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Original Research Article

High cortisol levels as a risk factor for athletes poor sleep quality in training centers

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ABSTRACT

Background: Intense training in athletes may able to disrupt the HPA axis which leads to increased cortisol levels and low- level quality to sleep. This study investigates whether elevated cortisol levels are a risk factor for low-level sleep quality in athletes.
Methods: This case-control study was conducted from June to November 2017 at a training centre in Denpasar. Subjects included athletes are from athletics, badminton, and bicycle racing who are preparing for a national tournament. Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI), and serum cortisol levels were assessed. Bivariate and multivariate analyses were performed to determine the relationship between cortisol levels and sleep quality.
Results: The study included 64 athletes. Cortisol levels were significantly higher in athletes with low-level sleep quality (270.86±93.43 nmol/l) compared to those with good sleep quality (195.84±61 nmol/l). High cortisol levels were strongly associated with low-level sleep quality (OR 7.67; 95% CI 2.52-23.28; p<0.001). Multivariate analysis confirmed high cortisol levels as an independent risk factor for low-level sleep quality (OR 8.19; 95% CI 2.59–25.89; p<0.001). Elevated cortisol levels are a significant independent risk factor for low-level sleep quality in athletes undergoing intense training.
Conclusions: Elevated cortisol independently predicted poor sleep-in athletes undergoing intense physical training.

Keywords: Cortisol, Low-level sleep quality, Athletes, HPA axis

INTRODUCTION

Nowadays, athletes are facing significant challenges in maintaining a balance between intensive training and adequate recovery to enhance their performance. Intensive physical exercise is able to increase both physical and mental stress, potentially triggering elevated cortisol levels in athletes.[1–3] Cortisol, as a major stress hormone, plays a crucial role in regulating the body's response to stress and has significant impacts on athletes' health and performance.[4–7]

The increase in cortisol levels due to intensive training has been associated with various negative effects, including sleep disturbances such as insomnia. Sleep disorders are common issues experienced by athletes, which is able to disrupt their physical and psychological recovery and affect their performance during competitions.

Previous research has shown that a better understanding of the relationship between cortisol levels and athletes' sleep quality is essential for developing effective stress management strategies. Therefore, this study aims to

investigate whether high cortisol levels are an independent risk factor for low-level sleep quality in athletes during intensive training periods.

With a focus on the impact of cortisol on athletes' sleep quality, this study is expected to provide insights into the relationship between high cortisol levels and low-level sleep quality during intensive training programs, aiming to develop effective stress management strategies to support optimal athlete performance.[1,2,8,9]

METHODS

This study is an analytical observational study using a case-control study design to determine high cortisol levels as a risk factor for athletes' low-level sleep quality in the training centre. The research was conducted at the athlete training centre in Denpasar from June to November 2017. This study was approved by the Ethical Committee of the Faculty of Medicine Udayana University/Sanglah Hospital. All eligible subjects received an adequate explanation about this study and signed informed consent.

Population and sample

Subjects were recruited from three different sports branches, namely athletics, badminton, and bicycle racing, all of whom underwent intensive training programs in preparation for the 2017 national sports competition (PORPROV). Subjects with a prior history of sleep disturbance, major depression, and moderate-to-severe generalized anxiety, or those on medication that directly affected serum cortisol levels (including but not limited to antidepressants, antipsychotics, and anxiolytics) within the last 30 days were excluded from this study. Eligible subjects were divided into case and control groups according to their sleep quality status. After a statistical sampling calculation, a minimum of 32 subjects for each group was recruited, totalling 64 subjects. All subjects were recruited by random sampling method and were specifically examined for their sleep patterns and quality using the Pittsburgh Sleep Quality Index (PSQI) questionnaire. All subjects had their blood checked and measured for serum cortisol levels at Sanglah Hospital Pathology Laboratory.

