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Prediction of stress level in military submariners, based on physical conditioning and sleep quality variables

Predicción del nivel de estrés en submarinistas militares, en base a variables de acondicionamiento físico y calidad del sueño

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Abstract. The objective of the study was to predict the level of stress in military submariners based on physical fitness and sleep quality variables. Cross-sectional and correlational research, with a sample of 40 male submariners (28.70±3.98 years old). Body mass and composition data were analyzed (MCT), height, BMI, waist, body fat (%G), dominant handgrip (PMDom), cardiorespiratory fitness (VO2max), squats, sit-ups, relative power of lower limbs (PotRel MMII), stress (PSS-10), Epworth Sleepiness Assessment (ESE) and Pittsburgh Sleep Quality Index (PSQI). Overall, negative associations (p<0.05) were observed between VO2max and MCT, BMI, %BF, and waist; PotRel MMII and age and %BF; squat and %G; sit-up and MCT, BMI, %BF and waist; and finally, stress and $VO2_{max}$ and sit-up. Furthermore, positive associations (p<0.05) between BMI and MCT; %BF and MCT and BMI; waist and age, BMI, MCT, and %BF; squats and PMdom., $VO2_{max}$ and PotRel MMII; sit-ups and $VO2_{max}$, PotRel LL and squats; ending with PSQI and stress. Furthermore, among the stress level prediction equation models developed, the equation Stress=15.92+1.538(PSQI)-0.497(VO2max)+0.188(Squat) met the proposed requirements, which is based on sleep quality, cardiorespiratory fitness, and number of squats.
Keywords: Submariner; stress, physical fitness, sleep quality, military personal.

Resumen. El objetivo del estudio fue predecir el nivel de estrés en submarinistas militares en función de variables de condición física y calidad del sueño. Investigación transversal y correlacional, con una muestra de 40 submarinistas masculinos (28,70±3,98 años). Se analizaron datos de masa y composición corporal (MCT), altura, IMC, cintura, grasa corporal (%G), agarre manual dominante (AMDom), aptitud cardiorrespiratoria (VO2max), sentadillas, abdominales, potencia relativa de miembros inferiores (PotRel MMII), estrés (PSS-10), Evaluación de la somnolencia de Epworth (ESE) e Índice de calidad del sueño de Pittsburgh (PSQI). En general, se observaron asociaciones negativas (p<0,05) entre el VO2max y el MCT, el IMC, el %G y la cintura; PotRel MMII y edad y %G; sentadilla y %G; abdominales y MCT, IMC, %G y cintura; y finalmente, estrés y VO2max y abdominales. Además, se encontraron asociaciones positivas (p<0,05) entre IMC y MCT; %G y MCT e IMC; cintura y edad, IMC, MCT y %G; sentadillas y AMdom., VO2max y PotRel MMII; abdominales y VO2max, PotRel MMII y sentadillas; terminando con PSQI y estrés. Además, entre los modelos de ecuaciones de predicción del nivel de estrés desarrollados, la ecuación Estrés=15,92+1,538(PSQI)-0,497(VO2max)+0,188(Squat) cumplió con los requisitos propuestos, la cual se basa en la calidad del sueño, la aptitud cardiorrespiratoria y el número de sentadillas.
Palabras clave: Submarinista; estrés, condición física, calidad del sueño, personal militar.

