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Abstract

The aim of this study was to investigate the influence of training load on objective and subjective sleep measures among elite rugby sevens players during preseason. Nine international male rugby sevens players participated in this study. Actigraphic and subjective sleep assessment were performed on a daily basis to measure sleep parameters. Training load was measured during the entire pre-season period and sleep data from the highest and lowest training load week were used in the analysis via magnitude-based inferences. During the highest training load, *likely* to *possibly* small, moderate decreases in time in bed (Effect sizes; ± 90% confidence limits: -0.42; ± 0.44 for session rating of perceived exertion [sRPE], -0.69; ± 0.71 for total distance covered [TDC]) and total sleep time (-0.20; ± 0.37 for sRPE, -0.23; ± 0.35 for TDC) were found. *Possibly* small (-0.21; ± 0.35 for high speed distance [HSD], -0.52; ± 0.73 for acceleration/deceleration [A/D]) and *likely* moderate (-074; ± 0.67 for TDC) decreases were observed in subjective sleep quality. P*ossibly* small to *very likely* moderate changes in sleep schedule were observed. Sleep quantity and subjective quality appear to be deteriorated during higher loads of training. This study highlights the necessity to monitor and improve sleep among elite rugby sevens players, especially for intense period of training.

Keywords: team-sport, fatigue, recovery, rugby.

Introduction

Due to its physiological function (14) and potential to facilitate performance, sleep is an emerging area in sport science. Through the sleep deprivation/restriction paradigm, several studies have found negative effects of sleep loss, relating to both physical and cognitive performance (13). However, the current challenge in sport is to understand how sleep influences performance in elite athletes in their natural environment, rather than in a laboratory-based environment which lacks ecological validity.

One sport where limited studies have investigated sleep is rugby sevens. Rugby sevens is a high-intensity, intermittent team sport characterized by a large proportion of accelerations, high-intensity running and sprint but also collision-based actions (26). To the best of our knowledge, only one study has been partially conducted on sleep in rugby sevens (28). Among 41 rugby sevens players (New Zealand male and female national teams), their subjective sleep quality (7.1 ± 3.3 AU) and quantity (7.3 ± 1.0 hours) assessed by the Pittsburgh sleep quality index was poorer than players from rugby union. However, despite valuable findings, only questionnaires were used during this study.

One potential reason for this reported poorer sleep could be due to an intensified training period (15), which has been recently shown to change sleep activity among other professional rugby codes players during preseason (4,24,29,30). Particular concern of prolonged sleep disruption is the potential that it could lead to an excessive level of accumulated fatigue and a nonfunctional overreaching state (22). Nevertheless, no similar study has been conducted yet among rugby sevens players during preseason.

Due to the intensive physical demands, preseason training periods typically include daily and weekly accumulated total and high intensity activities higher than other rugby codes. For example, during a rugby union preseason, weekly distances covered range from 9774 ± 1404 to 11585 ± 1810m for forwards and backs respectively (6). In contrast, weekly total distance covered by rugby sevens players during preseason is approximately 20000 ± 8000m (*unpublished observations*). Therefore we expect that sleep among rugby sevens athletes would be deteriorated. Moreover within a preseason training period, training loads are periodized to provide players with a stimulus and period of adaptation (25). In turn, during such periods athletes are likely to be exposed to highly variable training loads, where there may be periods of low and high training loads. However there is limited research to suggest how this altering load affects sleeping patterns. Such information will be worthwhile in order to optimize training periodization.

Therefore, the aim of this study was to investigate the influence of the highest and lowest training load during a preseason period on objective and subjective sleep measures among elite rugby sevens players.

