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State of body functions of submarines of the Socialist Republic of Vietnam before a short sea trip

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ABSTRACT

Based on the state of the functions of the central nervous system, circulatory system, and respiratory system, the psychophysiological status and reserve capabilities of the body of submariners of the Socialist Republic of Vietnam are assessed before a short sea trip. The study was conducted in 2023 as part of the research work "Ecolan M-2.2" that was participated by 117 submariners in the inter-trip period and 45 submariners 1–3 days before sea trip on the territory of the Socialist Republic of Vietnam. The state of the functions of the central nervous system, circulatory system, and respiratory system, reserve capabilities, and psychophysiological status of the body were examined. The daily and weekly routines of submariners during permanent deployment were analyzed. Submariners of the Socialist Republic of Vietnam in the inter-cruise period and before a short sea trip have a predominantly good state of body functioning in the examination of various systems and sufficient reserve capabilities. Despite the normal functional state of the examined submariners, 13 tended to have deteriorated body function and 5 had a borderline functional status. The small number of submariners with a borderline functional status may lead to erroneous activities during sea trips and cause emergencies. This, in turn, is fraught with disruption of the combat mission and even death. The results indicate the need to develop medical and physiological measures in the Navy of the Socialist Republic of Vietnam to maintain and restore the functional status of submariners during various periods of combat training activities. In the future, for a more qualitative development of medical and physiological measures, the medical support received by submariners of the Navy of the Socialist Republic of Vietnam, morbidity, and results of dispensary follow-up must be evaluated.

Keywords: submariner; Vietnam; functional status; circulatory system; military professional performance; submarine; military-professional adaptation; reserve capabilities of the body; psychophysiological status.

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Состояние функций организма подводников Социалистической Республики Вьетнам перед краткосрочным выходом в море

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АННОТАЦИЯ

На основании состояния функций центральной нервной системы, систем кровообращения и дыхания оценивается психофизиологический статус и резервные возможности организма подводников Социалистической Республики Вьетнам перед краткосрочным выходом в море. Исследование проведено в 2023 г. в рамках научно исследовательской работы «Эколан М-2.2» с участием 117 подводников в межпоходовом периоде и 45 подводников за 1–3 суток до выхода в море на территории Социалистической Республики Вьетнам. Исследовано состояние функций центральной нервной системы, систем кровообращения и дыхания, резервных возможностей и психофизиологического статуса организма. Проанализирован суточный и недельный распорядок дня подводников в пункте постоянной дислокации. Установлено, что подводники Социалистической Республики Вьетнам в межпоходовом периоде и перед краткосрочным выходом в море обладают преимущественно хорошим состоянием функций различных систем организма и достаточным уровнем его резервных возможностей. Однако, несмотря на нормальное функциональное состояние обследованных подводников, у 13 из них выявлена тенденция к его ухудшению, у 5 — пограничное функциональное состояние. Наличие даже такого небольшого количества подводников с признаками пограничного функционального состояния среди членов экипажа подводной лодки может привести к возникновению ошибочных действий во время выхода в море и развитию аварийной ситуации. Это, в свою очередь, чревато срывом выполнения боевой задачи и даже гибелью личного состава. Полученные результаты указывают на необходимость разработки в Военно-морских силах Социалистической Республики Вьетнам медико-физиологических мероприятий, направленных на поддержание и восстановление состояния функций организма подводников в различные периоды учебно-боевой деятельности. В дальнейшем, для более качественной разработки медико-физиологических мероприятий, необходимо провести анализ медицинского обеспечения подводников Военно-морских сил Социалистической Республики Вьетнам, оценить их заболеваемость и результаты диспансерного динамического наблюдения.

Ключевые слова: подводник; Вьетнам; функциональное состояние; система кровообращения; военно-профессиональная работоспособность; подводная лодка; военно-профессиональная адаптация; резервные возможности организма; психофизиологический статус.

