# Relationshp Between Sleep Quality, Mood State, and Performance of Elite Air-Rifle Shooters

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**Research Article**

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#### Abstract

## Background

To evaluate the impact of pre-competition sleep quality on the mood and performance of elite air-rifle shooters.

## Methods

This study included 23 elite air-rifle shooters who participated in an air-rifle shooting-competition from April 2019 to October 2019. Sleep time, sleep efficiency, sleep latency, and wake-up time after sleep onset were monitored using actigraphy. The Pittsburgh sleep quality index and Profile of Mood State were used to assess sleep quality. Competitive State Anxiety Inventory-2 was used to evaluate mood state.

## Results

The average time to fall asleep, sleep time, sleep efficiency, and subjective sleep quality were 20.6 ± 14.9 min, 7.0 ± 0.8 h, 85.9 ± 5.3%, and 5.2 ± 2.2, respectively. Sleep quality decreased as the competition progressed. Pre-competition sleep time in female athletes was significantly higher than that on the competition day ($P = 0.05$). Pre-competition sleep latency was significantly longer in women than in men ($P = 0.021$). During training and pre-competition, the tension, fatigue, depression, and emotional disturbance were significantly lower in athletes with good sleep quality than in athletes with poor sleep quality. Athletes with good sleep quality had significantly more energy. The PSQI total score was positively correlated with positive emotion, TMD, cognitive anxiety, and somatic anxiety POMS scores, and negatively correlated with energy and self-confidence scores. Race scores and depression and somatic anxiety scores were negatively correlated.

## Conclusion

Poor sleep quality negatively impacted the mood of athletes; however, sleep indices and competition performance of athletes during competitions were not significantly correlated.

### Background

Air-rifle shooting is a precision sport and has complex performance requirements. Research has shown that good sleep quality is important for better physical and emotional recovery of athletes, which, in turn, ensures excellent performance [1]. Shooters not only have to maintain their concentration during long-term training and competitions but also need to have quick reactions during each shot and deal with tension and pressure for long periods of time during major competitions. These demanding sports consume more energy and often cause sleep problems, such as difficulty falling asleep and waking up at night, especially before major competitions [2, 3].

Sleep and circadian rhythms have a direct relationship with cognitive and metabolic functions (4). In sports science, sleep time and sleep quality [5] are considered to be the key factors affecting athletic ability, recovery after exercise, and sports performance. Recently, an increasing number of studies have investigated the relationship between emotional and mental health and the performance of athletes during competitions [6]. Good sleep plays an important role in the sports performance, energy recovery, disease damage control, metabolism, cognitive memory, and emotional health of elite athletes, allowing the ability for better physical and emotional recovery [7]. While the sleep quality of athletes may not necessarily be better than that of non-athletes, their discipline and focused training for highly competitive sports may have positive effects on their sleep quality [8]. Sleep monitoring and regulation have become important aspects of the pre-competition preparation and regimen of athletes.

The science and technology team in-charge of the Shanghai shooting team found that the motor pattern, training content, competition level, and mood state of elite athletes had an impact on their sleep. To ensure high performance and well-being of athletes, studying their sleep patterns and establishing effective pre-competition sleep evaluation and regulation protocols to improve the preparation strategies of elite athletes is of great importance.

## Methods

# Subjects

We conducted a descriptive study on the Shanghai elite air-rifle shooting team. Data were collected from April to October 2019 during the preparation period for the national competition. The inclusion criteria were as follows: 1) elite air-rifle shooters at the national level or above, 2) systematic training, and 3) consistent training time and training program. The exclusion criteria involved retired athletes and athletes taking medication for medical conditions, including sleep medication. All participants provided written informed consent.

# Data collection and definition

Data including age and gender as well as sleep diary information were collected from at least two completed national competitions. Sleep quality was evaluated using the Pittsburgh sleep quality index (PSQI) scale, mood state was evaluated using the Profile of Mood State (POMS) scale, and competition performance was evaluated by recording the number of rings.

According to the training arrangement, the research was divided into four stages: baseline, pre-competition, competition-day, and post-competition. The baseline stage represented daily training. The daily training time was 5.5 ± 1.5 h and included live firing training exercises. The number of shells spent was 116.9 ± 8.5. The pre-competition stage included the three days before the competition: usually the day before departure, registration day, and pre-competition training day. The competition-day stage included the day of the competition, and the post-competition stage referred to the day after the completion of the final event by the athlete.