Methods

Experimental Approach to the Problem:

All preseason training took place at the same training center in Marcoussis (France) from 10th October to 25th November. Actigraphic sleep assessment was performed on a daily basis to measure sleep quality and quantity from Sunday night to Friday morning. During this period, players completed two to four training sessions (morning and afternoon) per day from Monday to Friday (Table 1). External load was recorded using global positioning system (GPS). Total distance covered (TDC), high speed distance (HSD) and the total number of acceleration and deceleration (A/D) were used. Internal load was assessed using session rating of perceived exertion multiplied by training duration (sRPE) for all sessions. Each training day was followed by a recovery session composed of stretching (static stretching, foam rolling), nutrition (snack with 20 g of protein and high glycemic index carbohydrates) and hydrotherapy (cold and/or hot bath). No training camps took place during this period so that players could sleep in their normal home-based environment.

Subjects:

Fourteen male international rugby sevens players from the French national team were initially recruited for the study. All players had at least one full year of experience in the "World Rugby HSBC sevens series". If players had sleep disorders diagnosed by the medical staff, they were removed from the analysis. Four players were excluded from the analysis because they took part in a practice tournament in Singapore which may have affected the results of this study due to potential effects of jet lag and travel fatigue on sleep parameters during the experiment. Nine players (age; 27.9 ± 5.3 years, height; 181.8 ± 10.9 cm, body mass; 85.4 ± 12.7 kg) were retained for analysis. These data arose from the monitoring process in which player activities were measured daily during the season. Participants provided informed consent prior the beginning of the present study. Ethics approval was granted by the University ethics board and the recommendations of the Declaration of Helsinki were respected.

*****Insert Table 1 here*****

Procedures:

Sleep assessment: Athletes were allocated an Actiwatch MotionWatch 8 (Cambridge Neurotechnology Ltd., Cambridge, UK) which was worn on the non-dominant wrist. The Actiwatch uses activity counts to apply published algorithms resulting in a reliable and valid method for monitoring sleep (27). The threshold used for sleep analysis was the validated threshold recommended by the manufacturer for sleep study. When players went to bed and where ready to sleep (moment where they turned off the light), they pressed on the event button marker on the top of the watch for two seconds. This was considered 'bed time'. The same procedure was repeated when players were ready to get up. This was considered 'get up time'. The sleep variables were calculated as follows by the software MotionWare 1.1.25 (Cambridge Neurotechnology Ltd., Cambridge, UK) and are presented in Table 2. Additionally, players were asked to rate their sleep in a diary on a customized mobile application (typeform©, Bac de Roda 163, Barcelona, Spain). Ratings were recorded in terms of subjective sleep quality using a Likert visual 10- point analog scale, where 1 corresponds to ‘very poor’ and 10 equals ‘excellent'.

***** Insert Table 2 here*****

Training load quantification: During every field session players wore a GPS unit capturing data at 16 Hz (SensorEverywhere, Digital Simulation, France). GPS units were positioned in a customized pocket placed in their shirt and located between the scapulae. To limit potential inter-unit variability, each player wore the same unit for the total duration of the preseason. The GPS data were captured and computed with SensorEverywhere software (Digital Simulation, France). Preliminary validity work showed a trivial bias against timing gates for velocity (0.11 ± 0.04 $m \cdot s^{-1}$), with a low between-unit typical error of measurement (TEM) over the various constant speed tested (0.01 ± 0.01 to 0.04, ± 0.04 $m \cdot s^{-1}$ and 0.5, ± 0.15 to 0.6, ± 0.35% from walk to sprint respectively) and a trivial between-unit TEM for maximal sprint and acceleration (respectively 0.06 ± 0.03 % and 3.1 ± 6.4%) (*Unpublished observations*).

Regarding high speed distance, an individual speed threshold was determined during the second week of the preseason with an incremental aerobic test started at 8 $km \cdot h^{-1}$ for 2 minutes followed by 0.5 $km \cdot h^{-1}$ increments in velocity each minute (7). The final speed reached was used to determine the high speed distance threshold. An absolute threshold was used for acceleration ($\geq$2.5 $m \cdot s^{-2}$) and deceleration ($\leq$-2.5 $m \cdot s^{-2}$). RPE on 1-10 scale was used to quantify internal load (10) and was collected and inputted into a mobile application (typeform©, Bac de Roda 163, Barcelona, Spain) within 30 minutes after each session. The RPE gathered was then multiplied by training duration to provide sRPE (10). Changes in training load are presented in Table 3.

