with previous research showing that bedtime and get-up time are directly dictated by their training schedule (23, 24). For example, previous research has shown that early morning starts reduce sleep duration and increase pre-training fatigue levels (24). We propose that the additional time spent sleeping in a morning due to the (later) scheduled training sessions was why the participants mean sleep durations from the present study fall within the 'normative' range.

Sleep onset latency was moderate to largely higher in the COMP phase (~27 min) compared to the other phases (~17-19min). This is line with previous research by Erlacher et al. (5) and Juliff et al. (14), who found that athletes slept worse than normal during competition phases and that a high percentage of the athletes who suffered from disturbed sleep attributed this to problems with sleep onset latency. The main reasons for higher sleep onset latency during competitive settings are thoughts about the competition, nervousness and overall pre-competition anxiety (4, 5, 14). Given the potential negative effect of increased sleep onset latency on competition performance, having strategies in place that counteract or limit some of these potential effects could improve sleeping profiles and may improve subsequent competition performance. For example, athlete education on the effect of bedroom temperature, the (limited) use of electronic devices and/or the use of relaxation techniques and napping may improve sleeping behaviors in competitive settings (7, 9). In addition, supplement use that may negatively affect sleep behavior (e.g. caffeine (2)) is typically higher in competitive phases compared to other (training) phases. Therefore, advising athletes on the appropriate use of supplementation during the competitive setting may limit potential sleep disturbances (9).

The findings of this study also show that sleep efficiency across all 4 testing phases ranged between 82% to 85%. Sleep efficiency of healthy young adults is typically >90% (21) and although our findings are notably lower than this, they were in accordance with those documented by Leeder et al. (17) when examining the sleep profiles of elite athletes. However, sleep efficiency in this study was greater than that reported by Sargent et al. (23) who examined elite swimmers during a training camp (~70-77%). Sargent et al.' (23) findings are most likely to be explained by the high training loads induced by the high intensity nature of training during the camp. Small to moderate differences in FI and restfulness were observed across all phases, which suggests that sleep quality was somewhat maintained in each phase. However, individual sleep quality may have substantially been affected during the different phases of the study (see Figure 1). Taylor et al. (25) found that sleep onset latency, total sleep time and REM sleep were comparable in competitive female swimmers in the onset of peak training, peak training and taper. Through the use of polysomnography they found that slow wave sleep was significantly reduced following taper, as was the number of movements during sleep. However, only small differences in restfulness (activity>1) between the phases within our study were observed and this was possibly due to the training load not being substantial enough to induce a state of overreaching and thereby potential decreases in sleep quality.

Importantly, this study highlights the substantial intra-individual differences in the influence of different training phases on sleep characteristics. This is further illustrated by Figure 2 which shows the individual responses in total sleep time and sleep onset latency for four representative athletes within the study. Whilst the differences in grouped means are likely to have very little practical implications, the outliers within the group (e.g. individual sleep onset latency during COMP of 39, 43 and 49 min) could have sleep disturbances that are not necessarily detected when looking at the between-group differences. For example, sleep onset latency is substantially longer in a competition phase for two athletes (Figure 2B and D) whilst for the other two sleep onset latency is not affected in competition (Figure 2A and C). Hence, stresses around competition (i.e. pre-competition anxiety) might have a substantially bigger effect on some athletes compared to others, further warranting the need for an individualized approach to sleep monitoring and interventions. Similar between-individual differences are observed in terms of total sleep time. Even though, on average the athletes in this study meet the recommendations for adequate sleep in healthy adults, when evaluating individual cases it can be observed that not all athletes met these recommendations. For some athletes, a mean sleep time of around 6.5 hours of sleep during both training and competition was observed which could have a practical impact in terms of adaptive response and recovery (9-11, 14) from training. Furthermore, between-individual differences in total sleep time during different training phases can also be seen in Figure 2. For example, some athletes' sleep was substantially longer in the REST phase (e.g. Figure 2D) compared to training or competition phase. However, for other athletes sleep was actually lower during the REST phase compared to the training or competition phases (e.g. Figure 2A and B). Fullagar et al. (8) compared sleep responses of elite footballers across training days and both day and night matches. They also highlight the importance of monitoring individual responses and suggest that grouping players may not capture the nuances of such individual responses to changes in environment or training phase (8). For example, four players within their cohort showed a mean sleep duration ranging from 460 – 581min with some players sleeping ~2 hours more than others on training days.

