Adaptative Sports

Effect of Paralympic powerlifting training on sleep and its relationship with training load

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Abstract - Aim: This study aims to compare the sleep parameters in Paralympic powerlifting athletes during days with and without training, and to analyze the relationship between the training load and sleep on the same day and the relationship between the previous night's sleep and the training load of the following day. **Methods:** Actigraphy was used to analyze the sleep parameters of 11 Paralympic powerlifting athletes for 14 days (7 days without and with training), whereas Ratings of Perceived Exertion (RPE) analysis was used to assess training load. In addition, the Horne and Östberg chronotype questionnaire and the Epworth Sleepiness Scale were applied. **Results:** Athletes show morning and indifferent chronotype and low daytime sleepiness. We found that on training days, sleep onset latency (SOL) was lower (average 5.3 min faster), whereas total sleep time (TST) and sleep efficiency (SE) were higher (TST averaged 169 min and SE 7% higher) compared to non-training days. In addition, the TST of the night before the training days correlated positively with the RPE of the following day, and the training volume correlated negatively with the SE of the same day. **Conclusion:** Our findings show that Paralympic powerlifting training had positive effects in increasing TST and SE and decreasing SOL on training days. These results show the positive effects of this type of training in improving sleep in athletes with physical disabilities. In addition, a good night's sleep the day before training can make it possible to put more effort into the next day's training. Therefore, guiding athletes to sleep more before training with more intense loads is recommended.

Keywords: para-athletes, sports for persons with disabilities, athletic performance, sleep, training load and paralympic.

Introduction

Achieving optimal recovery in the training process is important in improving physical and cognitive performance because high-performance athletes often experience high physical and psychological demands[1]. Some strategies are applied in sports training to optimize recovery and improve the athletes' performance, and among them is sleep[2]. Sleep is considered a behavioral, physiological, and reversible state that affects psychophysiological recovery[3]. To determine the role of sleep quality in the recovery process, several sleep parameters, such as sleep architecture, total sleep time (TST), sleep efficiency (SE), and sleep onset latency (SOL), among others, must be considered[4].

Previous studies have reported that people with physical disabilities, such as spinal cord injury[5] and amputation[6], complain more often about their sleep than those without disabilities. Furthermore, Paralympic athletes present a high rate of sleep complaints[7], poor sleep quality, excessive daytime sleepiness[8], and acute and/or chronic sleep restrictions[9].

In general, when athletes undergo intense training periods with increased training load, TST tends to decrease, which can negatively impact their recovery[10]. Training load is a key variable in promoting and monitoring athletes' performance. Training load measures can be classified as external and internal load. External load refers to an absolute measure of work performed by athletes during exercise and consists of the number of sets, repetitions, work intensity, and so on. However, similar external loads can generate different physiological and psychological stress, creating varying insights for each athlete[11]. Therefore, internal load represents the psychophysiological responses to stimuli produced by an external load and includes heart rate, hormonal changes, and the ratings of perceived exertion (RPE)[11]. The RPE is an interesting instrument to analyze the internal load of resistance training due to its sensitivity to different stimuli, as well as its practicality, low cost, simplicity, and validity[12].

Paralympic powerlifting (PP) is a sport that requires muscle strength and is the only discipline adapted to bench press, practiced by men and women with physical disabilities in the lower limbs[13]. Athletes with disabilities have inadequate sleep[9] and training may have negative impacts on protein synthesis[14]. An example would be an increase in catabolic hormones (cortisol) and a decrease in anabolic hormones (testosterone), which could disturb muscle metabolism and, consequently, decrease skeletal muscle development during training[15]. In contrast, resistance training consumes much energy[16] and this reduced energy could facilitate sleep so that the body reaches a positive energy balance and restores itself for a new wakefulness[17]. There are also other theories that explain the positive effects of exercise on sleep, among which are the theories of thermoregulation[18], restoration[19], anxiolytic[20], and antidepressant[21].