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Introduction

Job characteristics of submariners are of an unusual, confined, and isolated nature (Martin-Krumm *et al.*, 2021; Van Puyvelde *et al.*, 2022). Possible changes in the health of soldiers exposed to this environment may come from a sedentary lifestyle, sleep deprivation, and even high levels of stress (Kang & Song, 2018; Miranda *et al.*, 2022). During a mission, the vessel can be submerged for weeks, with submariners operating in restricted environments that involve unusual stimuli, such as changes in circadian rhythm (Van Puyvelde *et al.*, 2022), monotonous environment (Martin-Krumm *et al.*, 2021), deprivation of natural light (Van Puyvelde *et al.*, 2022), shift work (Duplessis *et al.*, 2007), among others. In this sense, Trousselard *et al.* (2015) noted an increase in negative mood, a deterioration in positive mood, and less restorative sleep among its crew. Margel *et al.* (2003) monitored the sleep of a submarine crew and found a total sleep time below average and recommended levels during a patrol. Already, Pawar *et al.* (2007) reported high occupational stress in 7.7% of their submariners. At appropriate levels, stress can be a positive element, offering the individual better conditions to react and make decisions. However, it can cause serious damage to the integrity of individuals when a certain limit is exceeded.*(Silva et al.*., 2015). In this way, physical, cognitive, psychological, and social consequences can be observed, such as low immunity, headaches, difficulty learning and concentrating, problems with sleep quality, social isolation, and relationship difficulties. (Tricoli, 2010). These changes can be enhanced when associated with a decrease in the crew's physical fitness levels, or even a possible sedentary lifestyle.(Silva et al., 2015).

The recommendation for an active lifestyle is to perform physical activity 5 days a week at moderate intensity, or a combination of moderate to high intensity 3 to 5 days a week. (American College of Sports Medicine, 2021). However, work activities in restricted environments reduce the possibility of movement and thus can accentuate a sedentary lifestyle and its associated harmful effects, such as cardiovascular, psychological, or sleep-related problems. (Fernando et al., 2023; Martin-Krumm et al., 2021;

Vázquez et al., 2023). The consequences can be particularly harmful, and it is important to know how the individual is doing before the mission and provide recovery after it.

The study of physical valences, in general, is important for understanding physical fitness and its interactions with specific work activities, both those related to health (body composition, flexibility, muscular strength, muscular endurance and cardiorespiratory fitness), and related to performance (speed, power, agility, coordination and balance etc.) (Cunningham et al., 2018; Dudley et al., 2023).

Practicing regular physical exercise on board a submarine can be a strategy for maintaining physical fitness and reducing the level of stress produced by work activities in a restricted environment. In this way, the research into the psychophysiological variables of these individuals can promote an improvement in the working conditions of this population due to the identification of determining factors to avoid accidents, reduce stress, and improve health and quality of life. Therefore, the objective of this study was to predict the level of stress in military submariners based on physical conditioning and sleep quality variables.

Methods

This research is cross-sectional and correlational with the development of a model to predict the stress level of submariners. The study was approved by the Research Ethics Committee of Hospital Naval Marcílio Dias with CAAE number 60399822.7.0000.5256, by the guidelines of the National Health Council. Study participants signed an Informed Consent Form.

The study was carried out in 2023 with a convenience sample of 40 submariners (male) from the Brazilian Navy. This sample represents approximately forty percent of Brazilian submariners. Height and total body mass (TBM) measurements were recorded (digital scale with a stadiometer, Prix, Brazil), waist circumference (metallic measuring tape, Cescorf, Brazil), and skinfolds of the chest, abdomen, and thigh (Premier scientific adipometer, Cescorf, Brazil). From these measurements, the percentage of body fat (%BF) was estimated. (Jackson AS, 1978).

To measure cardiorespiratory fitness, the Cooper 2400m running test was applied on a 400m athletics track to obtain maximum oxygen consumption ($VO2_{max}$) (Cooper, 1977). To assess upper limb muscle strength, the maximum measurement of the dominant hand in the handgrip test was used (PMDom) using a dynamometer (Jamar, Sammons Preston, USA) (Marins, JCB; Giannichi, 2003). In evaluating the relative power of the lower limbs (PotRel LL), the average of five countermovement jumps was used, with an interval of 15 seconds between them (contact mat and Elite Jump System software, Cefise, Brazil) (Braz *et al.*, 2010). Sit-up tests and squats were also performed with maximum results in 2 minutes (Marins, JCB; Giannichi, 2003).

To assess the level of stress, the Perceived Stress Scale (PSS-10) validated for Portuguese was used. (Cohen, S., Kamarck, T., Mermelstein, 1983; Luft *et al.*, 2007). The drowsiness and sleep quality were assessed using the Epworth Sleepiness Scale (ESE) (Johns, 1991), translated and validated into Portuguese (Bertolazi AN., 2008) and the Pittsburgh Sleep Quality Index (PSQI) (Buysse *et al.*, 1989), respectively. For all questionnaires, the result of the sum of the items was considered.