The Objective sleep index was recorded during all the above-mentioned stages using Actigraph GT3X+ (Actigraph LLC, Version 6.13.4) which was worn around the non-dominant wrist, and the collected data were analyzed using the Actilife 6.13 software (9). The Actigraph GT3X+ is a small wearable device which has been proved to be able to obtain highly consistent information in combination with polysomnography, and is widely used in research to monitor the sleep of elite athletes (10, 11), and based on the principle of three-axis accelerometer and algorithm technology (12)

The sleep quality data were obtained from the PSQI questionnaire and a sleep diary. The Cole-Kripke algorithm (13) was used to automatically obtain the sleep-related indices of the athletes' sleep/wake behavior, including total sleep time, sleep latency, wake-time after sleep onset (WASO, determined by the awakening frequency and duration), and sleep efficiency. The Actigraph counts were generated and sleep consistency was evaluated. The following conditions were set during data collection: (1) if the Actigraph was not worn according to the instructions, data interruption could be clearly recorded on the Actigraph, and the data not fulfilling the requirements would not be considered; (2) if the sleep time difference between the data from the sleep diary and Actigraph was > 30 min, the sleep data would be adjusted to complete the data of the Actigraph; and (3) the sleep diary would be used to correct sleep latency. The PSQI scale was used to evaluate subjective sleep quality, and PSQI >5 was regarded as poor sleep. According to the Guidelines for the Diagnosis and Treatment of Insomnia for Chinese Adults, abnormal sleep signs indicated nighttime sleep time of < 7 h, nighttime sleep latency of >30 min, nighttime awakening, nightmares, daytime sleepiness, and poor sleep quality. Recording information in the sleep diary was mainly used to correct sleep latency. The average value of five consecutive daily training days was considered as the baseline sleep time. The data of the pre-competition stage was based on the average value of two of the three major national competitions in the entire year. The sleep data of the athletes participating in the qualifying and eliminating rounds of the 10-m air-rifle competition were collected on the day of the competition.

A short version of the POMS scale was revised by Zhu Beili et al. in 1995. It is a concise alternative and brief but accurate measure of the mood of athletes. The POMS-short form (14) and the Chinese norm were used to evaluate the mood of the athletes at the various stages. There are 40 questions in the short form of POMS and each answer is scored on a scale of 0–4. Finally, the scores of five negative emotions, namely, tension, anger, fatigue, depression, and panic and two positive emotions, namely, energy and self-regard were obtained. The Competitive State Anxiety Inventory-2 (CSAI-2) questionnaire (15) compiled by Martens et al. and revised by Zhu Beili et al. in 1994 and the Chinese norm were used to evaluate the competitive state of the athletes. The 27-item questionnaire is divided into three subscales: cognitive anxiety, somatic anxiety, and self-confidence. Each subscale was scored separately on a scale of 1–4. A high score indicated high cognitive anxiety, somatic anxiety, and self-confidence. Race scores were recorded from the total ring value of the 10-m air rifle from the national shooting competition.

# Statistical analysis

SPSS 22.0 software (IBM, USA) was used for statistical analysis, and the measured data were expressed as mean ± standard deviation. The intra-group analysis of variance was used to compare the sleep quality of athletes at the baseline, pre-competition, competition-day, and post-competition stages. The stage of the competition was used as the intra-group factor (a total of seven grades: baseline; pre-competition days 3, 2, and 1; competition days 1 and 2; and post-competition day 1) in each analysis of variance. An independent samples *t* test was used to analyze the differences in sleep core indices and mood state between different genders. Pearson’s correlation coefficient (r) was used to analyze the correlation between sports performance, sleep quality, and mood state. $P < 0.05$ was considered to be statistically significant.

# Results

Twenty-three elite air-rifle athletes were enrolled in our study (13 men and 10 women; average age, 23.11 ± 4.82 years). Four athletes had competed internationally and all had >2 years of experience at the national level.

