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Gender Characteristics of the Response of the Cardiovascular System in Military Personnel to Various Types of Physical Exertion

Abstract:

The authors present a comparative analysis of the cardiovascular system response in 63 military personnel (32 men and 31 women) during orthostatic, isometric, and hypoxic functional tests. The study aimed to identify gender differences in response to various types of physical exertion. To achieve this goal, theoretical research methods, physiological measurement techniques, and mathematical statistics were employed. The findings underwent comparative analysis, revealing that men had an average systolic blood pressure of 156.6 ± 24.43 mm Hg during isometric loading, while women recorded an average of 143.6 ± 11.85 mm Hg ($p = 0.01$). The diastolic pressure in men reached 107.1 ± 13.95 mm Hg, whereas in women, it was 96.5 ± 6.11 mm Hg ($p = 0.001$). In the hypoxic test, men demonstrated an average systolic blood pressure of 148.0 ± 20.61 mm Hg; for women, it was 130.6 ± 10.84 mm Hg ($p = 0.001$). Similar results were obtained in the comparative analysis of indicators during the orthostatic test. These data indicate a higher cardiovascular reactivity in men, which may reflect differences in adaptive mechanisms between gender groups among military personnel. The results underscore the importance of considering gender-specific characteristics in designing physical training programs for military personnel to ensure optimal physical loads and minimise risks of cardiovascular strain, particularly for men.

Keywords: military staff, gender differences, isometric load, hypoxic test, orthostatic test, blood pressure.

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Гендерні особливості реакції серцево-судинної системи у військовослужбовців на фізичні навантаження різного типу

Анотація:

У статті представлений порівняльний аналіз реакції серцево-судинної системи у 63 військовослужбовців (32 чоловіки і 31 жінка) під час виконання ортостатичної, ізометричної та гіпоксичної функціональних проб. Метою дослідження було виявлення гендерних відмінностей на різні типи фізичних навантажень. Для досягнення поставленої мети були використані теоретичні методи дослідження, фізіологічні методи дослідження та методи математичної статистики. Отримані результати були піддані порівнювальному аналізу в ході якого ми встановили, що у чоловіків при ізометричному навантаженні середній систолічний тиск становив $156,6 \pm 24,43$ мм рт. ст., а у жінок — $143,6 \pm 11,85$ мм рт. ст. ($p = 0,01$). Діастолічний тиск у чоловіків досягав $107,1 \pm 13,95$ мм рт. ст., тоді як у жінок — $96,5 \pm 6,11$ мм рт. ст. ($p = 0,001$). При гіпоксичній пробі чоловіки демонстрували середній систолічний тиск $148,0 \pm 20,61$ мм рт. ст., у той час як жінки — $130,6 \pm 10,84$ мм рт. ст. ($p = 0,001$). Подібні результати були отримані під час порівнювального аналізу показників під час виконання ортостатичної проби. Отримані дані свідчать про вищу реактивність серцево-судинної системи у чоловіків, що може бути проявом відмінностей у адаптаційних механізмах між статевими групами військовослужбовців. Отже, отримані результати підкреслюють важливість врахування гендерних особливостей при розробці програм фізичної підготовки для військовослужбовців, з метою забезпечення оптимального фізичного навантаження та уникнення ризиків перенавантаження серцево-судинної системи у чоловіків.

Ключові слова: військовослужбовці, гендерні відмінності, ізометричне навантаження, гіпоксична проба, ортостатична проба, артеріальний тиск.

Abbreviations:

AFU is Armed Forces of Ukraine

BP is blood pressure

HR is heart rate

Introduction

The relevance of the study of gender characteristics of the reactions of the cardiovascular system of military personnel to various types of physical activity is due to the need to optimise physical training in the AFU. Physical activity, which varies in intensity and nature, initiates specific adaptive responses of the cardiovascular system, which can differ significantly in men and women. Given the significant increase in the role of women in modern AFU, understanding the gender characteristics of the cardiovascular system's response to physical activity is important for developing effective and safe individual training programmes that will help increase the combat capability of military personnel and reduce the risk of injuries. Also, considering gender differences will not only optimise the level of physical fitness but also make it possible to develop the body's adaptive capabilities, ensuring a more stable functioning of the cardiovascular system in conditions of high physical and psychoemotional loads.