Inclusion criteria

Athletes aged between 18-35 years. Athletes who have undergone intensive training programs for a minimum of 4 weeks. Athletes willing to participate in the study and provide blood samples.

Exclusion criteria

Athletes undergoing treatment that affects cortisol levels. Athletes with a history of chronic sleep disorders prior to training. Athletes with medical conditions affecting sleep quality and cortisol levels.

Research instruments

Cortisol measurement

Blood samples are collected in the morning (between 7-9 AM) to measure serum cortisol levels using immunoassay methods at the RSUP Prof dr. I.G.N.G. Ngoerah laboratory.

Sleep quality measurement

Sleep quality is assessed using the Pittsburgh Sleep Quality Index (PSQI), which consists of several components assessing sleep quality.[10]

Research procedure

Preparation and socialization

Researchers conducted orientation sessions with athletes and coaches regarding the study's objectives and procedures.

Data collection

Athletes willing to participate completed the PSQI questionnaire and provide blood samples.

Data analysis

Collected data were analysed using statistical tests to determine the relationship between cortisol levels and sleep quality. Simple linear regression analysis was used to identify whether cortisol levels are an independent risk factor for low-level sleep quality.

Statistical analysis

Descriptive statistics

To describe the demographic characteristics of study subjects and the distribution of cortisol levels and sleep quality.

Inferential statistics

Chi-square tests was used to examine the relationship between cortisol levels and PSQI scores. Logistic regression analysis was be used to determine the influence of cortisol levels on sleep quality.

RESULTS

Subjects basic characteristics

As many as 64 subjects were included in this study. All of them were athletes who attended training camps as part of a preparation program for the 2017 PORPROV event. They were from athletics, badminton and bicycle racing

sport branches that met the inclusion and exclusion criteria. Subjects basic characteristics are shown as follow.

Table 1: Subjects basic characteristics.

Variables	N	Percentage
Sports		
Athletics	30	46.9
Bicycle racing	20	31.2
Badminton	14	21.9
Gender		
Male	37	57.8
Female	27	42.2
Age (years) Median (min-max)	16.50 (13-31)	

Note. N: Number of respondents; %: Percentage

According to Table 1, the recruited subjects were athletes of Denpasar city in athletics, bicycle racing and badminton with a median age of 16.5 years with a minimum age of 13 years and a maximum of 31 years. Male and female constituted 57.8% and 42.2% of the subjects, respectively.

Table 2: Subjects basic characteristics according to case and control groups.

Variables	Case (%) (n=32)	Control (%) (n=32)
Sports		
Athletics	18 (56.2)	12 (37.5)
Bicycle racing	9 (28.1)	11 (34.4)
Badminton	5 (15.6)	97 (28.1)
Gender		
Male	17 (53.1)	20 (62.5)
Female	15 (46.9)	12 (37.5)
Age (years) median (min-max)	17.00 (13-31)	16.00 (14-21)
Total	32 (100)	32 (100)

Note. %: Percentage; N: Number of respondents

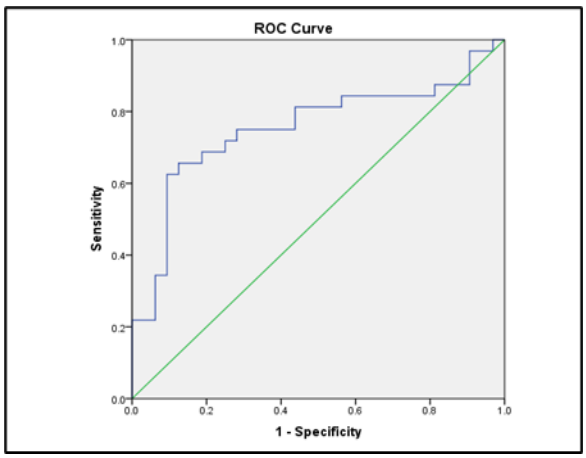

Figure 1: The results of the ROC procedure cortisol levels on sleep quality with an AUC value of 75.4%.