We noted that it took the athletes 20.6 ± 14.9 min to fall asleep. Total sleep time was 7.0 ± 0.8 h, sleep efficiency was 85.9 ± 5.3%, subjective sleep quality was 5.2 ± 2.2, and there was no obvious difference between bedtime and waking-up time during the training and competition stages (Fig. 1 and Table 1). Sleep-onset time, total time in bed, total sleep time, sleep efficiency, and WASO changed during the different stages. Sleep-onset time was the most delayed at baseline and on the day after the competition. Sleep-onset times on pre-competition day 2 and the first day of the competition were significantly earlier than that on the day after the competition ($P = 0.030$, $P = 0.049$; Table 1). There was no significant change in sleep latency. The total time in bed on the day after the competition was significantly lower than that on pre-competition day 3 and the day 1 of the competition ($P = 0.047$, $P = 0.026$; Table 1). The total sleep time decreased as the competition progressed, and the total sleep time on the day after the competition significantly decreased compared to that at the baseline stage and on the pre-competition day 3 ($P = 0.021$, $P = 0.045$; Table 1). Sleep efficiency was the highest at the baseline stage. Compared to that at baseline, sleep efficiency significantly decreased on the first day of the competition and the day after the competition ($P = 0.035$, $P = 0.017$; Table 1). WASO was the longest on the day after the competition, which significantly differed from that at the baseline and on the three days before the competition ($P = 0.040$, $P = 0.023$; Table 1). The awakening frequency did not change at different stages. The subjective sleep quality significantly changed between the competition and non-competition periods. The subjective PSQI score in the pre-competition stage was higher than that at baseline ($P = 0.12$; Table 1), indicating that the athletes believed that the sleep quality was regular during the competition.

Table 1
Sleep index variables at the baseline, pre-competition, competition day, and post-competition stages (± *s*)

| | **Baseline** | | **Pre-competition** | | **Competition day** | | **Post-competition** | |
|---|---|---|---|---|---|---|---|---|
| Sleep index variables | Male (n = 13) | Female (n = 10) | Male (n = 13) | Female (n = 10) | Male (n = 13) | Female (n = 10) | Male (n = 13) | Female (n = 10) |
| Sleep latency (min) | 12.1 ± 8.9 | 14.7 ± 10.7 | 20.2 ± $4.6^{\#}$ | 26.6 ± $7.2^{*\#}$ | 25.5 ± $12.1^{\#}$ | 26.7 ± $17.1^{\#}$ | 11.3 ± 8.3 | 6.8 ± 4.9* |
| Total sleep time (h) | 7.3 ± 0.4 | 7.9 ± 0.9 | 7.4 ± 0.9 | 7.2 ± $0.9^{\#}$ | 7.4 ± 0.8 | 7.0 ± $0.9^{\#}$ | 6.1 ± $0.8^{\#}$ | 6.6 ± $0.5^{\#}$ |
| Sleep Efficiency (%) | 91.3 ± 3.2 | 88.1 ± 3.7 | 86.6 ± 3.3 | 84.8 ± 7.9 | 81.9 ± $4.2^{\#}$ | 85.3 ± 5.0 | 78.5 ± $7.3^{\#}$ | 81.3 ± $3.1^{\#}$ |
| WASO (min) | 38.6 ± 9.3 | 67.3 ± 15.1 | 57.6 ± .6.1 | 69.3 ± 11.9 | 85.3 ± 10.3 | 78.8 ± 19.0 | 103.9 ± 25.5 | 92.3 ± 18.9 |
| PISQ > 5 | 7.3±1.3 | | 8.1±1.5 | | | | | |
| PISQ ≤ 5 | 3.6±1.6 | | 4.3±0.9 | | | | | |

Notes: #Significant difference. Mean values with the same superscript are significantly different ($P < 0.05$).

During the daily training stage, athletes with good sleep quality exhibited significantly lower tension ($P = 0.018$), fatigue ($P = 0.026$), depression ($P = 0.039$), and total of emotional disturb (TMD) ($P = 0.004$) scores than athletes with poor sleep quality. Consequently, athletes with good sleep quality had significantly higher energy ($P = 0.045$) than those with poor sleep quality. Before the competition, tension ($P = 0.002$), anger ($P = 0.009$), fatigue ($P = 0.007$), depression ($P = 0.011$), panic ($P = 0.000$), and TMD ($P = 0.000$) of athletes with good sleep quality were significantly lower than those of athletes with poor sleep quality. Energy ($P = 0.001$) and self-regard ($P = 0.039$) were significantly higher in athletes with good sleep quality than in those with poor sleep quality (Figure 3). The curves of athletes with good sleep in the baseline and pre-competition stages are iceberg shaped while the curves of athletes with poor sleep are inverted iceberg shaped, which directly reflects the differences in the overall emotional levels of athletes with different sleep qualities (Figure 2).