Therefore, considering the effect of training on sleep and that Paralympic athletes with physical disabilities sleep poorly, this study is the first to compare the sleep parameters of Paralympic athletes with physical disabilities between days with and without training, and to analyze the relationship between training load and sleep on the same day and the relationship between the previous night's sleep and the training load of the following day. The hypotheses are that athletes would sleep more on training days than on non-training days, and the training load is related to an increase in the same day TST, and TST would be related to an increase in the following day's training volume.

Methods

Ethical aspects

The Research Ethics Committee of the Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, approved this study (CAAE No. 27518619.4.0000.5149). All participants signed an informed consent form after being informed of the risks and benefits of the study.

Participants

The sampling was by convenience and consists of 11 PP athletes (nine men and two women) who train at the Brazilian Paralympic Reference Center (CTE/UFMG) in Belo Horizonte/MG, Brazil. All athletes were nationally classified by the Brazilian Paralympic Committee, with an average age of 37 ± 9 years, weight 77.2 ± 21.3 kg, height 160 ± 20 cm, and time of experience in the modality of more than 1 year and had competed in at least one national competition. Disability types among these athletes include transtibial amputation of the right leg (n = 2) and bilateral hip joint (n = 1); complete spinal cord injury in the thoracic region (n = 3), incomplete spinal cord injury in the thoracic region (n = 3), and incomplete spinal cord injury in the lumbar region (n = 1); and dwarfism (n = 1).

Sleep parameters

An actigraphy (Phillips Respironics Actiwatch Plus, Murrysville, PA, USA) was used on the nondominant wrist of each athlete to record the sleep-wake cycle for 14 days. Data was logged and transmitted to the Actware™ software. Also, this equipment measured the athletes' rest-activity and wakefulness using the threshold (>80 counts)[22]. Data on TST, SE, SOL, and wake after sleep onset (WASO) were then analyzed for each evaluation period, with and without training.

Horne and Östberg Chronotype Questionnaire

The athletes' circadian preference or chronotype was assessed using the Horne and Östberg Chronotype Questionnaire translated to Portuguese[23]. The questionnaire consisted of 19 self-assessment questions that record an individual's preferred hours in daily routine situations. Scores above 58, below 42, and 42-58 classify individuals as the morning, afternoon, and intermediate or indifferent types, respectively.

Epworth Sleepiness Scale (ESS)

The ESS is valid for the Portuguese language and assesses the probability of an individual falling asleep or dozing off in eight scenarios. Participants check a number from 0 to 3, where 0 represents no risk of napping and 3 represents a high risk of napping, and the sum of these scores determines the probability. A score of 11 or more suggests excessive sleepiness[24].

Training load

RPE was used where the athletes answered the question "How was the intensity of the training session?" on a scale of 0 (resting condition) to 10 (greater physical effort), approximately 30 min after the end of each training session. The perceived exertion score (intensity) is then multiplied by the training session duration expressed in minutes (volume) to measure the training load. Afterward, the results were expressed in arbitrary units (AU)[25].

Training characteristics

The team carried out three training sessions in the first week and four training sessions in the second week, which always took place in the morning between 8 am and 12 pm. In the first week, on each training day, the athletes performed five sets of five repetitions (5×5) using 80% of 1RM (one repetition maximum) on the adapted bench press and auxiliary exercises (45° incline bench press, shoulder press, triceps pulley, biceps curl with dumbbell and pronated row), with three sets of six repetitions (3×6) with 70%-90% of 1RM. In the second week, they performed five sets of three repetitions (5×3) with 85% of 1RM on the adapted bench press and the same set of auxiliary exercises from the previous week[26].

Experimental design

Sleep and training load parameters were collected for 2 weeks at the end of the team's training season, outside the competitive period. Sleep parameters were collected for 14 days, 7 days with training, and 7 days without training, these days being alternate and not consecutive. Athletes were instructed to use the actigraphy at all times of the day and night, except when taking a shower. In addition, the athletes had to fill in the sleep diary daily during the entire period using the actigraph. During training days, training load data were collected after training sessions.

