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Research article

Sleep deprivation induced anxiety and anaerobic performance

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Abstract
The aim of this study was to investigate the effects of sleep deprivation induced anxiety on anaerobic performance. Thirteen volunteer male physical education students completed the Turkish version of State Anxiety Inventory and performed Wingate anaerobic test for three times: (1) following a full-night of habitual sleep (baseline measurements), (2) following 30 hours of sleep deprivation, and (3) following partial-night sleep deprivation. Baseline measurements were performed the day before total sleep deprivation. Measurements following partial sleep deprivation were made 2 weeks later than total sleep deprivation measurements. State anxiety was measured prior to each Wingate test. The mean state anxiety following total sleep deprivation was higher than the baseline measurement (44.9 ± 12.9 vs. 27.6 ± 4.2, respectively, $p = 0.02$) whereas anaerobic performance parameters remained unchanged. Neither anaerobic parameters nor state anxiety levels were affected by one night partial sleep deprivation. Our results suggest that 30 hours continuous wakefulness may increase anxiety level without impairing anaerobic performance, whereas one night of partial sleep deprivation was ineffective on both state anxiety and anaerobic performance.

Key words: Psychophysiological disorders, mood, insufficient sleep, muscle fatique.

Introduction

Evidence suggests athletes worry about the effects of inadequate sleep on performance (Leger et al., 2005) although sleep deprivation on physical performance (e.g. anaerobic power, muscle strength, endurance, physiological responses such as heart rate, ventilation, oxygen consumption) is not clearly understood (Martin, 1981; 1986; Rodgers et al., 1995; Souissi et al., 2003; Youngstedt and O'Connor, 1999). Rodgers et al. (1995) reported that 48 hours period of sleep deprivation significantly decreased the physical work tasks requiring 30-45% VO_2max without affecting anaerobic power. Further, Souissi et al. (2003) demonstrated that duration of sleepless period may be important as peak power was not affected after 24 hours sleep deprivation but significantly decreased after 36 hours of wakefulness.

In contrast, it is well established that sleep deprivation can result in impairments in affective states (e.g. increased anxiety, depressed mood, anger, tension, frustration and irritability) and cognitive functions (JrLeDuc et al., 2000; Orton and Gruzelier, 1989; Scott et al., 2006). Martin and Gaddis (1981) demonstrated that 30 hours sleep deprivation significantly affected psychological responses without affecting physical performance. According to a recent study, it was found that 56 hours sleep deprivation was associated with a statistically significant increase in self reported symptoms of anxiety (Kahn-Greene et al., 2007).

The relationship between anxiety and athletic performance has been extensively studied (Craft et al., 2003; DeMoja and DeMoja, 1986; Hogg, 1980; Hume et al., 1993; Jones and Hardy, 1988; Kais and Raudsepp, 2004; Pijpers et al., 2005). Additionally, various theoretical models have been proposed to describe the relationship between anxiety and performance (Raglin, 1992; Thelwell and Maynard, 1996; Turner and Raglin, 1996). Inconsistent results have been obtained for the effect of anxiety on athletic performance. Some studies report negative correlation between anxiety and athletic performance (DeMoja and DeMoja, 1986; Hume et al., 1993). For instance, Hume et al. (1993) demonstrated a significant negative correlation between athletic attainment and anxiety level in 106 female gymnasts. In contrast, some studies showed positive correlation, whereby anxiety appeared to have helped performance (Kais and Raudsepp, 2004; Parfitt et al. 1995; Parfitt and Pates, 1999). For example, Parfitt and Pates (1999) showed that increase in somatic anxiety is associated with increase in anaerobic power.