The total PSQI score was positively correlated with the POMS negative emotion subscale, TMD, cognitive anxiety, and somatic anxiety and negatively correlated with the POMS positive emotion subscale (energy and self-regard) and self-confidence (all $P < 0.05$; Table 2). The sleep quality, time of falling asleep, sleep disorders, and daytime function on the PSQI scale were positively correlated with the POMS negative emotion subscale, TMD, cognitive anxiety, and somatic anxiety and negatively correlated with energy and self-confidence (all P < 0.05; Table 2). Sleep quality was negatively correlated with daytime function and self-regard (all $P < 0.05$; Table 2). Sleep time was positively correlated with only fatigue ($P < 0.05$; Table

2). We then analyzed the correlation between the PSQI scores, sleep quality, sleep time, total sleep time, sleep efficiency, sleep disorders, daytime function, and competition performance was analyzed. Our results revealed no significant correlation between competition performance and sleep indices (all P > 0.05; Table 3).

Table 2
Correlation analysis (r) between sleep index variables and mood state variables one week before the competition.

| Mood states variables (r) | PSQI score | Sleep quality | Sleep time | Total sleep time | Sleep efficiency | Sleep disorders | Daytime function |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Tension | 0.616** | 0.487** | 0.520** | 0.208 | 0.130 | 0.589** | 0.448** |
| Anger | 0.515** | 0.444** | 0.446** | 0.124 | 0.009 | 0.471** | 0.444** |
| Fatigue | 0.523** | 0.480** | 0.300* | 0.286* | 0.213 | 0.300* | 0.493** |
| Depression | 0.613** | 0.547** | 0.511** | 0.152 | 0.117 | 0.547** | 0.474** |
| Energy | −0.504** | −0.470** | −0.337* | −0.111 | −0.098 | −0.307* | −0.595** |
| Panic | 0.598** | 0.411** | 0.455** | 0.197 | 0.123 | 0.628** | 0.521** |
| Self-regard | −0.284* | −0.328* | −0.143 | −0.056 | −0.113 | −0.142 | −0.327* |
| TMD | 0.669** | 0.585** | 0.500** | 0.206 | 0.148 | 0.534** | 0.605** |
| Cognitive anxiety | 0.471** | 0.390** | 0.418** | 0.175 | 0.165 | 0.502** | 0.204 |
| Somatic anxiety | 0.585** | 0.524** | 0.512** | 0.191 | 0.001 | 0.562** | 0.426** |
| Confidence | −0.523** | −0.436** | −0.351** | −0.181 | −0.153 | −0.465** | −0.471** |

Notes: * $P < 0.05$; ** $P < 0.01$.

Table 3
Correlation analysis between sleep index variables and race scores in the competition

| Sleep index variables (Mean±SD) | | Score (number of rings) (Mean±SD) | *r* | *P* |
|---|---|---|---|---|
| PSQI score | 6.23±1.18 | 623.1 ± 3.45 | 0.308 | 0.555 |
| Sleep quality | 0.86±0.67 | | 0.316 | 0.562 |
| Sleep time | 0.28±0.45 | | 0.398 | 0.631 |
| Total sleep time | 7.3±0.9 | | 0.404 | 0.291 |
| Sleep efficiency | 87.2±5.4 | | 0.248 | 0.538 |
| Sleep disorders | 0.89±0.58 | | 0.320 | 0.319 |
| Daytime function | 1.51±0.83 | | 0.366 | 0.555 |

Notes: $^{*}P < 0.05$, $^{**}P < 0.01$ indicate significant correlation with the number of rings in the competition.

A correlation analysis was conducted between athletic performance and scores of POMS indices and three CSAI-2 scores. The results showed a statistically significant negative correlation between competition scores and depression subscale ($P = 0.002$), and a significant negative correlation was observed between competition scores and somatic anxiety in the CSAI-2 scale scores ($P = 0.025$; Table 4).