Statistical analysis

The Shapiro-Wilk test was used to examine the distribution of each variable. The mean and standard deviation was used as descriptive statistics. The Wilcoxon test and t-test were used to compare sleep parameters between days with and without training. The interpretation of the effect size values (D de Cohen) were insignificant (< 0.19), small (> 0.2), average (> 0.5), large (> 0.8), and exceptionally large (> 1.3). Spearman's correlation was used to analyze the relationship between sleep parameters and training load. The magnitude of the correlations was determined using the following scoring system: r < 0.1 (trivial), 0.1-0.3 (small), 0.3-0.5 (moderate), 0.5-0.7 (large), 0.7-0.9 (very large), > 0.9 (almost perfect), and 1 (perfect). All analyses were performed with $p \leq 0.05$ using SPSS v. 21.

Results

Characteristics of the chronotype and sleepiness of athletes

The chronotype analysis shows that PP athletes are predominantly of the morning type (*n* = 6), followed by the indifferent (*n* = 4) and afternoon (*n* = 1) types. Additionally, most athletes presented lower daytime sleepiness (*n* = 5; 12.4 ± 1.5), followed by normal sleepiness (*n* = 5; 3.4 ± 2.7) and maximum sleepiness limit (*n* = 1; 7 ± 0). These results suggest that athletes present a predominance of the morning chronotype and normal or low sleepiness.

Comparison of sleep parameters on days with and without training

Figure 1 shows the comparison between days with and without training in sleep parameters (TST, SOL, WASO, and SE). The results showed that the mean TST (Figure 1A) on days with training (521.2 ± 18.7) was higher ($p < 0.01$; d = 10.6) than on days without training (352.2 ± 12.4). Similarly, SE scores (Figure 1B) had significant differences ($p = 0.01$; d = 0.8) between days with (89 ± 6.1) and without training (82 ± 10.1), whereas the mean SOL (Figure 1C) was lower ($p = 0.01$; d = 0.3) on