A factor that could influence the strength of anxiety-performance relationships not considered adequately in the literature is the effect of sleep deprivation. Previous studies demonstrated that sleep deprivation is associated with increased anxiety in healthy young adults (Dinges et al., 1997; Kahn-Greene et al. 2007; Sagaspe et al. 2006). Sleep deprivation is associated with higher state anxiety levels which in turn alter athletic performance. Pedlar et al. (2007) demonstrated that it was possible to continuously decrease sleep time to an extremely low level for a prolonged period (44 days) and simultaneously maintain a very high work load; however, this pattern may have adverse affects on mood. Therefore, it has been thought that additional studies of sleep deprivation may help to elucidate the association between anxiety and athletic performance. We hypothesize that duration of sleep deprivation in the night preceding anaerobic athletic event is an effective variable in determining anxiety level and thus anaerobic performance. The aim of this study was to investigate the possible short-term total and partial sleep deprivation induced anxiety on anaerobic performance

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parameters such as peak power and mean power obtained from the 30-second Wingate Test in the same study population.

Methods

Participants

Thirteen healthy male students attending school of physical education accepted to participate in the study. As the Wingate test requires maximum power, only students who exercise regularly were accepted to the study. In addition just the males were included in the study in order to assure that the findings following sleep deprivation are not affected from gender differences (Caldwell and Leduc, 1998). Details of the study were explained to each participant and signed informed consents were obtained. The study was approved by the local ethics committee of Trakya University. A self-administered questionnaire was used to assess age, weight, height, with their participation age to sports, and the amount of training per week. The mean (±SD) age, height, BMI, participation age in sports, duration of training and the amount of training of the participants were given in Table 1. BMI was calculated as weight in kilograms per height in square meters. Since participants were unfamiliar with the procedures, the Wingate Anaerobic Test was applied to all participants two weeks prior to the experimental trials in order to provide familiarity.

Participants also kept a diary of their activities during the three days before the baseline night. Participants' time of going to bed varied between 10 00 p.m. and 11 00 p.m. The time of waking up varied between 07 00 a.m. and 08 00 a.m.

Table 1. General characteristics of participants (n = 13).

	Mean (±SD)	Range
Age (yrs)	22.0 (1.12)	21–24
Height (m)	1.77 (.05)	1.71–1.83
Weight (kg)	71.1 (6.45)	60–82
BMI ($kg \cdot m^{-2}$)	22.7 (1.89)	20–25
Participation age to sports (yr)	11.2 (3.11)	5–15
Duration of training (yr)	9.3 (4.44)	2–16
Amount of training (h/week)	5.78 (1.92)	3–10
PSQI score	4.22 (.86)	1–5

BMI: Body Mass Index; PSQI: Pittsburg Sleep Quality Index

Inclusion criteria

All participants were non-smokers and they took no medication or alcohol in order not to affect the measurements of anxiety (Crome and Bloor, 2005). No participant declared a psychiatric or another illness. In order to ensure that the study group shows homogeneity with respect to chronotype, morningness-eveningness questionnaire of Horne and Östberg (1976) was filled out and participants with similar characteristics were included. This questionnaire establishes five behavioural categories: definitively morning types (score=70-86), moderately morning types (score=59-69), neither types (score=42-58), moderately evening types (score=31-41) and definitively evening types (score=16-30). The reliability of the Turkish version of the Horne and Östberg questionnaire has been established in a previous study (Punduk et al., 2005). Moderately morning types (n = 6) and neither types (n = 7) were included in this study.

Subjective sleep quality of participants was investigated using Pittsburg Sleep Quality Index (PSQI) that is a self-noted questionnaire that assesses sleep quality and sleep disturbance over one-month period (Buysse et al., 1989). It comprises 19 individual items generating seven "component" scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication and daytime dysfunction. The sum of scores for these seven components yields one PSQI global score. In addition to showing global scores as a continuous variable, participants were dichotomized into "good" sleepers (PSQI < 5) and "poor" sleepers (PSQI > 5) according to previous methodology. We included good sleepers in our study. PSQI scores of all participants were lower than 5 in our study group. The mean (±SD) PSQI scores of participants were given in Table 1. A Turkish translation and reliability and validity studies of this scale were performed in a Turkish sample (Agargun et al., 1996).