Table 4
Correlation analysis between mood state variables and number of rings in competition

| Mood state variables (Mean±SD) | | | Race scores (number of rings) (Mean±SD) | *r* | *P* |
|---|---|---|---|---|---|
| POMS | Tension | 47.26±9.28 | 623.1 ± 3.45 | −0.127 | 0.092 |
| | Anger | 43.98±10.59 | | −0.091 | 0.079 |
| | Fatigue | 48.84±10.61 | | −0.221 | 0.052 |
| | Depression | 43.82±9.4 | | **−0.738**** | **0.002** |
| | Energy | 53.71±10.24 | | 0.215 | 0.067 |
| | Panic | 48.78±7.66 | | 0.019 | 0.141 |
| | Self-regard | 50.36±9.79 | | 0.122 | 0.098 |
| | TMD | 97.28±19.28 | | 0.009 | 0.179 |
| CSAI-2 | Cognitive anxiety | 20.17 ±8.54 | | 0.182 | 0.070 |
| | Somatic anxiety | 17.33 ±5.61 | | **−0.674*** | **0.025** |
| | Confidence | 21.00 ±7.4 | | 0.191 | 0.083 |

Notes: * $P < 0.05$, ** $P < 0.01$ significant correlation with number of rings in competition.

# Discussion

In this study, we analyzed the direct effect of sleep quality on athletes' mood and performance through subjective sleep evaluation and objective monitoring data. The main findings showed that poor sleep quality of athletes has a negative impact on the mood; however, there was no significant correlation between sleep indices and competition performance of athletes during competitions. Our results suggested that sleep changes under competition stress in athletes, but studies should focus more on sleep quality than on duration. The pre-competition preparation protocols and the time required for post-competition recovery should be adjusted and effective training plans should be formulated to ensure that athletes receive proper rest and recovery.

We observed that the daily sleep of shooters was consistent and the sleep quality was acceptable; however, their sleep/wake cycles were affected by competition stress. This was more evident among the female athletes. Only subjective sleep quality changed during the competition and non-competition periods. Total sleep time before, during, and after the competition was lower than that during the daily training stage. Sleep latency, sleep efficiency, and WASO had negative changes to varying degrees, and sleep latency before and after the competition significantly increased. The decrease in sleep efficiency is mainly caused by WASO. Our results are consistent with those of previous studies [16, 17], which suggested that athletes' sleep changes under the influence of competition stress, but more attention should be paid to sleep quality than to sleep duration. In addition, in events that span over a longer duration, this change in sleep pattern manifests throughout the competition and negatively affects subsequent training after the competition. On further analyzing the self-rated sleep pattern before the competition, we found that the severity of sleep problems before the competition was greater than normal and the distribution of PSQI scores was remarkably high (the higher the score, the worse the sleep quality), indicating that most athletes experienced lack of energy before the competition. Although the minimum recommended sleep time for adults to prevent health damage and decreased work efficiency is approximately 7 h [18], it may not be enough for athletes. Furthermore, sleep patterns may differ between genders due to the physiological and psychological differences between men and women. There is a growing body of evidence that suggests a correlation between the gut microbiome and sleep quality [19]. In-depth research and investigation should be conducted on this topic. Individual sleep analysis of key athletes revealed that the total time in bed in the daily training stage is usually not lower than that in the competition stage. The bedtimes of many athletes in the daily training stage is earlier than that in the competition stage, but this is not reflected in the total sleep time and sleep efficiency. This is because athletes usually do not fall asleep immediately after going to bed but may indulge in activities that stimulate the brain, which hampers effective sleep time and quality [20]. Although athletes consciously go to bed earlier than usual in the competition stage, different sleep rhythms and poor sleep consistency may lead to longer sleep latency, increased sleep fragmentation, and decreased sleep quality.