The analysis of sample characterization data included measures of central tendency and dispersion (mean, standard deviation, minimum and maximum values). Data normality was checked using the Shapiro-Wilk test. The associations between the study variables were analyzed using the c-test Pearson correlation. To develop the equation model to estimate the level of stress, the multiple linear regression test was used, adopting the forward stepwise method to select predictor variables for the model. The reliability of the model was measured by the adjusted coefficient of determination (R2adjust) and the standard error of estimate (EPE). The paired t-test was used between the stress observed by the questionnaire and the predicted stress. Pearson's correlation coefficient was applied to analyze the relationship between observed and estimated stress levels. The analyses were carried out using the IBM SPSS Statistics 25 statistical software, adopting $p<0.05$ for statistical significance.

Results

Table 1 describes the sample characterization results for all variables analyzed in the study. On average, individuals with a good %BF and waist circumference below the cutoff point for increased risk of developing cardiovascular diseases (>102cm), even with a BMI classified as overweight. A good maximum oxygen volume for age group and gender. Furthermore, the average scores of the questionnaires indicated average drowsiness, poor sleep quality, and perceived stress levels considered above average.

Table 1.
Sample characterization (n=40)

	Minimum	Maximum	Average	DP
Age years)	21.67	39.98	28.70	3.98
TBM (kg)	62.40	125.00	83.54	15.10
Height (cm)	163.00	190.00	176.28	7.03
BMI (kg/m²)	26.86	26.86	26.86	26.86
%BF	5.37	32.07	15.48	7.25
Waist (cm)	63.20	125.00	86.78	12.96
PMDom (kg/f)	34.00	77.00	53.08	9.49
$VO2_{max}$ (ml/kg/min)	22.52	56.00	44.04	7.39
Squat (max/2min)	63.70	63.70	63.70	63.70
Sit-up (max/2min)	47.53	47.53	47.53	47.53
PotRel LL (W/kg)	34.00	53.40	42.15	4.08
Stress (PSS-10)	4.00	37.00	15.88	7.52
ESE	2.00	18.00	9.03	4.02
PSQI	2.00	11.00	6.20	2.42

n=number of participants; SD= standard deviation; TBM=Total Body Mass; BMI= Body Mass Index; %BF= percentage of body fat; PMDom= dominant hand grip; $VO2_{max}$=maximum oxygen consumption; PotRel LL= relative power of lower limbs; ESE= Epworth Sleepiness Scale; PSQI= Pittsburgh Sleep Quality Index. Source: authors

2024, Retos, 59, 187-192

Table 2.
Correlation between variables of physical conditioning, stress, and sleep quality of Brazilian submariners

		Age	TBM	BMI	%BF	Waist	PMDom	$VO2_{max}$	PotRel LL	Squat	Sit-up	Stress	ESE
TBM	r	0.24											
	p-value	0.13											
BMI	r	0.21	0.89*										
	p-value	0.19	<0.01										
%G	r	0.28	0.73*	0.74*									
	p-value	0.07	<0.01	<0.01									
Waist	r	0.31*	0.94*	0.91*	0.75*								
	p-value	0.04	<0.01	<0.01	<0.01								
PMDom	r	0.05	0.30	0.26	-0.09	0.23							
	p-value	0.74	0.06	0.10	0.54	0.15							
$VO2_{max}$	r	-0.14	-0.65*	-0.67*	-0.74*	-0.66*	-0.07						
	p-value	0.37	<0.01	<0.01	<0.01	<0.01	0.68						
PotRel LL	r	-0.32*	-0.08	-0.05	-0.36*	-0.12	0.28	0.28					
	p-value	0.04	0.60	0.74	0.02	0.45	0.08	0.08					
Squat	r	-0.28	-0.23	-0.21	-0.54*	-0.26	0.43*	0.43*	0.59*				
	p-value	0.07	0.15	0.18	<0.01	0.11	<0.01	<0.01	<0.01				
Sit-up	r	0.11	-0.46*	-0.47*	-0.59*	-0.49*	0.25	0.61*	0.33*	0.52*			
	p-value	0.51	<0.01	<0.01	<0.01	<0.01	0.11	<0.01	0.03	<0.01			
Stress	r	-0.14	0.138	0.20	0.20	0.17	0.09	-0.42*	0.02	0.11	-0.33*		
	p-value	0.37	0.395	0.21	0.20	0.28	0.59	<0.01	0.89	0.50	0.04		
ESE	r	-0.18	-0.075	-0.18	0.09	-0.04	-0.30	0.01	0.06	-0.01	-0.17	0.31	
	p-value	0.25	0.647	0.27	0.55	0.80	0.06	0.93	0.73	0.97	0.30	0.05	
PSQI	r	-0.08	0.001	0.02	0.04	0.02	-0.03	-0.11	0.29	0.09	-0.11	0.56*	0.24
	p-value	0.64	0.997	0.89	0.79	0.89	0.85	0.49	0.07	0.60	0.49	<0.01	0.13