Study design

The protocol included three parts: (1) baseline measurements, (2) measurements following short-term total (30 hours) sleep deprivation, (3) measurements following partial sleep deprivation (Figure 1). With respect to duration, total sleep deprivation may be divided into

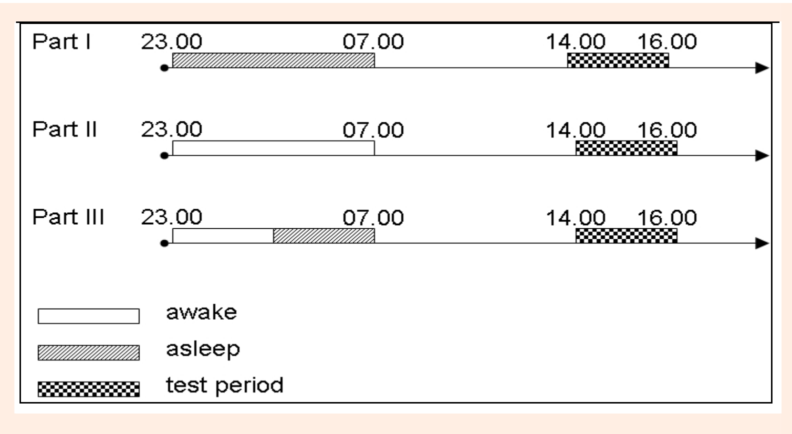

Figure 1. The study protocol. During the test period after having state anxiety scores, all participants undervent 30-second Wingate Test. Although Part II took place during the day following Part I, there was at least two weeks between Part II and Part III in order to obtain full recovery from the effects of total sleep deprivation.

Table 2. State anxiety and VAS scores before the Wingate test and values of peak power, mean power and anaerobic fatigue. Data are means (±SD).

	Baseline	Total sleep deprivation	Partial sleep deprivation	p
State anxiety score	27.6 (4.2)	44.9 (12.9) *§	29.6 (3.9)	.020
Sleepiness (VAS)	3.5 (6.6)	46.8 (35.5) *	17.3 (16.8)	.016
Peak power (w)	740.5 (62.8)	738.4 (85.7)	787.2 (90.2)	.055
Peak power (w/kg)	10.5 (1.4)	10.4 (1.6)	10.9 (1.4)	.120
Mean power (w)	555.4 (39.6)	558.3 (45.9)	579.0 (44.6)	.141
Mean power (w/kg)	7.9 (.9)	7.9 (1.0)	8.3 (.9)	.145
Anaerobic fatigue	45.6 (8.0)	44.1 (10.5)	49.4 (5.2)	.609

VAS= Visual Analog Scale. * $p < 0.05$ compared with baseline scores. § $p < 0.05$ compared with partial sleep deprivation scores

short-term (≤45 hours) and long-term (>45 hours) deprivation. Partial sleep deprivation refers to sleep duration less than 5 hours per night (Pilcher and Huffcutt, 1996).

The first part of the study was performed in the next day following the normal habitual sleep period. Following baseline measurements, participants remained awake whole night and day under the constant observation of two investigators in our laboratory. During the sleep deprivation period, the participants spent their time playing table games, reading books or watching television. They were restricted from taking caffeine, tea or other stimulants. The second Wingate Test was performed for each participant at the same time period (14.00–16.00) of the following day.

In the last section, all participants exposed to partial sleep deprivation at least two weeks after total deprivation experiment. They were observed by two investigators. The participants were allowed to sleep between 03.00-07.00 am. They were taken to the exercise laboratory at 08.00 am and kept awake until the Wingate Test was performed. During this period, participants were able to freely engage in a variety of activities (e.g. play computer games, read books, watch television). State anxiety scale and subjective sleepiness by visual analogue scale (VAS) were recorded before each Wingate test. The participants had isocaloric meals in lunch and dinner during the study protocol in order to assure that meals eaten do not affect sleep deprivation (Smith and Maben, 1993).