Data Analyses: The highest (intensified period) and lowest cumulative weekly training loads (i.e. sum of daily training load) during the observational period for each player and for each variable (*i.e.* sRPE, TDC, HSD and A/D) were used in the analysis. The lowest cumulative weekly training load was used as the baseline value. This week was used because it was not possible to record values before the beginning of the preseason due to the unavailability of players. During the highest and lowest training load weeks, average sleep parameter variables recorded across a five-night sleep period were calculated (18). Individual standardized change in mean between these weeks was calculated for sleep parameters and training load to calculate correlation.

Statistical Analyses:

All data were log transformed to reduce bias as a result of non-uniformity error. The descriptive data (mean ± standard deviation [SD]), presented in Table 4, are the back transformed mean and SD of the log transformation. A magnitude-based inferential (MBI) approach to statistics was used to assess differences between intensified period of training and baseline for training load variables and sleep parameters (16). Effect sizes (ES) and 90%

confidence limits (90% CL) were quantified to indicate the practical meaningfulness of the differences in mean values. The ES magnitude was classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0) and very large (>2.0-4.0) (Hopkins, 2009). Quantitative chances of greater or smaller changes in sleep parameters were assessed qualitatively as follows: <1%, *almost certainly not*; 1–5%, *very unlikely*; 5–25%, *probably not*; 25–75%, *possibly*; 75–95%, *likely*; 95–99.5%, *very likely*; >99.5%, *almost certainly*. Pearson correlations and 90% confidence intervals (CI) were calculated between individual standardized change in training load variables and standardized change in sleep variables. If the 90%CI over-lapped positive (0.1) and negative (-0.1) trivial values, the magnitude was deemed unclear. Clear correlations were interpreted as follows: trivial (0.0-0.1), small (>0.1-0.3), moderate (>0.3-0.5), large (>0.5-0.7), very large (>0.7-0.9) and nearly perfect (>0.9-0.1) (Hopkins, 2009).

Results

Descriptive sleep data are summarized in Table 4 and comparison between intensified period and baseline are shown in Figure 1. Results are presented as ES; ±90% CL. There was a *likely* small decrease in sleep onset time (-0.32; ± 0.48), wake up time (-0.40; ± 0.40) and get up time (-0.47; ± 0.39), a *possibly* small decrease in total sleep time (-0.20; ± 0.37) and fragmentation index (-0.24; ± 0.59) between the highest and lowest sRPE training load week. There was a *likely* moderate *decrease* in bed time (-0.69; ± 0.71) and sleep onset time (0.71; ± 0.60) and subjective sleep quality (-074; ± 0.67), a *likely* small decrease in wake up time (-0.49; ± 0.36) and get up time (-0.49; ± 0.36) and a *possibly* small decrease in time in bed (-0.26; ± 0.37) and total sleep time (-0.23; ± 0.35) between the highest and lowest TDC load week. For HSD, *possibly* small decreases were found in wake up time (-0.21; ± 0.34), get up time (-0.20; ± 0.33) and subjective sleep quality (-0.21; ± 0.35) between the highest and lowest training load weeks. A/D highlighted a *very likely* moderate decrease for bed time

(0.80; ± 0.49) and sleep onset time (-0.79; ± 0.45), a *likely* small decrease in subjective sleep quality (-0.52; ± 0.73) and a *possibly* small decrease in wake time (-0.30; ± 0.38) and get up time (-0.30; ± 0.38) between the highest and lowest training load weeks. Other results were deemed unclear.