For a comprehensive approach to the study of this issue, we conducted a detailed analysis of the scientific and methodological literature; we paid particular attention to scientific research involving young men and women who performed various types of physical activity (*Linde et al., 2018; Hnatkova et al., 2019; Ferreira et al., 2022; Ferreira et al., 2024*). Scientific papers that indicate gender differences in functional tests are considered in more detail. Studies conducted (*Guenette et al., 2010; Hunter et al., 2016*) suggest that women's diaphragms show higher resistance to respiratory muscle fatigue compared to men during endurance exercises. At the same time, according to the data (*Sheel et al., 2008*), women have smaller airway and lung volumes, such as lower rates of maximum exhalation at rest compared to men. As a result, women use up most of their respiratory reserve and have a higher metabolic cost of breathing. This fact has been confirmed in studies, which found that in women, during high-intensity physical activity, the respiratory muscles consume the greatest proportion of oxygen.

Based on the study's results (*O'Toole et al., 1989*), cardiac output increases proportionately to increased oxygen consumption during the acute phase of dynamic exercise. The mechanisms by which cardiac output increases during exercise may differ in men and women. However, despite some physiological differences that may affect the mechanism of changes, the overall response of the cardiovascular system to physical activity is similar in both sexes. However, studies conducted revealed gender differences in the cardiovascular system's response to different types of physical activity. Men had significantly higher absolute systolic blood pressure values at 50%, 75% to 100% peak heart rate in all modalities ($p < 0.05$). However, gender differences in systolic blood pressure responses varied when considering body weight, body surface area, and fat-free body weight.

Based on research results (*Barreto et al., 2015*), women had a more robust systolic blood pressure response under moderate intensity of physical activity, while men had less pronounced such reactions, regardless of the complexity of the exercise. The diastolic and mean blood pressure reactions were similar, but statistical significance for these indicators was not achieved. The results show that women usually show more pronounced cardiovascular responses to exercise.

When analysing the scientific literature, we found conflicting data, so according to the results of a pedagogical experiment (*Melrose, 2005*) involving 16 women and 15 men (mean age 22.6 ± 4.2 years), two isometric tests were performed at the level of 40% of the maximum. Participants performed the exercises in two different starting body positions. The results showed that men showed significantly higher values of mean blood pressure and diastolic blood pressure during exercise and recovery, regardless of body position. Gender differences in the cardiovascular response to relatively low levels of isometric exercise are a significant factor to consider when developing fitness programmes.

The study that was conducted (*Masatli et al., 2018*) implemented interval training protocols (+Gz; +2gz) under artificial gravity with blood pressure and heart rate detection; the study participants were 16 men and 12 women (mean age 28.4 ± 5.3 years). The results showed that the +Gz and +2gz protocols were more effective in stimulating the cardiovascular system for women than men, especially during the exercise phases. Women experienced an increase in diastolic blood pressure at all stages, especially during the +2gz phases. At the same time, the authors of the study believe that in order to achieve the necessary cardiovascular responses that

contribute to overcoming orthostatic instability when restoring the influence of normal gravity, it is advisable to use modified or individualised +Gz profiles, which is confirmed by the results of previous studies using artificial gravity (*Goswami et al., 2015*). Results obtained by a group of scientists (*Cheng et al., 2011*) indicate that during orthostatic exercise, women have more autonomic reactions than men. Women have a more active parasympathetic system, higher estrogen levels, and a lower centre of gravity. Thus, women are less effective at compensating for changes in blood pressure in response to an orthostatic test.

Thus, despite significant progress in research on the physiological mechanisms of adaptation to physical exertion, gender differences in cardiovascular response remain poorly understood, especially in the context of military service.