Как цитировать

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越南社会主义共和国潜艇海员短期出海前的身体机能状况

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摘要

根据中枢神经系统、循环系统和呼吸系统的功能状况，对越南社会主义共和国潜艇海员短期出海前的心理生理状况和机体储备能力进行了评估。这项研究是 2023 年在 "Ekolan M-2.2 "科研工作框架内进行的，有117名潜艇海员在航行间歇期参与，45名潜艇海员在越南社会主义共和国境内出海前1-3天参与。对中枢神经系统、循环系统和呼吸系统的功能状态、储备能力和机体的心理生理状况进行了研究。分析了潜艇海员在长期部署地点的每日和每周例行活动。研究发现，越南社会主义共和国潜艇海员在航行间歇期和短期出海前，机体各系统的功能状况良好，储备能力充足。然而，尽管接受检查的潜艇海员的机能状态正常，但其中13人的机能状态有恶化趋势，5人的机能状态处于边缘状态。即使潜艇海员中有如此少量具有边界功能状态迹象的潜艇海员，也可能导致出海过程中的错误行为和紧急情况的发展。这反过来又会导致战斗任务无法完成，甚至造成人员死亡。研究结果表明，越南社会主义共和国海军有必要制定医疗和生理措施，以维持和恢复潜艇海员在不同训练和作战活动期间的身体机能状态。今后，为了更好地制定医疗和生理措施，有必要分析越南社会主义共和国海军潜艇海员的医疗保障情况，评估他们的发病率和医务室动态观察的结果。

关键词： 潜艇海员；越南；功能状态；循环系统；军事职业能力；潜艇；军事职业适应；机体储备能力；心理生理状态。

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INTRODUCTION

The work of submariners is one of the most dangerous and stressful types of professional military activity. This is due both to the constant threat to life and effect on the whole complex of naval work factors, which negative affect the functional state of many body systems [1–4].

In the Russian Navy, medical and physiological measures have been developed to correct the negative influence of occupational factors on the functional state of submariners, including medical monitoring and control of the health and functional state (FS) of submariners. These measures include ways to maintain, improve, and restore the military and professional performance of submariners during periods of training and combat activities [5–8].

The activity of submariners during the inter-navigation period is conducted according to a typical weekly schedule; however, in preparation for going to sea, in the pre-navigation period, it significantly intensifies, and the load on the functional systems of the organism increases. During the pre-departure period, the submariner's work process is characterized numerous control activities, careful monitoring of the state of technical equipment, practicing and passing various tasks. During this period, the activities of submariners are associated with heavy physical exertion while performing general shipboard work, receiving and deploying weapons, food, drinking water, fuel, regeneration equipment, uniforms, gear, and other equipment. Moreover, the personnel's work and rest regimen are often disrupted by sleep and rest to maintain working capacity [1, 2, 5].

The preparation of a submarine crew for sea voyage is accompanied by the development of neuropsychic tension in shipboard specialists, particularly officers. This is caused by shortcomings or imperfections in the organization of the ship's provisioning services, necessary types of allowances, and disrupted deadlines for the implementation of the submarine preparation plan for sea departure, which are beyond the control of the ship's crew. Conversely, it is also attributed to the high personal responsibility of the officers for the readiness of their units [1, 5, 9, 10].

The implementation of preparatory measures and their quality are regularly monitored by specialists from the unit's headquarters and higher command. These controlled and scheduled inspections have revealed shortcomings in the preparation of the ship's crew and the technical means of the submarine for combat service at sea. These shortcomings must be eliminated within a short period [1, 5]. Accordingly, the state of function of various body systems and the level of their reserve capabilities are important during the pre-departure period. During this period, submariners exhibit functional tension and psychological stress, which lead to the development of pathological changes in different systems of the organism. Thus, several authors [1, 5, 11] revealed the onset of circulatory system disorders characterized by increased *Q–T* intervals; increased heart rates (HR), pulse (PP), and systolic blood pressure (SBP); and decreased reserve capabilities of the organism. In the end, this can lead to the disruption of the preparation period and failure of the combat mission.