*****Insert Table 3, 4 and figure 1 about here*****

Correlations are presented with 90% CI When considering standardized changes in sRPE, a clear and large negative relationship was found with fragmentation index (*r*= -0.53 [-0.85 - 0.09]). All other relationships with change in sRPE were unclear. A clear and large positive relationship (*r*= 0.63 [0.07-0.89]) existed between change in TDC and in subjective sleep quality. Other correlations were deemed unclear. Clear and large positive relationship (*r*=0.65 [0.10-0.89]) was observed between change in HSD and fragmentation index. Other relationships for this variable remained unclear. No clear relationship was found for the A/D and sleep parameters.

*****Insert figure 2 about here*****

Discussion

The aim of this study was to investigate the influence of the highest and lowest training load weeks on sleep parameters during an international rugby sevens preseason. This is the first study to objectively assess sleep among elite rugby sevens players. Results suggest that sleep quantity and subjective quality deteriorated during the week of highest training volume. This novel ecological descriptive study in international athletes sheds light on the notion that sleep patterns change during an elite rugby sevens preseason, and suggest that monitoring and improving sleep is necessary in an elite sport set up.

The findings of this study suggest that when international rugby sevens players have high training loads, especially with regards to TDC, HSD, A/D and sRPE, a change in sleep schedules occurs. Such findings are similar to those from previous studies conducted during training camps in rugby league where players went to bed and woke up earlier when training load increased (29,30).

The trend of going to bed and falling asleep earlier found in our study could be explained by the increased recovery needs induce by the frequent exposure to high volume and intensity training load and in turn increase the overall requirements for sleep (19). Additionally, these changes could be explained by feedback provided to player regarding their sleep during preseason which could potentially increase their awareness of good sleep practices. As such, coaches could take in account this result in order to schedule the first session later in the day in order to respect sleep/wake patterns (12) of their athletes and undertake sleep education workshops which may enhance the athletes ability to recover.

The observed changes in sleep schedule may induce decreases in sleep quantity. A *possibly* to *likely* small decrease of time in bed and total sleep time for high sRPE and HSD week may further reduce an athletes ability to recover from training (*e.g.* higher training load and less sleep). However, this decrease remained small and it is not known if it impacts a player's level of fatigue. Anecdotally, coaches reported that the last training day of the week was often adjusted due to player fatigue. Such adjustments could have been avoided if the training schedule allowed players more time to sleep in order to recover. However, no indicators of subjective and/or objective fatigue were measured and other contextual factors may affect performance during preseason. Further studies are warranted to investigate if small chronic sleep restriction during this period may influence or not the level of fatigue. As a strategy, to compensate for the lack of sleep, implementing short nap sessions (20-30 minutes) when athletes have two or three trainings per day, may be beneficial to reach a suitable sleep quantity (30).

We did not observe any meaningful changes in objective sleep quality indicators (*i.e.* fragmentation index, sleep efficiency, sleep onset latency) for external load during period of high training load. Sleep quality has been suggested to have positive effects on recovery and the adaptive training response during periods where physiological adaptations are crucial to performance (24). However, sleep quality indicators derived from actigraphy monitors differ to sleep quality assessed via polysomnography or self-reported measures and as such have to be interpreted carefully (5,15). Indeed, in our study, small to moderate decreases were found for subjective sleep quality for all external load variables. In contrast, results regarding sleep efficiency or fragmentation index remained unclear. Subjective sleep quality is defined as a broad of sleep complaint encompass problem to fall asleep, fragmented sleep or impaired daytime functioning (5). One possible explanation is that sleep quality declines due to muscle damage caused by running activities (15). Further studies are necessary to know if this decrease in subjective sleep quality is associated with changes in sleep structure (*e.g.* sleep stages) assessed through polysomnography and levels of muscle damage during intensified periods of training.

Our data confirm poorer sleep quantity and quality among rugby sevens players than recommended value (9,31), which should be acknowledged given the importance of sleep for athletic performance (13). Poor sleep quantity could increase the risk of sustaining musculoskeletal injury (20,23). However sleep quantity remained consistent with other studies in a similar population and context of preseason (4,24,30). As such these results highlighted the necessity to improve sleep among elite rugby sevens players.

