Archivos de Medicina
Artículo de Investigación

# Prediction of sleep quality in military submariners

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Recibido para publicación: 27-02-2024. Versión corregida: 30-07-2024. Aprobado para publicación: 12-08-2024.

**Modelo de citación:**
Koppke Miranda M.E., Brito Portugal G., Ferreira Viana B., dos Santos Bunn P., de Souza Vale R.G. **PREDICTION OF SLEEP QUALITY IN MILITARY SUBMARINERS**. Arch Med (Manizales). 2024;24(2). https://doi.org/10.30554/archmed.24.2.5077.2024

## Abstract

**Introduction:** *Insufficient sleep-in submariners can negatively impact the operational performance and health of this population.* **Objective:** *To develop an equation model to predict sleep quality in military submariners based on body composition, neuromuscular and cardiorespiratory variables, stress level, and sleepiness.* **Methods:** *A cross-sectional and correlational study was conducted with a sample of 37 submariners (men: 28.11±3.45 years). Data from the Pittsburgh Sleep Quality Index (PSQI) was used as a dependent variable, and as independent variables given body composition, height, BMI, waist circumference, body fat, dominant handgrip, cardiorespiratory fitness, squats, sit-ups, relative power of the lower limbs (PotRel LL), stress (PSS-10), and Epworth Sleepiness Assessment (ESE). The multiple linear regression test, adopting the forward stepwise method, was used to select predictor variables from the equation model to estimate sleep quality.* **Results:** *The sleep quality prediction model developed was as follows: PSQI=-3.476+0.176(PSS-10)+0.165 (PotRel LL) with R2adjust: 0.36 and EPE: 1.93.* **Conclusion:** *The construction of a specific proposed model related to submariners' health demonstrated that the level of sleep quality can be estimated with a low estimation error based on the stress level (PSS-10) and lower limb power (PotRel LL).*

**Keywords: S***leep, submariner, sleep quality, inadequate sleep, military personnel.*

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# Predicción de la calidad del sueño en submarinos militares

## Resumen

**Introducción:** *El sueño insuficiente en submarinistas puede afectar negativamente al rendimiento operativo y a la salud de esta población.* **Objetivo:** *Desarrollar un modelo de ecuación para predecir la calidad del sueño en submarinistas militares basado en la composición corporal, variables neuromusculares y cardiorrespiratorias, nivel de estrés y somnolencia.* **Métodos:** *Se realizó un estudio transversal y correlacional con una muestra de 37 submarinistas (hombres: 28,11±3,45 años). Como variable dependiente se utilizaron los datos del Índice de Calidad del Sueño de Pittsburgh (PSQI), y como variables independientes la composición corporal, la altura, el IMC, el perímetro de la cintura, la grasa corporal, la empuñadura dominante, la aptitud cardiorrespiratoria, las sentadillas, los abdominales, la potencia relativa de los miembros inferiores (PotRel LL), el estrés (PSS-10) y la Evaluación de la Somnolencia de Epworth (ESE). Se utilizó la prueba de regresión lineal múltiple, adoptando el método forward stepwise, para seleccionar las variables predictoras del modelo de ecuaciones para estimar la calidad del sueño. Resultados: El modelo de predicción de la calidad del sueño desarrollado fue el siguiente: PSQI=-3,476+0,176(PSS-10)+0,165(PotRel LL) con R2ajustado: 0,36 y EPE: 1,93.* **Conclusiones:** *La construcción de un modelo específico propuesto relacionado con la salud de los submarinistas demostró que el nivel de calidad del sueño puede estimarse con un bajo error de estimación a partir del nivel de estrés (PSS-10) y la potencia de las extremidades inferiores (PotRel LL).*

**Palabras clave:** *Sueño, submarinista, calidad del sueño, sueño inadecuado, personal militar.*

# Prevendo a qualidade do sono em submarinos militares

## Resumo

**Introdução:** *insuficiência de sono em submarinistas pode gerar um impacto negativo no desempenho operacional e na saúde dessa população.* **Objetivo:** *desenvolver um modelo de equação para predição da qualidade do sono em militares submarinistas baseado em variáveis de composição corporal, neuromusculares, cardiorrespiratória, nível de estresse e sonolência.* **Método:** *um estudo transversal e correlacional, com amostra de 37 submarinistas (homens: 28,11±3,45 anos). Foram analisados dados da avaliação da qualidade do sono de Pittsburgh (PSQI) como variável dependente, e como variáveis independentes dados de massa composição corporal, estatura, IMC, cintura, gordura corporal, preensão manual dominante, aptidão cardiorrespiratória, agachamentos, abdominais, potência relativa de membros inferiores (PotRel MMII), estresse (PSS-10)*, *avaliação da sonolência de Epworth. O teste de regressão linear múltipla, adotando o método forward stepwise, foi utilizado para selecionar variáveis preditoras do modelo de equação para estimar o nível de qualidade do sono.* **Re-**