*=p-value <0.05; TBM=Total Body Mass; BMI= Body Mass Index; %BF= percentage of body fat; PMDom = dominant hand grip; $VO2_{max}$= maximum oxygen consumption; PotRel LL= relative power of lower limbs; ESE= Epworth Sleepiness Scale; PSQI= Pittsburgh Sleep Quality Index. Source: authors.

The correlation analysis between the variables of interest is presented in Table 2. Negative associations ($p<0.05$) were observed between $VO2_{max}$ and TBM, BMI, %BF, and waist; PotRel LL and age and %BF; squat and %BF; sit-ups and TBM, BMI, %BF and waist; and finally, stress and $VO2_{max}$ and sit-ups. Furthermore, positive associations ($p<0.05$) between: BMI and TBM; %BF and TBM and BMI; waist and age, BMI, TBM and %BF; squats and PMdom., $VO2_{max}$ and PotRel LL; sit-ups and $VO2_{max}$, PotRel LL and squats; ending with PSQI and stress.

Table 3 presents the stress level prediction equation models developed for the variable selection criteria. For the model choice condition, the conditions of highest R, R2, R2adjust and lowest EPE were adopted. Thus, in model 3 the equation Stress=15.92+1.538(PSQI)-0.497($VO2_{max}$)+0.188(Squat) met the proposed requirements, having as predictor variables sleep quality, maximum oxygen volume, and the number of squats performed.

After choosing the model, the estimated stress level was calculated. There was a positive correlation between observed stress and estimated stress ($p<0.001$), and the values found did not differ from each other ($p>0.05$), as shown in Table 4. The linear regression between observed and estimated stress levels is illustrated in Figure 1.

Table 3.
Stress prediction equation models for selection criteria

	Equation	R	R2	R2Adjust	EPE
1	Stress=4.486+1.785(PSQI)	0.56	0.32	0.30	6.40
2	Stress =21.644+1.656(PSQI)-0.371($VO2_{max}$)	0.67	0.44	0.41	5.85
3	Stress =15.92+1.538(PSQI)-0.497($VO2_{max}$)+0.188(Squats)	0.71	0.50	0.46	5.61

PSQI= Pittsburgh Sleep Quality Index; $VO2_{max}$= maximum oxygen consumption; Source: authors

Table 4.
Analysis of the comparison and correlation between the observed stress level and the estimated stress

Observed stress		Estimated stress					
Average	DP	Average	DP	Δ	p-value (t-test)	R	p-value
15.55	7.65	15.54	5.43	0.01	0.995	0.71	<0.001

SD= standard deviation; Δ= difference in means; r= **Pearson** correlation**.** Source: authors.