One of the limitations of this study is that the study was carried out in a field-based environment. Whilst this ensures ecological validity, it also results in less control with regards to training variables (e.g. intensity, duration), nutritional factors (e.g. caffeine supplementation, alcohol) and environment (e.g. hotel versus home-based environment). Another limitation of this study is the short time periods in which the sleep data were collected (e.g. 3-7 days for COMP and REST). Sleep data over a more prolonged period could have resulted in a clearer overview of the sleep characteristics of the athletes. However, it must be noted that, it would be very rare for elite swimmers to be subjected to extended periods of competition and rest. Therefore, the testing phases in the present study are reflective of swimmers daily training practice. Lastly, evaluation of training characteristics was currently done using meters swam in pre-defined training zones without these training zones necessarily being scientifically validated or based on physiological thresholds/anchor points. However, the scope of this study was to examine sleep parameters in differing training phases, using swim volume as a descriptive measure. Future research should aim to incorporate additional monitoring (e.g. time spent in heart rate zones) to elucidate the link between training characteristics and sleep parameters.

To conclude, as a grouped average the swimmers in this study slept according to the sleep recommendations within healthy adult ranges (7.7 – 7.9 h). Sleep onset latency was moderately higher in competition phases and sleep quality moderately lower in a competition phase. However, limited differences were observed in terms of sleep quantity between phases. This study provides valuable insight in to the sleep characteristics of competitive swimmers. Future research should focus on the individual changes in sleep characteristics in response to changes in training phases given the substantial individual variation observed in the results of this study

PRACTICAL APPLICATIONS

Our descriptive analysis of the sleep characteristics of well-trained swimmers in this study can assist in identifying normative sleep behaviour for swimmers and other athletes. In a sport such as swimming, where early session start times are common practice, it was found that the offset of training times allowed the swimmers in this study to achieve sleep quantities that are in keeping with the normative 7-9 h per night and potentially offset disturbed sleep. Hence, we would encourage coaches to consider a slight offset in training times as this may have a substantial impact on sleep duration and thereby impact the athletes' adaptive responses and recovery from training. This study showed an extended sleep onset latency during a competition phase, which is in line with previous studies evaluating sleep behaviour during the competitive setting. Coaches and practitioners working with the athletes should be aware of the increased sleep onset latency during competitions, the potential reasons behind this (i.e. pre-competition anxiety, change in sleep environment) and the effect this might have on their performance potential. In addition, this study highlights the substantial between-individual variations in sleep responses during different training phases, stressing the need for an individual approach to sleep monitoring and interventions.

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Table 1. Sleep data collected with wrist actigraphy watches and recall sleep diaries for individual testing phases.

	REST **Mean** ± SD (min – max)	**TRAIN** **Mean** ± SD (min – max)	**TAP** **Mean** ± SD (min – max)	**COMP** **Mean** ± SD (min – max)
Sleep onset latency (SOL) (min)	17 ± 9 (9 – 34)	19 ± 12 (5 – 20)	19 ± 6 (10 – 34)	27 ± 11[a,b,c] (9 – 49)
Total sleep time (TST) (min)	471 ± 47 (410 – 570)	459 ± 44 (387 – 524)	473 ± 35 (412 – 536)	476 ± 42 (393 – 539)
Sleep efficiency (SE) (%)	82 ± 5 (71 – 89)	85 ± 5 (78 – 93)	85 ± 5 (75 – 90)	82 ± 3 (78 – 87)
Restfulness (RFN) (min)	158.9 ± 40.3 (110 – 237)	180.6 ± 44.8[a] (106 – 271)	176.0 ± 39.0 (98 – 245)	180.0 ± 44.6[a] (105 – 236)
Fragmentation index (FI) (%)	34 ± 6 (24 – 44)	38 ± 7 (25 – 52)	37 ± 7 (22 – 47)	37 ± 8 (23 – 55)
Bedtime (hh:mm)	23:55 ± 00:54 (22:17 – 02:15)	22:22 ± 00:28[a] (21:57 – 23:10)	22:24 ± 00:37[a] (21:30 – 23:28)	22:12 ± 00:37[a] (21:33 – 23:22)
Get-up time (hh:mm)	09:23 ± 01:18 (07:53 – 11:46)	07:25 ± 00:23[a] (06:45 -08:12)	07:46 ± 00:21[a] (07:08 – 08:14)	07:16 ± 00:36[a] (07:00 – 08:59)
Total daily nap time (min)	6 ± 10 (0 -30)	23 ± 20[a,c] (0 – 59)	12 ± 16 (0 – 45)	25 ± 24[a,c] (0 – 68)
Subjective sleep score (1-10)	7.3 ± 1.1 (6.1 – 10.0)	7.3 ± 0.9 (5.5 – 8.7)	7.7 ± 0.8 (5.9 – 9.0)	7.0 ± 1.4[c] (4.6 – 9.8)
Screen time before bed (min)	134 ± 52 (30 – 197)	168 ± 54 (51 – 244)	167 ± 40 (91 – 229)	129 ± 55[b,c] (36 – 230)

Values are expressed as mean ± standard deviation, with individual ranges expressed in brackets below.