Anaerobic test

The Wingate test consisted of a 30-second supramaximal cycling against a resistance load. Each test was performed on a Monark cycle ergometer (Model 894-E, Sweden) and for each participant the load was calculated as 0.090 kg x.kg^{-1} body mass. The participants warmed up by pedalling for 3 min against a 30 watt load. After 5 min rest period, by the command "start" the participant began pedalling as fast as possible against a predetermined work load until the end of the test period. Strong verbal motivation was given to participants to maintain maximal pedalling rate during the test. The data were used to calculate peak power and mean power as reported by Bar-Or (1987).

State-trait anxiety scale (STAI)

The STAI was developed by Spielberger et al. (1970) to measure state and trait anxiety. Each participant's level of anxiety was assessed using the STAI, which consists of 20 items, each representative of a category of anxiety symptoms. Oner and LeCompte (1985) determined the reliability and validity of the STAI for a Turkish population. Participants completed state anxiety scale before each Wingate test. Trait anxiety inventory was completed only before the first anaerobic test.

Sleepiness

Subjective sleepiness was recorded using VAS. Participants rated and reported how much sleepy they felt on a 100 mm horizontal line from "very alert" on the left and "very sleepy" on the right. Sleepiness score was measured as the distance of mark from the left in millimetres.

Statistical analysis

The state anxiety score was used as the basis to calculate the power of this study. The power of this study was 85.6% based on the maximum difference in the mean state anxiety score =17.6 between levels, standard deviation=12.9, type I error=5%, n=13.

General characteristics of the participants were presented as mean ± standard deviations and range. Normality distribution of variables was tested using Kolmogorov Smirnov test. The effects of three different sleep conditions on anaerobic performance and anxiety were evaluated by repeated measures analysis of variance (ANOVA) test, and then Bonferroni post-hoc test was used when the significance difference was obtained. Sleepiness was evaluated by Freidman repeated measures ANOVA test due to non-normal distribution, and then Bonferroni post-hoc test was used when significant difference was obtained. P-value <0.05 was considered statistically significant. Statistica 7.0 statistical software was used for statistical analyses.

Results

Trait anxiety scores (33.11± 5.13) verified that our study group was homogenous in terms of general anxiety level. Mean state anxiety scores after total sleep deprivation were significantly higher when compared to the baseline and partial sleep deprivation measurements (Table 2). VAS scores of total sleep deprivation day were significantly higher than the baseline measurements (Table 2). No significant difference was observed between the peak power, mean power and anaerobic fatigue values recorded during Wingate Test after the baseline, total and partial sleep deprivation nights (Table 2).

Discussion

The main finding of this study is that anaerobic performance parameters remained unchanged following 30 hours sleep deprivation, although state anxiety levels of the participants were significantly higher during the same period. In addition, one night of partial sleep deprivation was not associated with enhanced anxiety or impaired anaerobic performance. No statistically significant alterations in anaerobic performance resulting from one night of total or partial sleep loss were found.

Numerous studies have examined the relationship between anxiety and performance (DeMoja and DeMoja, 1986; Hogg, 1980; Hume et al., 1993; Jones and Hardy, 1988; Kais and Raudsepp, 2004; Parfitt et al. 1995; Parfitt and Pates, 1999; Pijpers et al., 2005). Sleep deprivation was not evaluated as a factor that could affect anxiety in studies focused on anxiety- performance relationship whereas some studies demonstrated that sleep deprivation was reported to produce anxiety in humans (Dinges et al., 1997; Kahn-Greene et al., 2007; Sagaspe et al. 2006). In the present study, sleep deprivation was evaluated as an anxiety inducer. The increase in anxiety levels was originally due to total sleep deprivation rather than competition stress or a pathological state.

It is questionable that whether these increased anxiety levels were high enough to influence anaerobic performance parameters (peak power, mean power and anaerobic fatigue). The peak power represents the highest maximal voluntary contraction during any 3- to 5- second period of the Wingate test. Peak power may be affected from central (motivation) and peripheral (neuromuscular) factors (Bernard et al., 1998). Our study revealed that increased anxiety levels resulting from total sleep deprivation do not appear to play any central or peripheral effect in healthy participants.