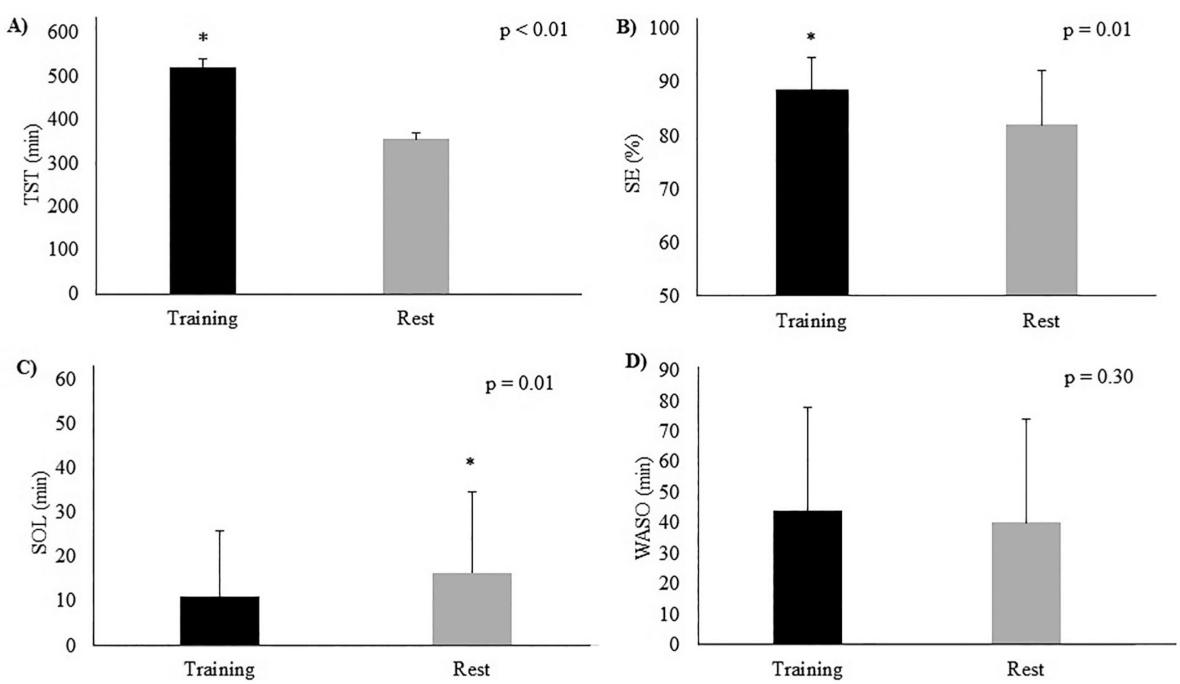

Figure 1 - Comparison of sleep parameters on days with and without training. Statistical analyzes = Wilcoxon test and paired t-test; * = indicates statistical difference ($p < 0.05$); TST = total sleep time; WASO = wake after sleep onset; SE = sleep efficiency; SOL = sleep onset latency.

days with training (11.1 ± 14.9) compared to days without training (16.4 ± 18.2). However, WASO scores had no significant differences ($p = 0.30$; $d = 0.1$) between days with (43.9 ± 34.2) and without training (40 ± 36). The results show a lower SOL (average 5.3 min faster), higher TST (average 169 min longer), and higher sleep SE (average 7% longer) on training days. Furthermore, the athletes slept on average 8 h 41 min on training days and 5 h 52 min on non-training days. The descriptive results of sleep parameters and training load are presented in Table 1.

Relationship between sleep parameters and training load

Based on correlation analyses between sleep parameters and training load, TST on the night before the training days was found to be correlated positively (Figure 2A) with the RPE on the following day ($p = 0.03$; $r = 0.40$). In addition, training volume showed negative correlation (Figure 2B) with same-day SE ($p = 0.05$; $r = -0.26$).

In addition to these correlations, any correlation with the AU, TTT, and RPE the next day ($p > 0.05$) was not observed when the relationship between SE, WASO, and SOL the night before training was analyzed. Likewise, any correlation between training load (AU, TTT, and RPE) and sleep parameters (TST, WASO, and SOL) on the same day ($p > 0.05$) was not observed.

Discussion

We compared the sleep parameters of Paralympic weightlifters during training and rest and investigated the relationship between training load and same-day sleep and the relationship between the previous night's sleep and the training load of the next day. We found that athletes fell asleep earlier (average 5.3 min faster), longer (TST 169 min longer) and with greater efficiency (average 7% higher) on training days than on non-training days. This shows that Paralympic weightlifting physical training improves the sleep of athletes with physical disabilities. Researchers[17] theorized that physical exercise could be a sleep facilitator based on some theories (e.g., energy conservation[17] and restoration theory[19]). The energy conservation theory[17] suggests that high energy expenditure during wakefulness, as observed in endurance athletes[16], would lead to a reduction in reserves metabolic and, as a consequence, a need for more time sleeping to achieve a positive energy balance[17] to achieve a full metabolic and functional recovery. However, the restoration theory suggests that the need for slow-wave sleep increases[19] because of the high catabolic demand during the day and the consequent decrease in the body's energy reserves.

Although sleep theories support the hypothesis of improved sleep on training days, as well as the observed effect size, there is a limitation in this study. On training days, athletes probably had to wake up earlier to travel to the training site, thus reducing the TST on the nights of sleep leading up to the training day. Sargent et al.[27], comparing training and rest periods of athletes from different sports by measuring sleep duration using an actigraph, demonstrated that athletes had a greater TST in the rest period than in training days. In addition, TST was noted to be higher because athletes slept later at night on rest days.

Table 1 - Description of sleep parameters and training load of Paralympic powerlifting athletes.