**sultados:** *o modelo de predição da qualidade do sono desenvolvido foi a equação PSQI=-3,476+0,176(PSS-10)+0,165(PotRel MMII) com* $R^2$*ajust: 0,36 e EPE: 1,93.* **Conclusão:** *a construção do modelo proposto específico relacionado a saúde dos submarinistas demonstrou que o nível de qualidade do sono pode ser estimado com um baixo erro de estimativa, baseado no nível de estresse (PSS-10) e na potência de membros inferiores (PotRel MMII).*

**Palavras-chave:** *Sono; submarinista, qualidade do sono; sono inadequado; militares.*

# Introduction

Military operations may result in insufficient and poor sleep quality, depending on the characteristics of the task to be performed [1]. Furthermore, these operations can be stressful, unexpected, urgent, and harsh environments [1]. The promotion of healthy sleep is important for the physical and mental health of military personnel. Poor sleep quality can negatively impact operational readiness, safety, and effectiveness by reducing cognitive performance [2]. Furthermore, evidence suggests that poor sleep quality has been associated with the development of mental health disorders such as depression, anxiety, post-traumatic stress disorder, and, consequently, a worsening of individuals' quality of life [3.4].

In this context, submarines can pose greater health risks. Submariners have a work environment considered as a typical isolated, confined, and extreme environment (ICE) [5], with deprivation of natural daylight and a 24-hour day-night circadian rhythm [6.7], associated with occupational confinement factors that can affect their health, such as shift work, noise, high levels of stress, and sedentary lifestyle [8–10].

The last two aspects have been frequently cited in the literature as variables related to sleep quality. Stressors on a submarine can include working and living in extremely small spaces, confinement, isolation from all interactions with the outside world, monotony in routine, prolonged separation from family members, and potentially dangerous operational responsibilities [11,12]. However, physical activity can minimize stress and improve sleep quality, as physical conditioning can positively affect these psychophysiological variables [13–15]. Furthermore, it is recommended by the American Sleep Disorders Association (ASDA) as a form of non-pharmacological intervention to improve sleep quality [16]. In this context, Ferreira *et al.* [17] and Gilmour *et al.* [18], evaluating military personnel in general, pointed out differences in sleep when evaluating individuals with different body compositions, just as Gasier *et al.* [19], specifically evaluating submariners, observed individuals with a higher percentage of body fat slept, on average, less than those with a lower percentage of body fat.

Insufficient sleep in this population can negatively impact operational performance and health. Activities that require concentration, emotional control, quick thinking, spatial orientation, and the ability to work under pressure can be compromised when you do not get adequate rest [17]. Therefore, the objective of the present study was to develop an equation model to predict sleep quality in military submariners based on body composition, neuromuscular, cardiorespiratory, stress level, and sleepiness variables.

# Methods

## Study design and sample

Cross-sectional and correlational research with the development of a model to predict sleep quality in submariners. The study was conducted in 2023, with a sample of 37 submariners (male) from the Brazilian Navy. The study participants represented approximately 40% of Brazilian submariners. The Research Ethics Committee of the Hospital Naval Marcílio Dias approved the study (CAAE number: 60399822.7.0000.5256), following the guidelines of the National Health Council.

## Sleep quality assessment

The Pittsburgh Sleep Quality Index - PSQI questionnaire was used [20], translated, and validated into Portuguese [21] to assess sleep quality. This instrument is self-administered, with scores from seven added components (subjective sleep quality, sleep latency, duration, efficiency, sleep-related disorders, use of sleep medications, and daytime dysfunction in the sleep-wake cycle), which can vary from 0 to 21. Scores from zero to five indicate good sleep quality, scores equal to or greater than 6 indicate poor quality, and scores > 10 indicate sleep disturbance.

## Stress level assessment

The Portuguese version of the Perceived Stress Scale (PSS-10) was used [22,23], to measure the degree to which individuals perceive stressful situations. The assessment consisted of 14 questions, with answer options ranging from zero to four (0=never; 1=almost never; 2=sometimes; 3=almost always; 4=always). The total scale was the sum of the scores for these 14 questions.

## Sleepness *assessment*

The sleepness was assessed using the Epworth Sleepiness Scale (ESE) [24]. A questionnaire consisting of eight items representing everyday situations, graded from zero to three points according to the intensity of sleepness, was used to analyze the chance of dozing off in each situation presented. The results were obtained by adding eight items, considering normal sleepness up to 10 points, average sleepness of 11 to 15 points, and abnormal daytime sleepness a score greater than or equal to 16 points.