In our study, the effect of sleep deprivation on anaerobic performance was evaluated by using a supramaximal exercise test. It was found that sleep deprivation did not affect anaerobic performance. In previous studies, the effect of sleep deprivation on performance was examined after treadmill walking at different levels of VO_2 max, and negative effects were reported (Martin, 1981; Rodgers, 1995). It seems that, there has been conflicting findings on the effect of sleep deprivation on physical performance. One of the reasons of this conflict may be examining the physical performance by different standardised physiological tests. Another reason of getting conflicting findings on the effect of sleep deprivation on physical performance may be the duration of sleep deprivation.

In the present study, both total and partial sleep deprivation were investigated in the same study population. Several studies (Rodgers et al., 1995; Symons et al., 1988; Takeuchi et al., 1985) investigated especially the effects of total sleep deprivation on anaerobic performance. In general, no deterioration was revealed in anaerobic performance following total sleep deprivation. However, a recent study reported that 24 h sleep deprivation unaffected but 36 h wakefulness decreased anaerobic performance (Souissi et al., 2003). In a previous study, Mougin et al. (1996) investigated the effects of partial sleep deprivation on the next day anaerobic performance in 8 highly trained athletes. Their findings revealed that partial sleep deprivation does not contribute to differences in various aspects of supramaximal exercise including mean power and peak power. In the light of above considerations, we suggest that short-term total or partial sleep deprivation is not effective on anaerobic performance, even though anxiety levels may be increased to some extent.

Anaerobic performance parameters could obtain specific information for supramaximal exercise levels of individuals. We performed only one test in a day and all tests were taken at the same time period (14.00-16.00 p.m.) to prevent circadian variation effects (time-of-day effect). Bernard et al. (1998) demonstrated the time-of-day effect in the maximal anaerobic power of cycle test. They reported that there were significant differences between the morning and the afternoon measurements whereas no differences were observed between 14.00 and 18.00 hours. We preferred the same time period in order to remove the time-of-day effect.

In this study anxiety and performance responses were obtained in the laboratory environment. Performing the measurements in laboratory provided us a more tightly controlled environment. However, in terms of ecological validity, laboratory environment may be disadvantageous as sportive environment is ever-changing with its weather conditions and existence of other competitors. A recent study revealed that sleep time was positively related to vigor and inversely related to fatigue throughout an expedition to the South Pole in winter (Pedlar et al. 2007). Laboratory assessment isolates the participant from all these ecological conditions. This may reduce the ecological validity of this study.

There are several limitations of the study. First, we measured state anxiety only once prior to anaerobic measurements. Continuous monitorization of anxiety by certain intervals during whole day would be beneficial. Secondly, our study includes subjective anxiety evaluation; further studies are needed to demonstrate objective self evaluations such as heart rate, blood pressure and muscular tension to confirm our findings. Additionally, our study population covered only male participants. Therefore, extrapolation of these results to female athletes may lead to misinterpretations.

Another confounding factor may be the order effect. All participants were subjected to total sleep deprivation and then to partial sleep deprivation. There were two weeks between these two deprivation protocols. We think that an alternate model (first partial, then total) would give the same results as two weeks period is long enough for recovery.

Conclusion

In summary, many athletes can worry about the effects of inadequate sleep on athletic performance in sports activities. We investigated the effects of total and partial sleep deprivation induced anxiety without any competition stress on anaerobic parameters. We showed that only short-term total (30 hours) sleep deprivation but not partial sleep deprivation may enhance anxiety in healthy participants. Finally, we suggest that short-term total sleep deprivation may alter self reported anxiety levels to some extent which seems to be ineffective on anaerobic performance.

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Key points

- Short time total sleep deprivation (30 hours) increases state anxiety without any competition stress.
- Anaerobic performance parameters such as peak power, mean power and minimum power may not show a distinctive difference from anaerobic performance in a normal sleep day despite the high anxiety level induced by short time sleep deprivation.
- Partial sleep deprivation does not affect anxiety level and anaerobic performance of the next day.

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