The study aimed to conduct a comparative analysis of the cardiovascular system's response in men and women based on the results of orthostatic, hypoxic, and isometric tests to determine gender differences.

The study involved 63 military personnel, including 31 women and 32 men, with an average age of 32.8 ± 2.4 years. The criteria for inclusion in the pedagogical experiment were an average level of physical fitness that meets the requirements of military service, the absence of acute or chronic diseases of the cardiovascular and respiratory systems, voluntary consent to participate in the study, and experience in performing physical activities similar to those provided for in the conditions of the pedagogical experiment.

Methods

To elucidate existing approaches and research results related to gender differences in cardiovascular responses to different types of physical activity, we conducted a systematic review of current scientific publications, which allowed us to identify theoretical concepts and methodological approaches in this area, as well as identify scientific gaps that require further research. We paid particular attention to gender differences in the mechanisms of adaptation of the cardiovascular system to isometric and orthostatic loads, which allowed us to formulate topical issues for further experimental studies. In addition, the analysis of modern literature allowed us to form the basis for functional tests that do not require additional diagnostic equipment and are pretty simple and convenient for practical use while providing high information content of the results.

To determine gender differences in cardiovascular function during different types of physical activity, we used three functional tests: orthostatic, hypoxic, and isometric. A detailed description of the diagnostic equipment, the sequence of conducting these samples and the gradation scale is presented in the authors' work (*Petrachkov & Yarmak, 2023*).

The results were analysed using Statistica 10.0 software. Descriptive and inference statistics methods were used to determine the reliability of differences between sample indicators. For independent samples, group mean values were compared using the student's t-test. The critical significance level (p) was assumed to be 0.05.

Results

The data we obtained, presented in the appendix (*Table 1*), show some sex differences in military personnel in the cardiovascular system response during the orthostatic test. However,

there are also similar reactions of the body to changes in the initial position of the body. Thus, systolic and diastolic blood pressure indicators in the body's horizontal position indicate no significant differences between men and women. In particular, the average value of systolic blood pressure in the group of men was 125.4 ± 16.16 mm Hg, and the group in women— 121.3 ± 9.55 mm Hg ($t = -1.33$; $p = 0.19$), which is not statistically significant. Similarly, the obtained values of diastolic blood pressure in the horizontal position of the body were similar in both sex groups: 81.1 ± 12.57 mm Hg in men and 82.3 ± 7.95 mm Hg in women ($t = 0.48$; $p = 0.63$).

When moving to an upright body position, significant gender differences in systolic and diastolic blood pressure were found. In men, systolic blood pressure increased to 149.0 ± 22.27 mm Hg, while in women only up to 124.3 ± 11.78 mm Hg, which is a statistically significant difference ($t = -5.92$; $p < 0.001$). Similar results are observed in the reaction of diastolic blood pressure; the average group indicator in men in an upright body position was 99.9 ± 17.81 mm Hg compared to 86.1 ± 7.12 mm Hg in women ($t = -4.33$; $p < 0.001$). The results may indicate a more pronounced vascular response and adaptation of the cardiovascular system in men to orthostatic stress.

Regarding the heart rate, in the horizontal position, this indicator in men was 72.2 ± 8.90 beats·min⁻¹, while in women – 74.4 ± 22.60 beats·min⁻¹ ($t = 0.54$; $p = 0.63$), which is also not statistically significant. When moving to an upright body position, the heart rate in men increased to 86.0 ± 12.39 beats·min⁻¹, and in women to 83.2 ± 17.14 beats·min⁻¹ ($t = -0.78$; $p = 0.53$), which also does not show significant differences between the sex groups. However, it is worth noting that the orthostatic increase in heart rate, which indicates the adaptation of the cardiovascular system to changes in body position, in men was 13.8 ± 2.11 beats·min⁻¹, while in women it was lower than 8.7 ± 2.19 beats·min⁻¹ ($t = -4.81$; $p < 0.001$). Our results indicate a more pronounced orthostatic response in men, possibly due to the peculiarities of physiological adaptation to orthostatic stress.