Most studies [5, 12] have provided data characterizing the state of body functions in the European North of Russia identified during the examination of submariners serving on nuclear-powered submarines (NPS). However, existing literature does not sufficiently reflect the influence of the unfavorable hot and humid climatic conditions on the state of functions of the central nervous system (CNS) and circulatory system and the level of the reserve capabilities of submariners serving on diesel-powered submarines (DPS). On these submarine designs, the habitability conditions are less favorable than on ships with NPS, which induces additional stress on body functions. Moreover, the effect of thermal loads on submariners' body is considered an additional unfavorable factor of habitability, which often leads to tension and even failure of the mechanisms of regulation of adaptive capabilities.

Therefore, an urgent task of naval medicine is to assess the functional status of various systems of submariners preparing for a DPS cruise in a hot and humid climate.

This study aimed to assess the psychophysiological status and reserve capabilities of submariners of the Socialist Republic of Vietnam (SRV) before a short-term departure to sea based on the state of function of the central nervous, circulatory, and respiratory systems.

MATERIALS AND METHODS

The study was conducted as part of the research and development project "Ensuring the Occupational Health of Military Submarine Seafarers" (codenamed "Ecolan M-2.2") in SRV in 2023.

The study was conducted in compliance with the ethical principles stipulated for research involving human participants. The study analyzed the actual daily and weekly routines of Vietnamese submarine crews. The research enrolled a total of 117 submariners during the inter-departure period (group 1) and 45 submariners before short-term deployment (group 2) of four DPSs. In group 1, submariners' FS was assessed during the inter-cruise period (submarines 1 and 4) considering routine training and combat activities. Group 2 was assessed 1–3 days before short-term submarine deployment (5–7 days). Notably, only officers serve on SRV submarines. Groups 1 and 2 were distributed by specialty as follows: navigational combat unit (BS-1) included 14 and 8 specialists, whereas the mine-torpedo combat units (BS-2 and BS-3) comprised 12 and 2 specialists,

respectively. The control and communication combat unit (BS-4, 7) included 25 and 13 specialists, respectively. The electromechanical combat unit (BS-5) comprised 57 and 20 personnel, respectively. Finally, the separate services unit included 9 and 2 individuals, respectively. For groups 1 and 2, the mean ages of the submariners were 35.7 ± 3.4 and 36.7 ± 3.7 years, with a mean body mass of 68.4 ± 7.5 and 67.3 ± 7.3 kg, and a mean height of 168.7 ± 15.2 and 167.9 ± 14.6 cm, respectively.

The subjective state was evaluated using the well-being, activity, and mood (WAM), self-assessment questionnaire (SAQ), and submariners' complaints card, which inquired about the presence, severity, and duration of health complaints. The following methods were employed to assess the FS state of the CNS: response to a moving object (RMO), critical flicker fusion frequency (cFFF), and attention assessment, interference tolerance, and dynamometry, implemented in the computer complex of psychophysiological testing called "NS-Psychotest" (Ivanovo). The psychophysiological status of submariners was also assessed with visual acuity test using Landolt's rings, memorizing 12 numbers and mental arithmetic. HR, SBP, and diastolic blood pressure (DBP) were determined to characterize the FS of the circulatory system. PP, stroke output (SO) according to Starr, and cardiac output (CO) were calculated. The Strange, Genci, and Serkin tests were performed to evaluate the reserve capabilities of the organism. The first phase entailed determining the breath-holding time in the sitting position. The second phase comprised performing 20 squats for 30 s, followed by determining the breath-holding time. The third phase involved determining the breath-holding time after 1 min. Furthermore, the following indices were calculated: Kerdo's autonomic index (KAI), adaptation potential (AP), physical performance index (PPI), and physical state (PS) [13, 14].

The primary data were processed using IBM SPSS Statistics. Correlation and comparative analyses by the *t*-criterion were performed for the dependent samples. Statistical reliability of the results was measured using the significance level, which did not exceed 0.05. The obtained values are presented as means and mean square deviations.

The authors express their sincere gratitude to the Naval Command and staff of the Joint Russian–Vietnamese Tropical Research and Technological Center (Hanoi) for the organization of productive scientific interaction and assistance in conducting scientific studies within the framework of the research topic "Ensuring the Professional Health of Military Submariners", cipher "Ecolan M-2.2".