The investigation of the mood state of athletes revealed that the pre-competition mood of male athletes was better than that of the female athletes. Therefore, gender should be considered as a factor affecting the mood state of athletes before a competition. On comparing the mood state of athletes at different sleep levels, we observed that sleep quality was directly related to mood. PSQI scores of $\leq 5$ and $>5$ represent good sleep quality and poor sleep quality, respectively. Our results showed that athletes with different sleep qualities in the baseline and pre-competition stages showed the same results, i.e., the athletes with good sleep quality had significantly lower negative emotions, higher scores of positive emotions, and lower TMD than those with poor sleep quality. Figure 3 shows that athletes with good sleep presented iceberg-shaped curves, while those with poor sleep presented inverted iceberg-shaped curves. These results directly reflect the differences in mood state and are consistent with the results of several previous studies [21, 22]. Lack of quality sleep will lead to negative mood changes, which negatively affects the athletes' cognition, decision-making skills, and motor skills [23]. Moreover, poor sleep quality and lack of sleep increase fatigue and tension in athletes, affecting their success in competitions. Therefore, it is very important for athletes to have good sleep, which will contribute to effective physical and emotional recovery. However, we found that sleep time is correlated only with fatigue and has little correlation with emotion. Therefore, the total sleep time of athletes is not the main factor affecting their emotional state.

According to the results of the correlation analysis of sports performance, sleep, and emotion, we did not find any relationship between pre-competition sleep quality and sports performance. In fact, many studies have found that despite the variation in sleep patterns of athletes during the competition, it does not always lead to poor performance [24]. However, our study discovered that better sports performance is indicative of lower depression and somatic anxiety level of athletes. In addition, this finding is consistent with that of previous studies, showing that emotion has a predictive effect on sports performance [25]. Although there is no direct relationship between sleep and sports performance, the high correlation between sleep and emotion indicates that sleep may affect sports performance through the interaction between sleep and emotion. The findings of this study illustrate three points: first, sleep is not the main factor affecting sports performance; second, it is necessary to investigate whether change in sleep is caused by emotional factors or location changes during competitions; and lastly, long-term changes in sleep are concerning and need to be investigated. Previous studies have proved that long-term decline in sleep quality can lead to an imbalance in the autonomic nervous system, resulting in athletes experiencing symptoms similar to those experienced during overtraining, resulting in a decline in immunity and cognitive function [26]. A single episode of sleep deprivation was found to affect the glutamine content in rats, resulting in a decline of the body's ability to exercise [27] Although coaches and athletes believe that sleep is a part of the recovery process, sleep quality is often not considered in the training plan and competition protocol [28]. Due to the lack of attention on the importance of sleep training, in some cases, sleep time is sacrificed by increasing time for physical training or other activities. When athletes experience sleep problems, most of them have no corresponding strategies to improve their poor sleep. Therefore, sleep training should focus on enhancing the sleep management of athletes, such as improving healthy sleeping habits, ensuring sleep consistency, finding the causes of sleep problems, and regularly evaluating and receiving feedback on the sleep quality of athletes. These processes will help athletes maintain good sleep, reduce the interaction between sleep and emotions, and in turn, improve sports performance.

# Conclusions

Our study established that sleep and mood are factors that influence the well-being of athletes during competitions, therefore, more attention should be paid to the sleep quality and mood state of athletes before, during, and after high-performance and precision sport competitions. The impact of improper sleep on performance may accumulate over time, leading to negative changes in the emotional state of athletes by affecting their mood, which in turn affects sports performance. Taking our data into consideration can help coaches and trainers better understand the implications of such changes in athletes, adjust pre-competition preparation protocols, and the time required for post-competition recovery, and formulate effective training plans to ensure that athletes receive proper rest and recovery.

# List Of Abbreviations

Pittsburgh sleep quality index PSQI

Profile of Mood State POMS

Competitive State Anxiety Inventory-2 CSAI-2

# Declarations

## Ethics approval and consent to participate

This study was approved by Ethics Committee of Shanghai Anti-Doping Center therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki (Revised in 2013). All methods were carried out in accordance with relevant guidelines and regulations. All participants gave their informed formal consent prior to their inclusion in the study.

## Consent for publication

N/A

## Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript”.


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## Authors' contributions

JJ L and Y A carried out the studies, participated in collecting data, and drafted the manuscript. JJ L and Y A performed the statistical analysis and participated in its design. JJ L and J Q participated in acquisition, analysis, or interpretation of data and draft the manuscript. All authors read and approved the final manuscript.