Efficiency of several strategies has been proved in the literature such as sleep extension (21), sleep hygiene (11), nutrition (17), light therapy or post exercise recovery (32). More than the strategy itself, practitioners should consider the context and how they delivered such strategies within their recovery routines (1). Despite differences observed in sleep parameters, we found only three *clear* relationships between standardized change in training load and standardized change in sleep parameters. This lack of other correlations could be explained by the large inter individual variability of sleep responses during intensified training, which highlights a challenge of undertaking sleep studies. In turn, these results highlight the necessity to monitor and improve sleep on an individual and night basis during intense periods of training in order to decrease sleep curtailment and its potential negative effects (*e.g.* injury, poor performance and recovery).

While this study is the first to provide information on sleep in international rugby sevens players, it is not without its limitations. Despite the low value of training load used as the respective control in comparison to the highest training loads, it would be better to appreciate baseline values for athletes following a period of rest, and no training. Indeed, this week occurred during the fifth week of preseason and in turn sleep was possibly deteriorated.

Secondarily we did not record sleep during the weekend which is a limitation of our study due to the potential changes in sleep patterns (*e.g.* difference between week and weekend). The staff responsible for the international players did not want the research team to record sleep during the weekend in order to allow players time off professional duties. Moreover, due to the nature of the rugby sevens, the sample size was small which is a limitation considering the high interindividual variability surrounding sleep (3). As such a bigger sample size seems appropriate for future studies in this population. Furthermore, no daily fatigue measures were recorded. As such we do not know how these sleep changes affect the level of subjective and/or objective level of fatigue. Further studies should include a range of potential fatigue measures (muscle damage, wellbeing, and performance tests) to appreciate the complexity of sleep changes among athletes during intensified periods of training. Finally the lack of an association between acceleration and deceleration and sleep parameters may have been missed as the GPS units have a poor ability to detect these movement patterns (2).

This study showed elite rugby sevens players fall asleep and wake up earlier during the highest training load week of preseason. Additionally, sleep quantity and subjective quality deteriorated during this period. To avoid excessive fatigue due to restricted sleep, adaptation in the training schedule is needed during high weekly training loads to promote sleep extension which might be beneficial for training efficiency and recovery. Further studies are warranted to explore the influence of this poor sleep on objective fatigue markers.

Practical Applications

The main practical applications of this research include the finding that increases in training load may deteriorate sleep parameters without any change in sleep environment. As such practitioners should educate athletes about the effects of good sleep habits particularly during periods of intensified training. Furthermore, due to high between-players variability in sleep patterns, individual sleep monitoring is suggested.

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Figure and table legends

Table 1. : medical/physiotherapy checkup, : lunch, : gym session, : field session, : recovery session, rest period.

Table 2. Definitions of each sleep variable.

Table 3. Changes in training load between intensified period of training and baseline. ***: very likely change/difference between training period. SRPE: session rating of perceived exertion, TDC: total distance covered, HSD: high speed distance, A/D: number of acceleration and deceleration, (AU): Arbitrary Unit, (m): meter, (n): number.

Table 4: Changes in sleep parameters between intensified period of training and baseline. *: possibly, **: likely and ***: very likely change/difference between intensified period of training and baseline. SRPE: session rating of perceived exertion, TDC: total distance covered, HSD: high speed distance, A/D: number of acceleration and deceleration.

Figure 1. Difference in sleep parameters between highest and lowest training load weeks. *: possible, **: likely and ***: very likely change/difference between intensified period of training and baseline. Gray zone stands for trivial.

Figure 2. Correlation between standardized change in training load variables and sleep parameters. SRPE: session rating of perceived exertion, TDC: total distance covered, HSD: high speed distance, A/D: number of acceleration and deceleration.

Table1. Typical training schedule during the period of the study.