RESULTS AND DISCUSSION

Submarine crews reside in well-appointed dormitory accommodations, with each crew comprising 2–4 individuals. The working day for submariners lasts 15–16 h. The total amount of sleep per day is between 8 and 9 h, with continuous sleep lasting 7 h and an additional 1.5–2 h designated as "admiral's hour" after lunch. Approximately 7 h per day are dedicated to shipboard work. Specialty classes are held for 2 h. Notably, SRV submariners engage in a considerable amount of rigorous physical training between voyages, and this intensity is maintained even before going to sea. Compulsory physical training is conducted for approximately 3 h during the day, for approximately 20 h per week, including weekends and holidays. The time allotted for personal needs, which often includes activities such as soccer and volleyball, is approximately 2 h per day.

The indicators of submariners' subjective state exhibited minimal variations across periods of combat training activities. Accordingly, the subjective state scored 4.8 ± 0.8 and 27.63 ± 14.41 points in group 1 and 4.7 ± 1.11 and 27.65 ± 13.93 points in group 2, respectively, as determined by the WAM and SAQ. The satisfactory indicators of submariners' subjective state are corroborated by a few health complaints (group 1, 6.04 ± 6.17 points; group 2, 6.1 ± 4.96 points), their severity (group 1, 7.44 ± 7.72 points; group 2, 7.45 ± 7.29 points). The results demonstrated that the mean scores for the duration of health complaints were 7.28 ± 7.4 and 8.1 ± 8.5 points for groups 1 and 2, respectively. The well-being and mood indicators of submariners before going to sea tended to decrease at the expense of a slight increase in the activity index, which can be related to the increase in the intensity of military work during submarine preparation for going to sea (Table 1).

The FS indicators of submariners' CNS indicate insufficient mobility of excitation and inhibition in the CNS or population norm. Therefore, the average values of the cFFF in groups 1 and 2 were low (group 1, 33.4 ± 5.75 Hz; group 2, 33.79 ± 3.37 Hz) and did not differ from each other (Table 2).

The mean reaction time as assessed by the attention assessment technique increased in group 2 in comparison with that in group 1. This finding indicates a potential decline in concentration and attention stability among divers before sea deployment. The mean reaction time as assessed by the interference tolerance technique tended to decrease in group 2. This may be indicative of an increase in the strength of CNS processes before embarking on a sea voyage. This could be interpreted as an enhanced capacity to resist the influence of external factors when engaged in military and professional activities (Table 3).

The dynamometry results (Table 4) indicated that the maximum muscle strength of the right hand was 6%–10% greater than that of the left hand in both groups. The muscle strength of the right hand represented 65%–70% of the body weight, which serves as a reliable indicator of the physical condition of submariners. In addition, the retention time for

a given effort is considerably shorter than that observed in Russian naval specialists [1]. Furthermore, the maximal muscle strength of the right and left hands were slightly higher in group 1, whereas the retention time and static endurance was higher in group 2.

In evaluating the degree of advancement in mental cognitive processes, the number of rings observed in the visual acuity test using Landolt's rings was higher in group 2 (329.03 ± 59.59) than in group 1. The number of errors made by group 1 (305.64 ± 77.10) was not significantly lower than that by group 2 (7.03 ± 5.11 and 8.29 ± 7.40, respectively). As regards the speed of information processing, the value of this index was nearly identical in both groups (group 1, 0.62 ± 0.18 bps; group 2, 0.61 ± 0.26 bps), as shown in Table 5.

The evaluation of the mental arithmetic of submariners revealed identical values for written sums (group 1, 10.21 ± 3.74; group 2, 10.48 ± 6.21), number of errors committed (group 1, 0.82 ± 0.98; group 2, 0.77 ± 1.18), and relative value of erroneous actions (group 1, 0.20 ± 0.14; group 2, 0.21 ± 0.20) in both groups. The study of visual memory by memorizing 12 numbers showed nearly identical values of both short-term memory volume and speed of information memorization.