Subsequently, they were divided into case and control groups. The case group consisted of athletes with low-level sleep quality with a PSQI value of >5 while the control group comprised subjects with a good sleep quality with a PSQI value of ≤5. Their basic characteristics are displayed in Table 2.

Athletes from athletics dominated both case and control groups by more than half (56.2%) and approximately a third (37.5%) from the total subjects, respectively. Male subjects also dominated both groups by 53.1 and 62.5% in the case and control groups. The median age of the case group was 17 years, while the control group was 16 years old.

Subjects' plasma cortisol levels and its ROC

In this study, plasma cortisol levels of all subjects were in the range between 97.8 nmol/l to 448.3 nmol/l (normal values 166-507 nmol/l). Receiver Operating Characteristic (ROC) analysis and Area Under the Curve (AUC) were performed to determine the ability of cortisol levels for predicting low-level sleep quality. The ROC curve (Figure 1) showed that cortisol levels were diagnostic, given the position of the curve, i.e., within the 50% and 100% range. Furthermore, the AUC value obtained from the ROC method was 75.4% (95% CI; 62.8% - 88.0%, p<0.001). Statistically, the AUC value of 75.4% indicated sufficient diagnostic power. The results of the ROC coordinates indicated that the cutoff value of cortisol levels ≥ 208.05 nmol/l used in this study had a sensitivity and specificity of 75% and 71.9%, respectively.

Cortisol levels were classified into two groups, i.e., those with high (≥208.05 nmol/l) and low (<208.05 nmol/l) plasma cortisol levels.

The relation between athletes' high cortisol levels and low-level sleep quality

The relation between high cortisol levels and sleep quality was assessed using bivariate analysis. The hypothesis was tested using chi-square statistics. The odds ratio (OR) was obtained with a confidence interval (CI) of 95%. The results of this analysis are presented in Table 3.

Table 3: Bivariate analysis of cortisol levels and sleep quality.

		Case N (%)	Control N (%)	OR (95% CI)	P value
Cortisol levels	High	24 (72.7)	9 (27.3)	7,67 (2.52-23.28)	<0.001
	Low	8 (25.8)	23 (74.2)		

Note. %: Percentage; N: Number of respondents; OR: Odds ratio; CI: Confidence interval; P: P-value

According to Table 3, it is shown that the total athletes with high cortisol levels were 33 subjects with 24 subjects

(75%) in the case group and 9 subjects (28.1%) in the control group. High cortisol levels significantly increased the odds of low-level sleep quality (OR 7.67; 95% CI 2.52-23.28; p<0.001).

The relation of other factors with low-level sleep quality

Other factors such as age, gender and sport types also play a role in causing athletes' low-level sleep quality. The relation between other factors as a cause of low-level sleep quality was measured by using the chi-square test. The results of the analysis are presented in Table 4.

According to Table 4, there was no statistically significant difference between gender and low-level sleep quality (OR 0.68; 95% CI 0.25-1.84; p=0.45). In the age variable, there were 15 subjects (46.9%) who were less than 16.5 years old in the case group and 17 subjects (53.1%) in the control group. The relation between age and sleep quality was measured using chi-square and there was no significant relation between age and low-level sleep quality as well (OR 0.78; 95% CI 0.29-2.08; p=0.62).

Table 4: Bivariate analysis of other factors in relation to sleep quality.

		Case (%) (n=32)	Control (%) (n=32)	OR (CI 95%)	P value
Sex	Male	17 (53.1)	20 (62.5)	0.68 (0.25-1.84)	0.448
	Female	15 (46.9)	12 (37.5)		
Age	<16.5 years	15 (46.9)	17 (53.1)	0.78 (0.29-2.08)	0.617
	≥16.5 years	17 (53.1)	15 (46.9)		
Sport branches	Athletics	18 (56.2)	12 (37.5)	2.143 (0.79-5.83)	0.133
	Non-athletics	14 (43.8)	20 (62.5)		

Note. %: Percentage; n: Number of respondents; OR: Odds ratio; CI: Confidence interval; P: P-value

Table 5: Multivariate analysis cortisol levels and types of sports with low-level sleep quality.