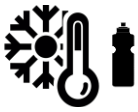
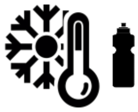
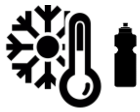
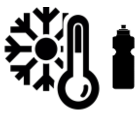
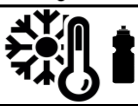
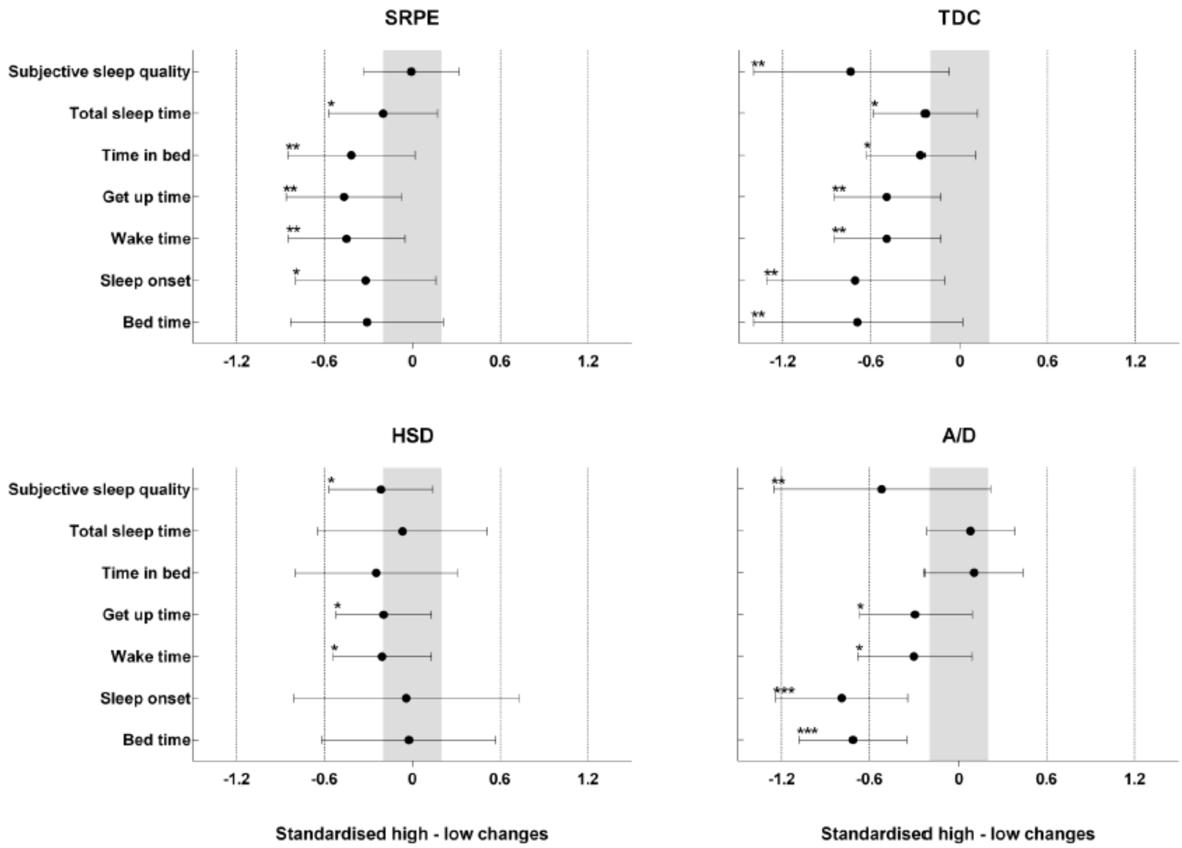
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0830-0900				**Pre warm up**			
0900-1000					**Injury prevention**		
1000-1100							
1100-1200							
1300-1400							
1500-1600							
1600-1700							
1700-1800							

Table 2. Definitions of each sleep variable.