The results obtained indicate that gender differences exist in the cardiovascular system's response to orthostatic load, worth considering when organising physical activity and training for military personnel of different sexes.

(Table 2) shows the results of indicators of the cardiovascular system of military personnel of men and women during the performance of two functional tests, a test with local isometric load and a hypoxic test. According to the data obtained, there are statistically significant ($p < 0.05$; $p < 0.01$; $p < 0.001$) gender differences in the responses of the cardiovascular system, which indicates the specifics of the body's adaptation to different types of exercise in representatives of different sexes.

When performing the test with a local isometric load, men recorded higher systolic blood pressure values of 156.6 ± 24.43 mm Hg compared to women, whose indicator was 143.6 ± 11.85 mm Hg ($t = -2.77$; $p = 0.01$). The results may indicate a more pronounced blood pressure response in men to local static load. Also, diastolic blood pressure in men was significantly higher; the average group result was 107.1 ± 13.95 mm Hg in women; this indicator corresponded to 96.5 ± 6.11 mm Hg ($t = -4.04$; $p < 0.001$). The heart rate during isometric exercise was also statistically significantly higher in men at 95.0 ± 18.66 beats·min⁻¹, compared to 87.1 ± 11.30 beats·min⁻¹ in women ($t = -2.10$; $p = 0.04$). The average blood pressure in men was also higher and corresponded to 123.6 ± 16.21 mm Hg in women; this value was $112.0 \pm$

4.48 mm Hg ($t = -2.11$; $p = 0.04$). The results indicate that in men when performing local isometric loads of 50% of the maximum, mechanisms that contribute to a greater increase in blood pressure may be due to physiological differences or a stressful state.

Comparative results of the hypoxic test analysis also revealed significant differences. The mean Group value of systolic blood pressure in men was significantly higher and was 148.0 ± 20.61 mm Hg; in women, by almost 18 mm Hg, it was smaller and was 130.6 ± 10.84 mm Hg ($t = -3.98$; $p < 0.001$). The average group diastolic blood pressure was also significantly higher in men and was 100.8 ± 14.75 mm Hg compared to 85.6 ± 5.89 mm Hg in women ($t = -5.07$; $p < 0.001$). However, the heart rate in men was 77.4 ± 18.37 beats·min⁻¹, which did not show a significant difference with the indicator in women (72.4 ± 5.87 beats·min⁻¹, $t = -1.34$; $p = 0.18$). It is also worth noting that the average group indicator of average blood pressure in men was also higher (116.5 ± 16.17 mm Hg) compared to women (98.3 ± 2.75 mm Hg, $t = -3.34$; $p = 0.01$).

So, comparative analysis of the results allows us to establish that men show higher average group results in most of the studied indicators during the performance of functional tests, particularly with local isometric and hypoxic load. Reactivity of the cardiovascular system is manifested by a significant increase in systolic and diastolic blood pressure, average blood pressure, and heart rate in response to these loads, which may be due to physiological differences in vascular and neuromuscular control between the sexual groups of military personnel.

Discussion

Undoubtedly, the relevance of the chosen topic of scientific research is due to the growing role of women in the armed forces of Ukraine and the need to develop individual approaches to the intensity of physical activity during practical physical training classes. An analysis of the scientific literature shows that although the physiological adaptations of the cardiovascular system to exercise are similar in men and women, there are significant gender differences that affect their reactivity in response to different types of physical activity and conditions. Some studies point to higher respiratory muscle stability in women (*Guenette et al., 2010*), while others highlight a greater tendency for men to increase systolic pressure during intense physical activity (*Gilbert et al., 1991*). Taking into account such differences is an important aspect that can help optimise approaches to physical training, ensuring individualisation of programs and improving the health safety of military personnel of both sexes. In addition, a review of the scientific and methodological literature allowed us to justify the choice of functional tests that are convenient and accessible for use in military service and provide high information content for the results.