	Coefficient	OR (CI 95%)	P value
High cortisol levels	2.103	8.19 (2.59 to 25.89)	<0.001
Branch of sports	0.905	2.43 (0.78-7.83)	0.124
Constants	-1.494		

In the sport branches variable, it was divided into athletic and non-athletic (cycling and badminton). There were 18 subjects (56.2%) from athletic sports and 14 subjects (43.8%) from non-athletic sports (bicycle racing and badminton). The relation between sports and low-level sleep quality was measured using the chi-square test and obtained OR 2.14 (CI 95% 0.79-5.8; p<0.133), which means there was no statistically significant relation between different types of sport branches and low-level sleep quality.

The relation between independent risk factors and low-level sleep quality

According to bivariate analysis, high serum cortisol levels and types of sports were associated with low-level sleep quality. Furthermore, a multivariate analysis was conducted to see whether high serum cortisol levels and different types of sports were independent risk factors for low-level sleep quality. The result of logistic regression analysis is shown in Table 5.

The multivariate analysis demonstrated that high cortisol levels were a significant factor for low-level sleep quality among athletes (OR 8.19; 95% CI 2.59 – 25.89; p<0.001). Thus, high cortisol levels were a statistically significant independent risk factor for low-level sleep quality.

DISCUSSION

Characteristics of study subjects

The subjects in this study were athletes from Denpasar City who participated in a training camp in preparation for the 2017 Provincial Sports Week (PORPROV) and met the inclusion and exclusion criteria, agreeing to be research samples. The subjects were divided into two groups: the case group consisting of athletes with low-level sleep quality and the control group consisting of athletes with good sleep quality. Each group consisted of 32 subjects, totalling 64 participants.

Basic characteristics of the study subjects

The sports variables in this study included athletics, cycling, and badminton. There were varying percentages of low-level sleep quality across these sports. Athletes with low-level sleep quality comprised 56.2% from athletics, 28.1% from cycling, and 15.6% from badminton.

These sports were part of the 2017 PORPROV Bali and have similar training loads and energy requirements.

In terms of gender, male athletes (53.1%) experienced low-level sleep quality more frequently than female athletes (46.9%). This aligns with Jonathan, who found that sleep efficacy was low-leveler in male athletes compared to females. The ratio of males to females with low-level sleep quality was 1.13:1, consistent with Gabriele, who found a similar ratio (1.02:1) among adolescent athletes.[11,12]

For age variables, the median age was 16.5 years, with older athletes (≥16.5 years) experiencing low-level sleep quality more frequently (53.1%) than younger athletes (<16.5 years) at 46.9%. The age ratio for low-level sleep quality was 1.13:1, similar to Gabriele, who reported a ratio of 1.26:1 for athletes aged 15-19 compared to those aged 10-14.[12]

High cortisol levels and low-level sleep quality

The cortisol levels in this study ranged from 97.8 nmol/l to 448.3 nmol/l, within the normal range (166-507 nmol/l). using the receiver operating characteristic (ROC) analysis and area under the curve (AUC) method, cortisol levels were categorized as high or not high. The ROC analysis showed an AUC value of 75.4% (95% CI; 62.8%-88.0%, p< 0.001). The cutoff point for cortisol was ≥208.05 nmol/L, with a sensitivity of 75% and specificity of 71.9%.