		Actigraph				Training load		
T/R	**Day**	**TST (min)**	**SE (%)**	**SOL (min)**	**WASO (min)**	**RPE**	**TTT (min)**	**AU**
T	1	531 ± 187	92 ± 4	9 ± 12	31 ± 21	3 ± 1	111 ± 14	348 ± 110
R	2	352 ± 121	85 ± 6	8 ± 7	34 ± 27	–	–	–
R	3	357 ± 90	79 ± 11	19 ± 23	46 ± 37	–	–	–
T	4	529 ± 142	90 ± 5	13 ± 14	42 ± 33	6 ± 2	152 ± 25	968 ± 437
R	5	330 ± 86	82 ± 10	20 ± 18	30 ± 21	–	–	–
T	6	506 ± 96	88 ± 5	4 ± 3	48 ± 27	4 ± 2	192 ± 15	852 ± 415
R	7	368 ± 107	81 ± 15	13 ± 13	41 ± 30	–	–	–
T	8	520 ± 162	86 ± 9	11 ± 14	46 ± 35	5 ± 2	178 ± 26	906 ± 400
R	9	467 ± 118	81 ± 11	29 ± 43	71 ± 69	–	–	–
R	10	307 ± 137	80 ± 10	17 ± 14	34 ± 35	–	–	–
T	11	520 ± 120	87 ± 6	14 ± 16	57 ± 55	5 ± 3	186 ± 14	1028 ± 604
R	12	371 ± 98	86 ± 5	15 ± 14	33 ± 27	–	–	–
T	13	527 ± 178	90 ± 5	15 ± 23	33 ± 19	5 ± 2	167 ± 19	899 ± 492
T	14	352 ± 104	81 ± 11	17 ± 14	47 ± 52	3 ± 1	173 ± 21	618 ± 239

T = day with training; R = rest; TST = total sleep time; WASO = wake after sleep onset; SE = sleep efficiency; SOL = sleep onset latency; AU = arbitrary units; RPE = ratings of perceived exertion; TTT = time total training.

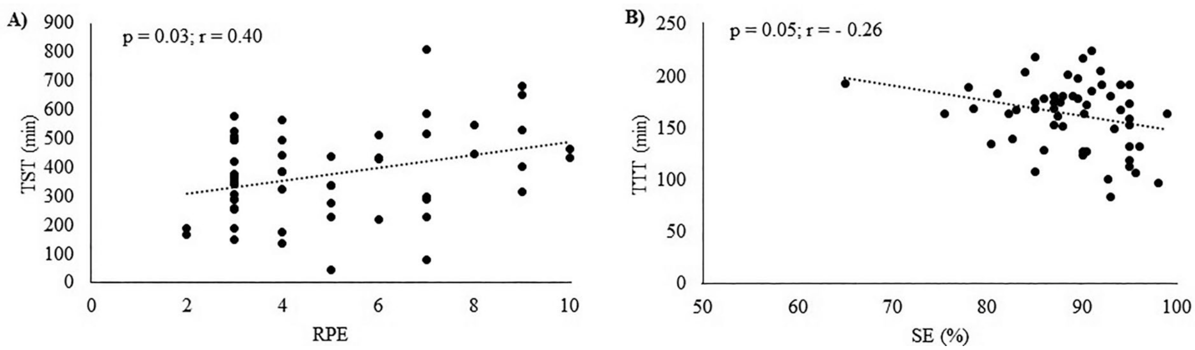

Figure 2 - Correlations between sleep parameters and training load. Statistical analyzes = Spearman test; TST = total sleep time; SE = sleep efficiency; RPE = ratings of perceived exertion; TTT = time total training.

For sleep to be considered restorative, both quantity and quality of sleep should reach recommended values, e.g., sleep duration (i.e., TST) should last more than 7 h in healthy people and between 9 and 10 h for athletes (short or long sleepers are excluded)[28]. In the present study, the athletes slept on average of 8 h 41 min on training days and 5 h 52 min on non-training days, indicating that although athletes sleep more on training days, the TST is still below recommendation for athletes on days with and without training, based on sleep recommendations for athletes[28]. In addition, on rest days, the low amount of sleep may be related to athletes expending less energy than on training days[16]. However, no specific sleep recommendation exists for Paralympic athletes. Still, are worrying because the low amount and quality of sleep are related to the athletes' time away from work, and the severity and amount of musculoskeletal injuries[29].