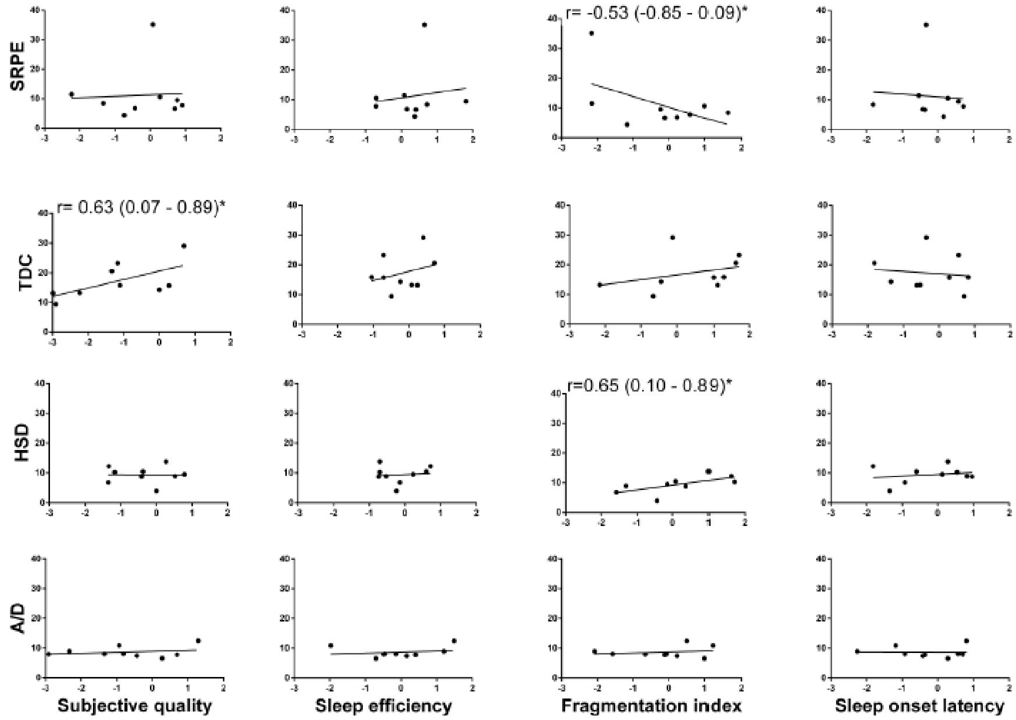
Sleep variables (units)	Definition
Bed time (hh:mm)	Estimated clock at which the player attempt to sleep (press the button marker)
Sleep onset (hh:mm)	Estimated clock time at which the player fell asleep
Wake time (hh:mm)	Estimated clock time at which the player woke up
Get up time (hh:mm)	Estimated clock time at which the player stop sleeping (press the button marker)
Time in Bed (min)	Time between bed time and get up time
Sleep onset latency (min)	Time between bed time and sleep onset
Total sleep time (min)	Time spent asleep determined from sleep onset to wake up time, minus any wake time
Sleep efficiency (%)	Total sleep time divided by the time in bed
Fragmentation index (%)	Sum of the mobile time (%) and the immobile bouts ≤1 min

Table 3. Mean± SD for the training load parameters and standardized change in mean during intensified period of training and baseline.

	sRPE (AU)		TDC (m)		HSD (m)		A/D (n)	
	Low	High	Low	High	Low	High	Low	High
Descriptive values	1984 ± 711	5216 ± 674	8994 ± 2164	29207 ± 3793	988 ± 562	3874 ± 440	112 ± 24	353.0 ± 53
Standardized change in mean	1.68 ± 0.59***		5.05 ± 0.54***		2,83 ± 0.58***		5.00 ± 0.65***	



SRPE
TDC
HSD
A/D
Subjective sleep quality
Total sleep time
Time in bed
Get up time
Wake time
Sleep onset
Bed time
-1.2
-0.6
0
0.6
1.2
Standardised high - low changes



SRPE
TDC
HSD
A/D
r= -0.53 (-0.85 - 0.09)*
r= 0.63 (0.07 - 0.89)*
r=0.65 (0.10 - 0.89)*
Subjective quality
Sleep efficiency
Fragmentation index
Sleep onset latency

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