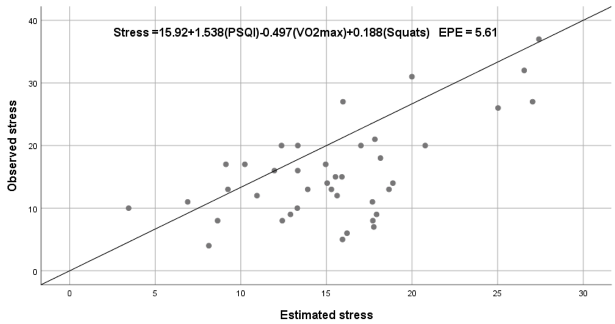

Figure 1. Linear regression between observed and estimated stress levels for Brazilian submariners. Source: author

Discussion

The study aimed to predict the level of stress in military submariners based on physical fitness and sleep quality variables. Stress in military personnel in general is reported in the literature (Bookwalter *et al.*, 2020; Goldbach *et al.*, 2023; Maglione *et al.*, 2022), as well as specifically in submariners (Brasher *et al.*, 2010, 2012; Eid & Johnsen, 2002). Concern for the health of this population is due, in part, to occupational factors, however, lifestyle behaviors play an important role (Sergi *et al.*, 2023).

Regarding the results of the correlation among the physical fitness, stress, and sleep quality variables, the body composition variables were the most associated with the other fitness variables, both positively and negatively. The systematic review analyzing the tactical population (firefighters, police, and military) by Sergi *et al*. (2023) corroborates this information: increased BMI associated with decreased $VO2_{max}$ (Houck *et al*., 2020), lower muscular resistance (Maglione *et al*., 2022), greater muscular strength and power, but negatively associated with speed and agility (Rtibale *et al*., 2010).

About the stress predictor variables found in the selected equation model, sleep quality, $VO2_{max}$, and number of squats were included. The relationship between sleep quality and stress is also reported in the review by Schlotz (2019). An important variable, as the author found that inadequate sleep before exposure to stress impaired the hypothalamic-pituitary-adrenal response to increased cortisol.

The results found regarding $VO2_{max}$ in the prediction are reinforced in the literature (Andrew Steptoe, Jennifer Moses, Andrew Mathews, 1990; Duarte AFA, Pitaluga Filho MV, Moraes JM, 2003), even using different methods to assess the level of stress (questionnaires, skin conductivity level, hemodynamic responses, and hormonal variables). In all variables analyzed, individuals with better performance in cardiopulmonary tests showed attenuated responses to the applied stressors, compared to those with lower levels of conditioning. Rodrigues et al. (2007) report in their study with military personnel that individuals with better cardiorespiratory conditions tend to present reduced patterns in the autonomic stress response. From the point of view of anaerobic exercises, endorsing the variable lower limb strength through the squat test, Martinsen *et al*. (1989) bring as a conclusion from their clinical trial that the effects of psychophysiological improvements associated with exercise are not restricted to aerobic forms of training.

Physical activity positively affects stress and sleep quality (Ropke *et al*., 2018; Silva *et al*., 2015; Zhai *et al*., 2021), and the study of the relationships between these variables is important. Schnohr *et al*.(2005) found that increasing physical activity levels or accepting another exercise-based intervention could decrease the level of perceived stress. Therefore, a practical application arising from the results inherent in the present study is the encouragement of practices to improve the quality of sleep and regular physical exercise, mainly prioritizing the training of cardiorespiratory fitness and lower limb strength, to mitigate levels of stress in submariners.

Some limitations of the present investigation can be cited, such as the study design that made it impossible to monitor the sample and the fact that the military personnel were not on a mission. On the other hand, a positive point was that the study covered a large part of the effective population of Brazilian submariners. As a strong point, we use validated tests and questionnaires, applied by trained evaluators and interviewers, minimizing bias and enabling reliable results.

Conclusion

The model for predicting the level of stress in military submariners was based on sleep quality, cardiorespiratory fitness, and quantity of squats. Improving physical fitness can reduce the level of stress within a restricted work environment such as a submarine, and at the same time, this indicates that it can be a strategy to minimize the effects of stress on the quality of life of this population. Future research is suggested that intends to continue the initial exploration, to support the reduction of stress and the improvement of the operational quality of the submariner population.

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