[a] statistically different from REST ($p<0.05$).

[b] statistically different from TRAIN ($p < 0.05$)

[c] statistically different from TAP ($p < 0.05$)

Figure 1. Mean individual participant sleep variable data displayed for each testing phase (REST, COMP, TRAIN and TAP) along with the group mean for each testing phase. A) Sleep onset latency, B) Total sleep time (TST) C) Sleep efficiency (SE) D) Fragmentation index E) Daily nap time F) Screen time exposure before bed.

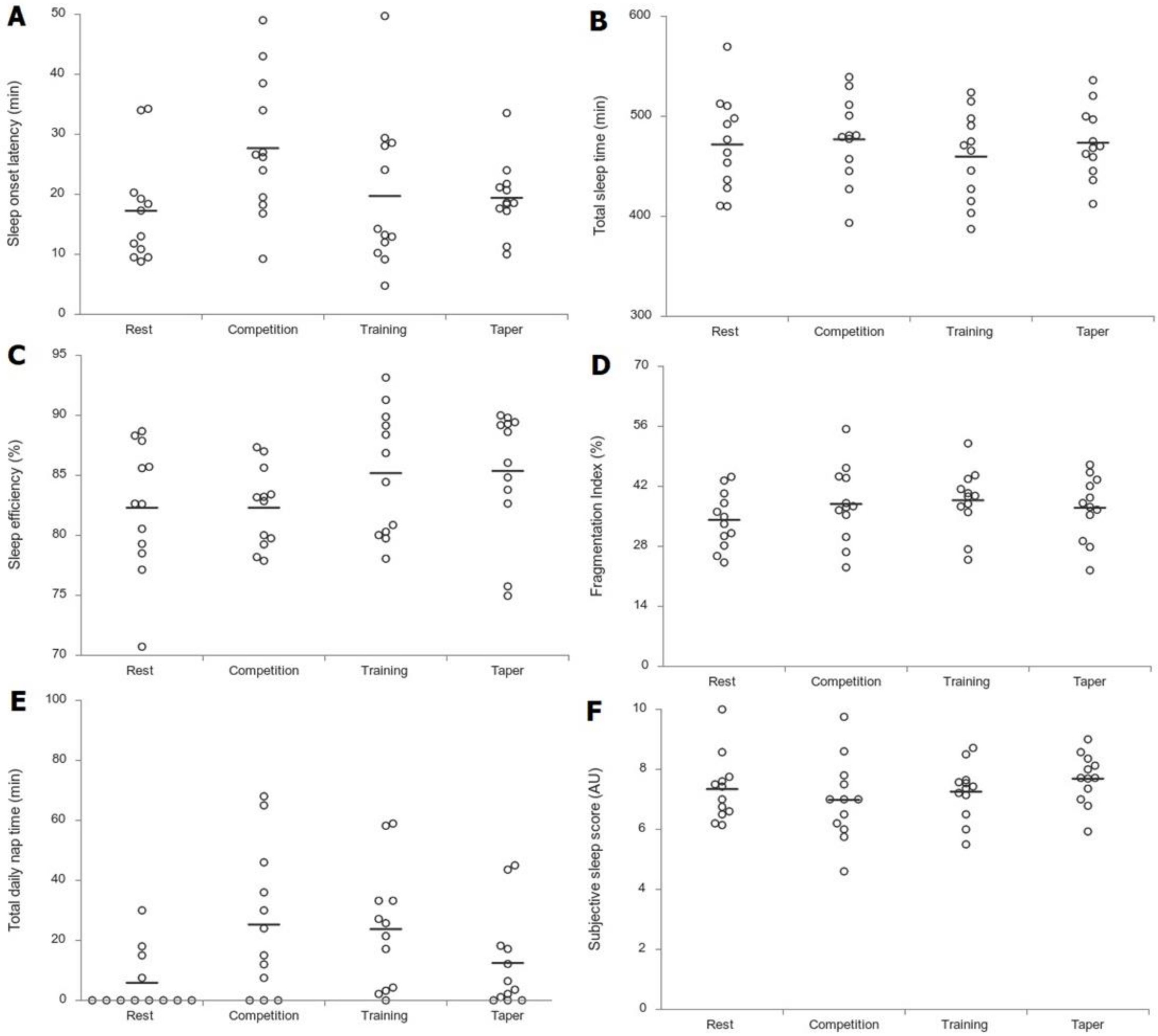

Figure 2. Representative plots of total sleep time (bars) and sleet onset latency (line) for four individual athletes (A, B, C, D)