In the study, 24 subjects (75%) in the case group and 9 subjects (28.1%) in the control group had high cortisol levels. The mean cortisol level was higher in the case group (270.859±93.434 nmol/l) compared to the control group (195.838±60.999 nmol/l). Chi-square analysis revealed an OR = 7.667 (95% CI = 2.524-23.284, p< 0.001), indicating that high cortisol levels significantly increase the risk of low-level sleep quality by 7.667 times. This finding is consistent with Sylvie et al, who found a significant relationship between higher cortisol levels and sleep problems (p<0.001), and Jin Ling et al, who reported a positive correlation between cortisol levels and sleep disturbances (r = 0.60, p<0.001).

High cortisol levels impact the central nervous system, altering electrical waves in the limbic system and hippocampus, affecting sleep cycles, increasing waking frequency, and reducing slow-wave sleep, leading to fragmented sleep and insomnia.[13–15]

Other factors influencing low-level sleep quality

Other factors influencing low-level sleep quality in athletes include sports type, gender, and age. For gender, 17 males (53.1%) were in the case group, and 20 males (62.5%) were in the control group, while 15 females (46.9%) were in the case group and 12 females (37.5%) were in the control group. Chi-square analysis showed an OR = 0.680 (95% CI = 0.251-1.843, p=0.448), indicating no significant relationship between gender and low-level sleep quality. This is consistent with Gabriele who found no significant gender differences in sleep quality among adolescent athletes (p=0.999). However, charest and grandner, reported significant differences in sleep quality between males and females, possibly due to including post-menopausal women, unlike this study, which focused on athletes aged 13-31.[1]

For age, 15 subjects (46.9%) under 16.5 years were in the case group, and 17 subjects (53.1%) were in the control group. Chi-square analysis showed an OR = 0.779 (95% CI = 0.292-2.078, p=0.617), indicating no significant relationship between age and low-level sleep quality. This contrasts with Gabriele, who found significant differences in sleep quality between younger and older athletes (p<0.001). The discrepancy may be due to the different activity levels of the age groups studied.[12]

For sports type, after categorizing into athletics and non-athletics (cycling and badminton), 18 subjects (56.2%) from athletics experienced low-level sleep quality compared to 14 subjects (43.8%) from non-athletics. Chi-square analysis showed an OR = 2.143 (95% CI = 0.788 – 5.825, p=0.133), indicating no significant relationship between sports type and low-level sleep quality. This differs from Belval, who found significant differences in sleep disturbances across sports. The difference may be due to this study focusing only on individual sports (athletics, cycling, and badminton), unlike the previous study, which included both individual and team sports.[4]

Independent risk factors for low-level sleep quality

Multivariate logistic regression analysis identified high cortisol levels as an independent risk factor for low-level sleep quality (OR = 8.188; 95% CI = 2.589-25.894; p<0.001). This aligns with Pulopulos, who found a significant relationship between low-level sleep efficiency and high cortisol levels, and Charest and Grandner, who reported a significant association between low-level sleep quality and high cortisol levels. Charest and Grandner also found a positive correlation between cortisol levels and sleep disturbances (r = 0.60, p<0.001). High cortisol levels affect the central nervous system, altering electrical waves in the limbic system and hippocampus, disrupting sleep cycles, and leading to fragmented sleep and insomnia. High cortisol levels can also cause cortisol awakening response (CAR), leading to fragmented sleep.[1,8,16]

Strengths and limitations

This study's strength lies in the relatively few studies investigating cortisol levels as a risk factor for low-level sleep quality in athletes, especially in Indonesia. The study subjects were homogeneous, excluding those with severe anxiety and depression, ensuring more accurate results. Additionally, subjects were well-informed about the questionnaire procedures, enhancing the accuracy and

reliability of the data collected using validated and reliable instruments.

However, this study has limitations, such as not determining the duration of elevated cortisol levels that cause low-level sleep quality and not identifying the minimum cortisol increase that leads to low-level sleep. The study sample was limited to a specific population and location, so the results may not be generalizable to other populations and settings.

CONCLUSION

High serum cortisol levels were a significant independent risk factor for poor sleep quality among athletes who underwent intense physical training.

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