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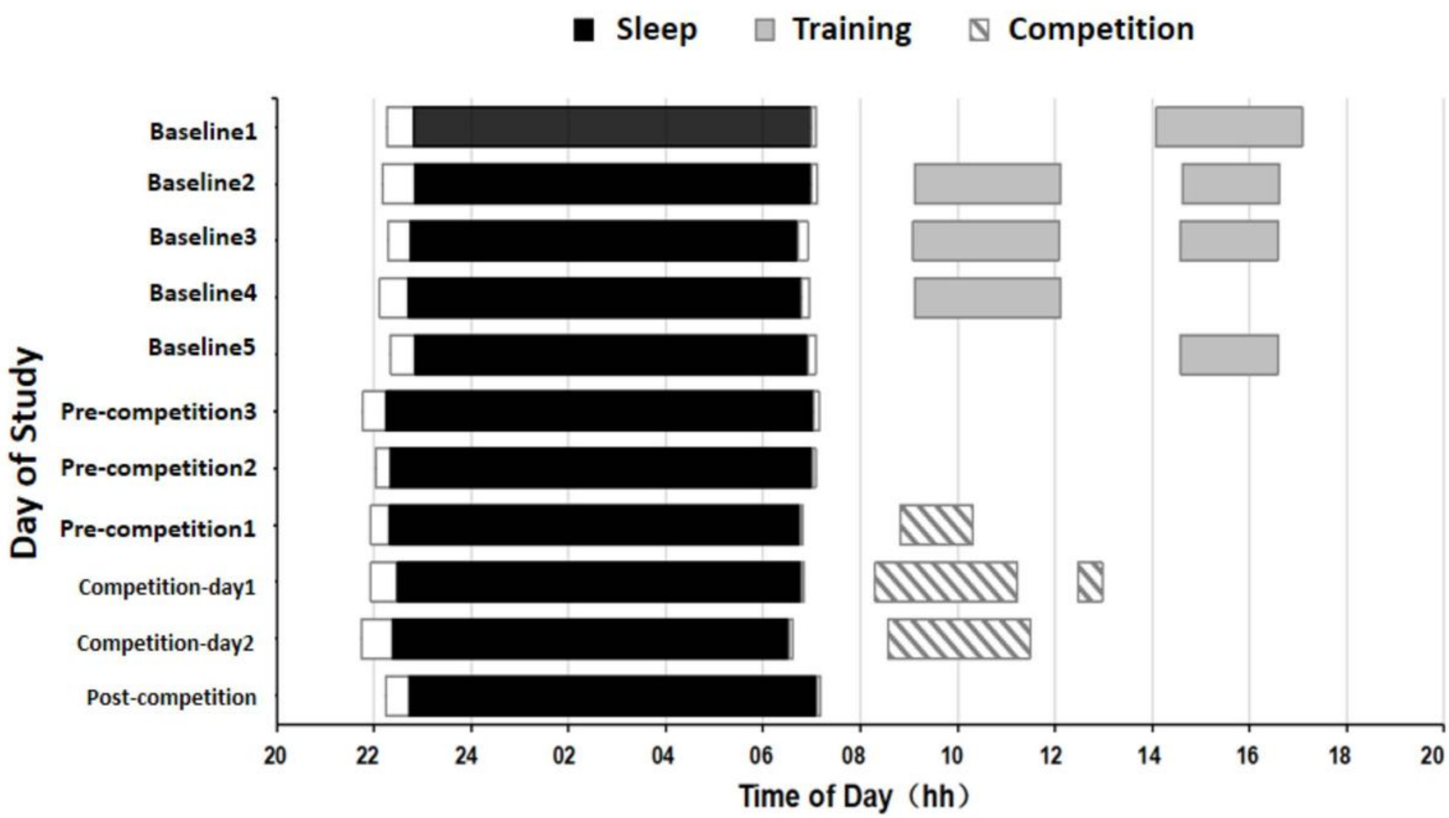
# Figures




## Figure 1

Sleep/wake behavior of 23 shooters at the baseline and before, during, and after the match. Each line represents a 24-hour period from 20:00 to 20:00. The first five lines represent the sleep/wake behavior during baseline. The remaining lines represent the 3 pre-match days, 2 nights preceding and following the match day, and 1 day after the match. The black and white horizontal bars represent the average of all nighttime sleep times, including sleep time, sleep latency, start of sleep, and wake time. The light grey horizontal bar indicates the training time at baseline. The black and white bar indicates the time of the match.