## Body composition assessment

Height and total body mass (MCT) were measured on a digital scale with a stadiometer (Prix, Brazil). Waist circumference was measured with a metallic measuring tape (Cescorf, Brazil) and skin folds of the chest, abdomen, and thigh were measured with a Premier Scientific Adipometer (Cescorf, Brazil). From these measurements, the body fat percentage (%BF) and Body Mass Index (BMI) were estimated [25.26].

## Assessmentneuromuscular and cardiorespiratory fitness

To evaluate the relative power of the lower limbs (PotRel LL), the average of five countermovement jumps was used, with an interval of 15 s between them, using the contact mat and Elite Jump System software (Cefise, Brazil) [27]. To obtain maximum oxygen consumption (VO-2max) and measure cardiorespiratory fitness, the Cooper 2400m running test was applied on a 400m athletics track. [28]. To assess upper limb muscle strength, the maximum measurement of the dominant hand in the handgrip test was used (Hg Dom), using a Jamar dynamometer (Sammons Preston, USA) [29]. Abdominal and squat tests were also performed, with maximum results observed within 2 min [29].

## Statistical analysis

Sample characterization included measures of central tendency and dispersion (mean and standard deviation). Data normality was checked using the Shapiro-Wilk test. To develop the equation model to estimate sleep quality, the multiple linear regression test adopted the forward stepwise method to select predictor variables for the model. The reliability of the model was measured using the adjusted coefficient of determination (R2adjust) and the standard error of estimate (EPE). A paired t-test was used to compare the sleep quality observed by the questionnaire and the predicted sleep quality, and the Pearson correlation coefficient was applied to analyze this relationship. Statistical analysis was performed using the statistical software IBM SPSS Statistics 25, with statistical significance set at $p < 0.05$.

Table 1 presents the sample characterization results for the variables analyzed in this study. Young individuals with a BMI classified as overweight but with %BF classified as good, waist circumference below the cutoff point for increased risk of developing cardiovascular diseases (>102 cm), and good general physical fitness. The average scores on the questionnaires used indicated levels of perceived stress, considered above average, average sleepness, and poor sleep quality.

Table 2 presents the model of the prediction equation for sleep quality, based on the selection criteria. The conditions with the highest R, R2, R2adjust, and lowest EPE values were adopted as the model choice conditions. Thus, in the model equation PSQI=-3.476+0.176(PSS-10)+0.165(PotRel LL) met the proposed requirements, with stress level as a predictor variable and the relative power of the lower limbs.

Subsequently, the estimated sleep quality was calculated. There was a positive correlation between observed and estimated sleep quality ($p < 0.001$), and the values did not differ between the groups ($p>0.05$) (Table 3).

**Table 1. Sample characterization (n=37)**

| | Average | DP |
|---|---|---|
| Age (years) | 28.11 | 3.45 |
| **Body composition variables** | | |
| MCT (kg) | 83.33 | 15.28 |
| Height (cm) | 175.97 | 6.83 |
| BMI (kg/m²) | 26.89 | 4.53 |
| %BF | 15.10 | 6.76 |
| Waist (cm) | 86.41 | 13.38 |
| **Neuromuscular variables** | | |
| Hg Dom. (kg/f) | 54.19 | 9.25 |
| VO2max (ml/kg/min) | 44.20 | 6.66 |
| Squat (max/2min) | 64.81 | 10.49 |
| Sit ups (max/2min) | 47.08 | 12.84 |
| PotRel LL (W/kg) | 42.58 | 4.00 |
| **Stress level** | | |
| PSS-10 (total of points) | 15.89 | 7.86 |
| **Sleepness** | | |
| ESSE (total of points) | 9.06 | 4.16 |
| **Sleep quality** | | |
| PSQI (total of points) | 6.28 | 2.49 |

n=number of participants; SD= standard deviation; MCT=Total Body Mass; BMI= Body Mass Index; %BF= percentage of body fat; Hg Dom= dominant hand grip; VO2max=maximum oxygen consumption; PotRel LL= relative power of lower limbs; PSS-10=Perceived Stress Scale; ESE= Epworth Sleepiness Scale; PSQI= Pittsburgh Sleep Quality Index. Source: Prepared by the authors.

The linear regression between observed and estimated sleep quality is illustrated in Figure 1.

**Table 2.Sleep quality prediction equation models for selection criteria**

| | Equation | R | R2 | R2Adjust | EPE |
|---|---|---|---|---|---|
| 1 | PSQI=3.43+0.178(PPS-10) | 0.56 | 0.31 | 0.30 | 2.02 |
| two | PSQI=-3.476+0.176(PSS-10)+0.165(PotRel LL) | 0.62 | 0.39 | 0.36 | 1.93 |

PSQI= Pittsburgh Sleep Quality Index; PSS-10=Perceived Stress Scale; PotRel LL= relative power of lower limbs. Source: Prepared by the authors.