No differences in the indices of the circulatory system (Table 6) were found, with practically the same initial and

Table 1. Indicators of the subjective functional state in both groups of submariners in different periods of combat training, score
Таблица 1. Показатели субъективного состояния у подводников обеих групп в различные периоды учебно-боевой деятельности, балл

Methodology	Indicators	Group		*t*	*p* <
		1	2		
WAM	Well-being	5.49 ± 0.92	5.35 ± 1.22	0.68	0.076
	Activity	4.55 ± 0.99	4.66 ± 1.05	0.56	0.681
	Mood	5.62 ± 1.05	5.45 ± 1.03	0.79	0.999
	Subjective status	4.8 ± 0.8	4.75 ± 1.11	0.21	0.073
SAQ	Subjective status	27.63 ± 14.41	27.65 ± 13.93	0	0.996
Complaints Card	Number of complaints	6.04 ± 6.17	6.1 ± 4.96	–0.04	0.966
	Severity of the complaint	7.44 ± 7.72	7.45 ± 7.29	–0.01	0.995
	Duration of the complaint	7.28 ± 7.4	8.1 ± 8.5	–0.41	0.683

Table 2. Indicators of the functional state of the central nervous system in both groups of submariners in various periods of combat training
Таблица 2. Показатели состояния функций центральной нервной системы у подводников обеих групп в различные периоды учебно-боевой деятельности

Indicators	Group	Descriptive statistics ($\bar{x}$ ± σ)		*t*	*p* <
		$\bar{x}$	σ		
cFFF, mean frequency, Hz	1	33.46	5.75	–0.33	0.743
	2	33.79	3.37		
cFFF, mean frequency when increasing, Hz	1	31.76	4.98	0.191	0.849
	2	31.59	3.14		
cFFF, mean frequency when decreasing, Hz	1	35.29	7.02	–0.57	0.57
	2	36.03	5.16		
RMO, exact responses, %	1	39.29	16.74	–1.05	0.295
	2	42.56	12.91		
RMO, delayed responses, %	1	17.71	10.24	–0.78	0.439
	2	19.38	13.56		
RMO, premature responses, %	1	41.51	20.22	1.04	0.300
	2	37.59	15.96		
RMO, mean response time without considering the type of response, ms	1	77.75	43.71	0.99	0.324
	2	69.88	28.35		

calculated indices in the state of relative rest (within the physiological norm). The calculation of KAI showed slight predominance of parasympathetic influences on circulatory system functions (group 1, 19.65; group 2, –18.86 units). This testifies to the high reserve capacity of organisms and the training of submariners of the SRV Navy because a high intensity of preparation for submariners going to sea did not change the FS of the circulatory system.

The results demonstrate the mobilization of the reserve capabilities in submariners before a short-term departure to sea and the effective organization of personnel rest during this period.

Ruffier, Stange, Genci, and Serkin functional stress tests (Table 7) revealed multidirectional results. Thus, the Ruffier index (RI), which allows for the estimation of myocardial performance (resistance of the circulatory system to physical

Table 3. State of attention and noise immunity functions in both groups of submariners in various periods of combat training, conventional units
Таблица 3. Состояние функций внимания и помехоустойчивости у подводников обеих групп в различные периоды учебно-боевой деятельности, усл. ед.

Indicators	Group	Descriptive statistics ($\bar{x}$ ± σ)		*t*	*p* <
		$\bar{x}$	σ		
Attention assessment, functional level of the system	1	3.75	0.44	–1.47	0.144
	2	3.90	0.31		
Attention assessment, response stability	1	1.57	0.57	–2.13	0.035
	2	1.85	0.37		
Attention assessment, functional level	1	2.74	0.67	–1.66	0.099
	2	3.00	0.46		
Interference tolerance, functional level of the system	1	3.30	0.54	–3.03	0.003
	2	3.70	0.57		
Interference tolerance, response stability	1	1.17	0.61	–2.42	0.017
	2	1.55	0.76		
Interference tolerance, functional level	1	2.21	0.65	–2.43	0.016
	2	2.60	0.68		

Table 4. Indicators of static endurance of the hand muscles in both groups of submariners in various periods of combat training
Таблица 4. Показатели статической выносливости мышц кисти у подводников обеих групп в различные периоды учебно-боевой деятельности