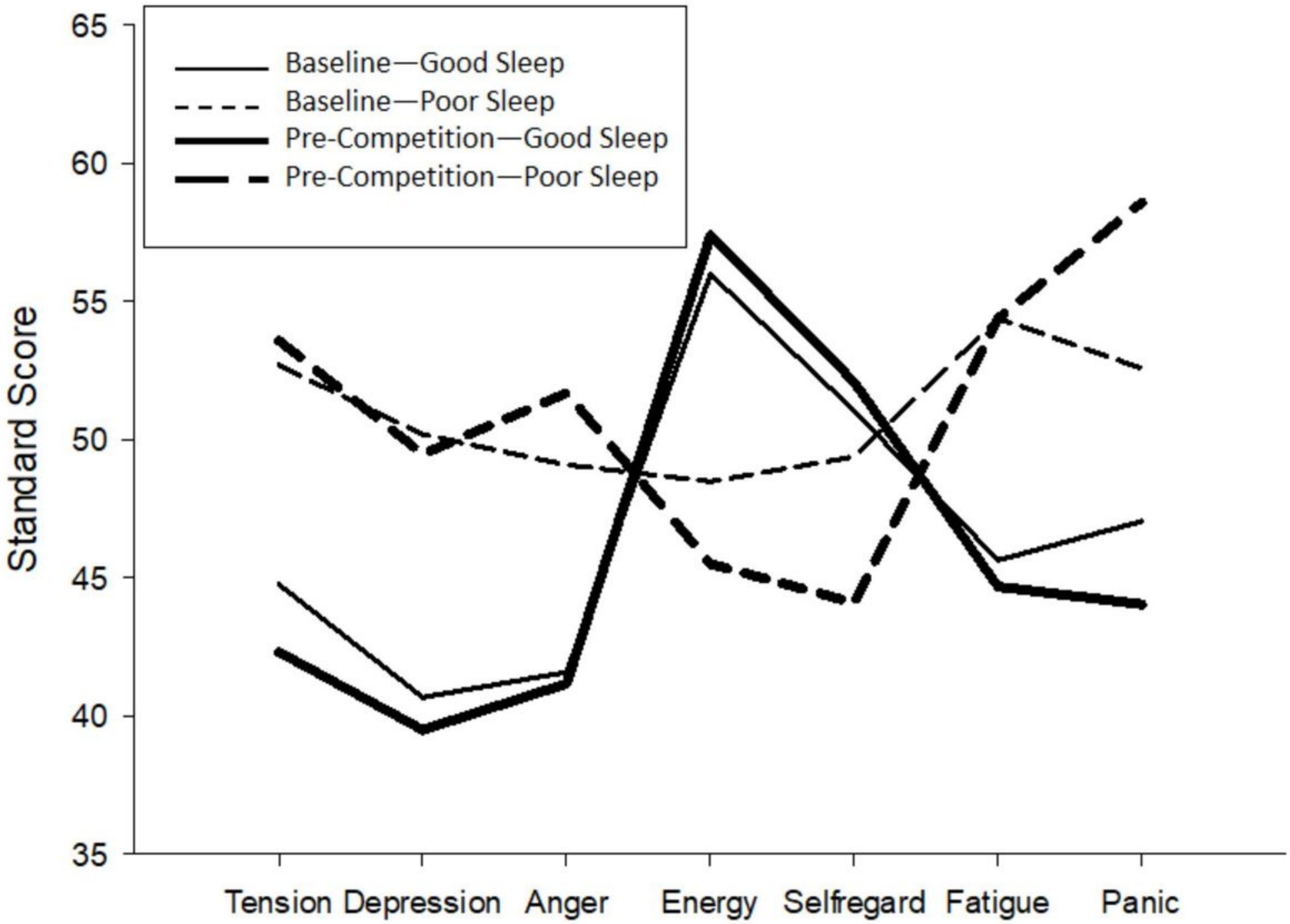



Figure 2

Comparison of the mood states of athletes with different sleep quality