**Table 3. Analysis of the comparison and correlation between observed sleep quality and estimated sleep quality**

| PSQIobserved | | PSQIestimated | | Δ | p-value (t-test) | r | p-value |
|---|---|---|---|---|---|---|---|
| Average | DP | Average | DP | | | | |
| 6.20 | 2.42 | 6.21 | 1.52 | 0.01 | 0.950 | 0.62 | <0.001 |

PSQI= Pittsburgh Sleep Quality Index; SD= standard deviation; Δ= difference in means; r= correlation by Pearson. Source: authors.

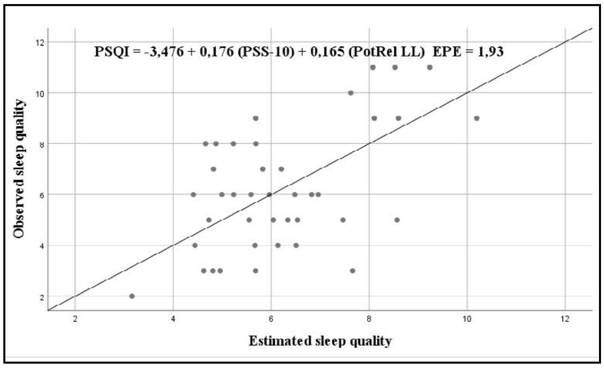


**Figure 1:** Linear regression between observed and estimated sleep quality for Brazilian submariners. Source: Prepared by the authors.

## Discussion

the objective of the present study was to develop an equation model to predict the sleep quality of military submariners based on body composition, neuromuscular variables, stress level, and sleepiness. The results showed that the level of stress and relative power of the lower limbs were predictors of sleep quality in submariners.

The average results obtained regarding the quality of sleep indicated poor sleep in the PSQI according to the assessment instrument used. [20]. Compared to the Dutch submariners in the study by Nieuwenhuys *et al.* [30], the present study obtained worse results, as they were classified as having good sleep quality (4.8 ± 1.29). Another widely used instrument for assessing this variable is wrist actigraphy. In this context, Margel *et al.* [31] evaluated the total sleep time of Israeli military personnel (4.75 hours), Van Puyvelde *et al.* [7] evaluated Dutch (6.62 hours), and Trousselard *et al.* [32] evaluated French people (6.77 hours), they obtained results below the recommended time for individuals over 18 years old [33], indicating poor sleep quality.

One of the variables included in the predictive model was stress level. The analysis of this psychophysiological condition for this population has been extensively studied, as submarines are complex and stressful workplaces where they work for long periods in continuous operations and are isolated from the external environment. [34.35]. The perceived stress considered above average in the present study using the PSS-10 questionnaire corroborates the findings of studies using other instruments. Brasher *et al.* [34], using the Work and Wellbeing Questionnaire (WWBQ) and the Scale of Positive and Negative Affect and Stressful Life Events (SLEs), found a stress rate in UK submariners (40%) higher than the stress rate of military personnel in general who served on other ships (28%). Furthermore, Rapley *et al.* [36] used the Outcome Questionnaire (OQ-45) in Americans, and Nan-nan *et al.* [12] used a questionnaire on work stressors of Chinese submarine crews (Work Stress Self-Assessment Scale) and found similar results on stress levels.

Regarding the power of the lower limbs, another variable included in the predictive model, studies that specifically evaluated submariners are scarce. However, for other populations, some studies have addressed the importance of muscle mass and strength in sleep quality [15,37,38]. Kovacevic *et al.* [39] developed a systematic review of randomized studies on the effect of resistance exercise on sleep. The authors concluded that studies on isolated chronic resistance exercise suggest improvements in subjective sleep quality. The review also indicated that improvements in sleep quality were observed with high-intensity exercise three times per week.

A practical application of these results is in terms of encouraging actions to improve the stress levels of these individuals, as well as encouraging regular physical exercise, with priority for lower-limb power training, to mitigate the sleep problems of submariners. However, the present study has some limitations that can be highlighted, such as the cross-sectional design, as this type of research design cannot establish a cause-effect relationship. Furthermore, the assessments were not carried out on missions in which the environment was restricted inside a submarine. On the other hand, a strong point is the use of validated questionnaires and scales, in addition to tests that assess physical capabilities, applied by trained interviewers and evaluators, minimizing biases and enabling reliable results.

## Conclusion

the construction of the specific proposed model related to submariners' health demonstrated that the level of sleep quality can be estimated with a low estimation error based on the stress level (PSS-10) and the power of the lower limbs (PotRel LL). Minimizing the effects of stress on the quality of life of this population, as well as improving physical conditioning, can be an efficient strategy to improve sleep quality within a restricted work environment, such as a submarine.

This study provided preliminary data for future research on the health and serviceability of submariners. Therefore, investigations are recommended to analyze the variables analyzed in clinical trials during missions with Brazilian military personnel effectively confined to months.

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