Indicators	Group	Descriptive statistics ($\bar{x}$ ± σ)		*t*	*p* <
		$\bar{x}$	σ		
Maximum muscle strength of the left hand, kg	1	43.94	7.28	1.20	0.233
	2	42.15	8.95		
Maximum muscle strength of the right hand, kg	1	48.03	7.13	1.25	0.214
	2	46.18	9.19		
Duration of holding with the left hand, s	1	28.12	21.18	–1.32	0.189
	2	32.85	24.61		
Duration of holding with the right hand, s	1	29.44	22.29	–0.86	0.391
	2	33.85	24.80		
Static endurance index for the left hand, units	1	926.69	125.32	–1.47	0.194
	2	969.24	129.47		
Static endurance index for the right hand, units	1	989.80	134.78	–1.63	0.231
	2	1094.23	148.56		

stress), and the Stange and Genci respiratory tests, which indicate the reserve capacity of the organism, tended to decrease in all submariners before a short-term departure to sea. This could indicate the use of the physiological reserves of the body before going to sea to maintain the high functional activity of the circulatory system. Serkin's test indices (phases 1–3), which characterize the body resistance to oxygen deficiency, tended to increase in group 2, which indicates a sufficient oxygen supply to the organism, ability of the circulatory and respiratory systems to remove the

Table 5. Psychophysiological indicators of attention, memory, and thinking among submariners in both groups of submariners in different periods of combat training activities
Таблица 5. Психофизиологические показатели внимания, памяти и мышления у подводников обеих групп в различные периоды учебно-боевой деятельности

Indicators	Group	Descriptive statistics ($\bar{x}$ ± σ)		*t*	*p* <
		$\bar{x}$	σ		
Number of viewed Landolt's rings, *n*	1	305.64	77.10	–1.57	0.118
	2	329.03	59.59		
Landolt's rings, number of errors, *n*	1	7.03	5.11	–1.43	0.154
	2	8.29	7.40		
Information processing speed, bits/s	1	0.62	0.18	0.33	0.74
	2	0.61	0.26		
Memorizing 12 numbers, amount of numbers memorized, *n*	1	8.10	2.12	0.49	0.624
	2	8.05	2.31		
Memorizing 12 numbers, information memorization rate, bits/s	1	0.67	0.15	–0.12	0.906
	2	0.67	0.17		
Mental arithmetic, number of mathematical operations, *n*	1	10.21	3.74	–0.31	0.759
	2	10.48	6.21		
Mental arithmetic, number of errors, *n*	1	0.82	0.98	0.22	0.823
	2	0.77	1.18		
Mental arithmetic, speed of mathematical operations, bits/s	1	0.20	0.14	–0.17	0.867
	2	0.21	0.20		

Table 6. State of the circulatory system functions in both groups of submariners in different periods of combat training activities
Таблица 6. Состояние функций системы кровообращения у подводников обеих групп в различные периоды учебно-боевой деятельности

Indicators	Group	Descriptive statistics ($\bar{x}$ ± σ)		*t*	*p* <
		$\bar{x}$	σ		
SBP, mmHg	1	125.09	12.61	0.44	0.66
	2	124.00	13.41		
DBP, mmHg	1	80.50	8.82	0.38	0.71
	2	79.86	8.48		
HR, bpm	1	67.28	10.55	0.04	0.96
	2	67.19	7.72		
Circulatory system response, score	1	5.07	0.37	2.79	0.006
	2	4.86	0.41		
PP, mmHg	1	44.59	9.65	0.24	0.810
	2	44.14	9.49		
SO, mL	1	52.77	8.38	0.38	0.703
	2	52.14	8.97		
CO, mL	1	3531.56	741.82	0.63	0.527
	2	3439.10	636.60		

formed carbon dioxide, and overall good physical fitness of the submariners. In addition, high values of Serkin's test indicated an increase in the adaptability of the submariners before a short-term departure to the sea.