The recommended values for restorative sleep are < 20 min (WASO), < 30 min (SOL), and > 85% (SE) are considered normal parameters[28]. Taking these data into account, our results show that the mean WASO scores did not meet the recommended values on days with and without training and SE was also below the recommendation on days without training. These sleep parameters were below expectations for an athlete possibly because of the types of disabilities included in the present study sample. Concerning this, Peters et al.[30] found that people with spinal cord injury are more prone to changes in the circadian rhythm due to a thermoregulation dysfunction, depending on the spinal cord injury level and the suppression of melatonin secretion, which is a sleep-inducing hormone. Furthermore, these changes were associated with shorter TST and SE and longer SOL[31].

Regarding the chronotype and daytime sleepiness, we found that PP athletes are predominantly morning and indifferent chronotypes, in addition to having low daytime sleepiness. This indicates that the regularity of training only in the morning (8 to 11 am) favors a better circadian adaptation of athletes, which is reflected in low daytime sleepiness even if their sleep quantity and quality are below recommendation. Thus, adjusting training schedules to the athletes' chronotype may favor sleep[32] and reduce daytime sleepiness. In contrast, a previous study[8] reported excessive daytime sleepiness in Paralympic athletes before the Beijing Paralympics. A possible explanation for such differences is the athletes selected by Silva et al.[8] that were evaluated in the period before a major competition, and stress, anxiety, and pre-competition pressure are factors that impair sleep and can cause greater daytime sleepiness.

In our research, no studies analyzed the relationship between objectively measured sleep parameters and the training load of Paralympic athletes. To date, the current work is the first to study correlations between objectively measured sleep parameters and the training load of Paralympic athletes. Based on the results, training volume was noted to be negatively correlated with SE on the same day, i.e., lower training volume improves SE. These results corroborate with the study by Campbell et al.[33] that evaluated junior sprinters, where a greater volume of training correlated with a less efficient sleep together with worse physical performance, indicating that the high volume of training could negatively impact the athletes' sleep[33].

The current study also hypothesized that TST in the previous night would be negatively correlated with sRPE during training sessions, i.e., the more athletes slept the night before training, the lower the perceived exertion would be. The hypothesis of the current study is supported by Cullen et al.[34] who observed a greater RPE in sleep-deprived athletes. However, data in the current study reject this hypothesis by revealing a positive correlation between TST on the night before training days and sRPE on the following day. This result means that the low amount of sleep the night before training correlated with lower effort sensitivity. This result may be attributed to the athletes' experience in training. In the present study, the athletes already have good control and self-perception of their daily training routine and sleep, as they are regularly evaluated by the multidisciplinary team and the team coach always monitors sleep before training. Thus, the athletes' good sleep quality is believed to have allowed them to perform better and with greater intensity the following day, explaining the greater perception of effort. Thus, good or bad sleep quality interferes with the quality of training the next day, indicating that athletes who sleep well (higher quantity and quality) can perform better in training because of better recovery[2], whereas the deprivation of a portion of the TST can lead to increased RPE and loss of strength[35].

Regarding the limitations and perspectives of future investigations, the present study did not correlate the external training load with the internal load and sleep. Furthermore, we could not compare the responses of training load and sleep parameters between different types of physical disability and training periods. Therefore, we suggest that future studies consider these aspects.

Conclusion

The main results of the present study demonstrate that athletes with physical disabilities slept more, took less time to sleep, and had greater SE on days with PP training, indicating positive effects of training on sleep parameters. In addition, training volume was related to SE on the same day, indicating that a lower training volume could favor greater SE. In addition, the TST of the night before training is related to the athlete's effort the next day, that is, an athlete who sleeps more can exert more effort. Therefore, it is important to assess and monitor sleep and training load to consider in PP training.

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