In further analysis, the results of simple integral methods, which most fully reflect the FS of submariners, were considered [13, 14]. Such methods include the AP, PPI, PS, and RI indices. Among all submariners examined, those who have unsatisfactory indicators according to at least one of the above-mentioned techniques were identified. In regard to the unsatisfactory indicators, an insufficient expression of adaptation (3.1–3.6 units) in accordance with the AP methodology, a low level of physical condition (<0.375 units) in accordance with the PS methodology, a low PPI (<3.16 units), and a reduction in cardiac performance (>10.1 units) in accordance with the RI were noted. In total, 13 submariners (8%) exhibited unsatisfactory results in at least one of the four indicators. Submariner 1 demonstrated unsatisfactory results in three of the four indicators, whereas submariners 119 and 162 exhibited unsatisfactory results in two of the four indicators. Of the 13 submariners, 6 were assigned to combat unit 1 and separate services (supply, chemical, and medical) and served on the crews of submarines 1 and 4 (which were examined under normal life conditions during the inter-cruise period), as detailed in Table 8.

The largest number of submariners from this group (8 out of 13 individuals) exhibited low RI values, which may indicate an insufficient level of adaptation reserves and functional efficiency of the circulatory system. Furthermore, low RI values indicated a slower rate of recovery from physical activity and reduced tolerance to intense physical activity in such submariners.

Upon examination of the submariners, five of them (submariners 1, 55, 103, 142, and 153) exhibited suboptimal adaptation, which, according to the AP methodology, corresponded to borderline FS. The participants were found to be aged >40 years, with an average height of 171.8 ± 4.3 cm, body weight of 72.2 ± 2.4 kg, and high HR, SBP, and DBP. In addition, they reported health complaints according to the complaints card questionnaire.

Three submariners (submariners 119, 134, and 162) exhibited diminished values of PPI indicators. These submariners were from the same submarine (submariner 4), but from disparate combat units and services. PPI, reflecting the state of reserve capabilities of the respiratory and circulatory systems, indirectly indicates the necessity for physiological measures to restore physical performance in these submariners.

One of the examined submariners (submariner 1), along with indices on AP and RI methods that were deemed unsatisfactory, exhibited a low PS, which may indicate an inability to perform strenuous physical work and, most crucially, a diminished capacity to tolerate submaximal physical loads during the inter-cruise period. Furthermore, in this submariner, the control of bodily functions revealed a strain on the circulatory system, as indicated by the SBP (150 ± 11 mmHg), DBP (94 ± 6 mmHg), and HR (101 ± 8 beats/min) readings. In addition, the respiratory system exhibited a strain, as evidenced by the Stange (45 ± 4 s) and Genci (19 ± 2 s) methods. The submariner

Table 7. Indicators of functional stress tests in both groups of submariners in different periods of combat training activities
Таблица 7. Показатели функционально-нагрузочных проб у подводников обеих групп в различные периоды учебно-боевой деятельности

Indicators	Group	Descriptive statistics ($\bar{x}$ ± σ)		*t*	*p* <
		$\bar{x}$	σ		
RI, units	1	5.27	4.35	1.39	0.193
	2	4.58	2.32		
Serkin's test, phase 1, s	1	65.77	21.16	–0.47	0.639
	2	68.55	26.73		
Serkin's test, phase 2, s	1	27.60	14.64	–0.27	0.791
	2	28.55	10.99		
Serkin's test, phase 3, s	1	53.14	19.86	–1.37	0.173
	2	61.15	28.68		
Stange's test, s	1	75.46	29.91	1.83	0.071
	2	62.25	19.83		
Genci's test, s	1	39.33	14.40	0.22	0.825
	2	38.45	17.88		

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Table 8. Submariners with reduced values of body function indicators
Таблица 8. Подводники со сниженными показателями состояния функций организма

Submariner, No.	Submarine, No.	Combat unit	Age/height/body weight	AP, units	PPI, units	PS, units	RI, units	SBP, mm Hg	DBP, mm Hg	HR, bpm	Complaints, number
1	1	1	41/174/74	3.29*	3.89	0.18*	11.6*	150	94	101	62
19	1	4	32/165/61	2.64	3.99	1.29	12.4*	116	82	102	17
53	1	1	35/177/74	2.88	4.15	1.35	12.8*	122	100	98	3
54	1	5	37/168/68	2.63	4.83	1.47	11.2*	119	79	89	6
55	1	Services	46/162/70	3.20*	3.62	1.67	6.8	144	96	79	28
103	3	Services	40/168/66	3.33*	3.58	1.68	6.8	173	90	74	54
119	4	7	40/172/72	3.06	3.15*	1.44	13.6*	130	103	93	10
134	4	5	32/168/60	2.81	2.97*	1.41	9.2	138	83	92	12
136	4	3	28/172/72	2.50	4.91	1.60	10.4*	129	82	74	9
142	4	1	42/183/80	3.31*	5.03	1.74	8.8	161	112	70	22
149	4	7	34/167/62	2.59	5.05	1.67	10.4*	136	80	71	3
153	4	3	45/172/71	3.20*	4.60	1.70	6.8	150	103	75	44
162	4	Services	31/165/75	2.71	2.36*	1.33	12.4*	123	67	100	6

Note: * — The value deviated from the physiological norm.
Примечание: * — показатель выходит за пределы физиологической нормы.

demonstrated a low speed of information processing (A = 0.34 ± 0.4 bits/s) in the visual analyzer according to the Landolt rings method and a low mobility of nerve processes in the cortical part of the visual analyzer (average frequency 31.2 ± 3.7 Hz) according to the cFFF method. Therefore, the poor results obtained from the integrated methods and indicators of bodily functions in submariner 1 may indicate a proclivity toward an FS decline. Thus, this submariner was recommended to undergo further medical examinations.

CONCLUSIONS

The examination of SRV submariners during the inter-cruise period and before a short-term departure to sea revealed that their body functions were predominantly in a good state. Overall, despite the FS of the examined submariners, 13 (8%) demonstrated a proclivity toward FS deterioration, whereas 5 (1.8%) exhibited borderline FS. These five submariners served on diverse submarines and multiple combat units and were identified during crew examinations at varying stages of training and combat operations. This underscores the need for continuous monitoring of the FS of the entire submarine crew. The recognition of even such a small number of submariners with signs of borderline FS among submarine crew members can lead to mistakes during sea entry and emergencies. This is associated with failure of the combat mission and loss of life [15, 16].

These observations collectively highlight the need for medical and physiological measures within the SRV Navy, encompassing the domains of medical observation, control over health, and fitness of the submariners. These measures should maintain and restore the FS of submariners during training and combat activities. To facilitate more effective medical and physiological measures in the future, the medical support provided to SRV Navy submariners must be evaluated, their morbidity assessed, and outcomes of dispensary dynamic observation analyzed.

ADDITIONAL INFORMATION

Authors' contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

The contribution of each author. E.V. Kryukov — development of the general concept, study design, data analysis; D.P. Zverev — data collection, data analysis, writing an article; E.V. Ivchenko — research design; D.V. Ovchinnikov — data analysis; A.N. Andrusenko — data analysis, writing an article; A.Y. Shitov — material collection, data analysis, writing an article; H.T. Bui — material collection; L.T.T. Nguyen — statistical data processing;

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Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

Вклад каждого автора. Е.В. Крюков — разработка общей концепции, дизайн исследования, анализ данных; Д.П. Зверев — сбор материала анализ данных, написание статьи; Е.В. Ивченко — дизайн исследования; Д.В. Овчинников — анализ данных; А.Н. Андрусенко — анализ данных, написание статьи; А.Ю. Шитов — сбор материала, анализ данных, написание статьи; Х.Т. Буй — сбор материала; Л.Т.Т. Нгуен — статистическая обработка данных; Ю.М. Бобров — анализ данных; А.А. Мясников — разработка общей концепции, анализ данных; В.В. Юсупов — сбор материала, анализ данных; В.А. Корзунин — сбор материала, анализ данных; Т.М. Нгуен — статистическая обработка данных; Е.О. Филиппова — сбор материала; О.Ю. Голубцов — анализ данных; К.Х. Нгуен — анализ данных; Ф.Х. Чинь — статистическая обработка данных; Х.В. Нгуен — систематизация и анализ данных; Т.В. Чыонг — систематизация и анализ данных.

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