A comparative analysis of the data obtained by the US revealed some gender differences in the response of the cardiovascular system to the orthostatic test. In the horizontal position of the body, there were no significant differences in the indicators of systolic and diastolic blood pressure. In the vertical position of the body, a significant increase in systolic blood pressure was found in men compared to women, which indicates a more pronounced vascular response in men to orthostatic load. The increase in heart rate during changes in the initial body position was also significantly higher in men, which may indicate the specifics of adapting the cardiovascular system to stressful conditions.

With a local isometric load of 50% of the maximum, there were significant gender differences in blood pressure indicators. This indicates a more intense vascular response in men, possibly due to physiological characteristics or the influence of stress factors. Analysis of the hypoxic test also revealed significant gender differences, in particular in the indicators of systolic and diastolic blood pressure, which indicates different levels of adaptation of the cardiovascular system in men and women during hypoxic exercise.

Thus, the study's results confirm the presence of gender differences in the cardiovascular system's responses to different types of physical activity, which should be considered when organising physical training classes for military personnel, especially men.

The prospects for further research will be aimed at studying the gender characteristics of the adaptive capabilities of the body under stress, in particular during physical and psychological stress that occurs in various situations of military activity.

Conclusion

The results obtained in a pedagogical experiment indicate that men's cardiovascular systems adapt to various types of physical activity through more pronounced sympathetic activation, which causes an increase in blood pressure and heart rate. In women, there is a less intense reaction, which can be due to both morphological features and hormonal factors that affect vascular tone and the function of the cardiovascular system.

The scientific data we have obtained are of practical importance, as they emphasise the importance of gender mainstreaming in the planning and implementation of physical training programs in military units. Considering gender differences will allow us to more accurately assess the functional capabilities of military personnel and ensure optimal physical activity. As a result, it will help reduce the risks of overloading the cardiovascular system in men and contribute to improving the effectiveness of the training process.

Conflict of Interest

The author declares that there is no conflict of interest.

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Appendix

Table 1. The results of the reaction of the cardiovascular system during the orthostatic test in military personnel of two sex groups, ($n = 63$)

Studied indicators	People, (n=32)		Women, (n=31)		t	p
	$\bar{x}$	S	$\bar{x}$	S		
BP systolic in a horizontal body position, mm Hg	125,4	16,16	121,3	9,55	-1,33	0,19
BP diastolic in a horizontal body position, mm Hg	81,1	12,57	82,3	7,95	0,48	0,63
BP systolic in a vertical body position, mm Hg	149,0	22,27	124,3***	11,78	-5,92	0,001
BP diastolic in a vertical body position, mm Hg	99,9	17,81	86,1***	7,12	-4,33	0,001
HR in the horizontal position of the body, beats·min ⁻¹	72,2	8,90	74,4	22,60	0,54	0,63
HR in the vertical position of the body, beats·min ⁻¹	86,0	12,39	83,2	17,14	-0,78	0,53
Orthostatic test, beats·min ⁻¹	13,8	2,11	8,7***	2,19	-4,81	0,001

Note: Verification of significant differences in the student's parametric t-criterion for independent samples between the results of performing an orthostatic test of military personnel of different sex groups, *** $p < 0,001$

Table 2. The results of indicators of the cardiovascular system during functional tests in military personnel of two sex groups, ($n = 63$)

Studied indicators	People, (n=32)		Women, (n=31)		t	p
	$\overline{x}$	S	$\overline{x}$	S		
Sample with local isometric load						
BP systolic, mm Hg	156,6	24,43	143,6**	11,85	-2,77	0,01
BP diastolic, mm Hg	107,1	13,95	96,5***	6,11	-4,04	0,001
HR, beats·min ⁻¹	95,0	18,66	87,1*	11,30	-2,10	0,04
Average blood pressure, mmHg	123,6	16,21	112,0*	4,48	-2,11	0,04
Hypoxic test						
BP systolic, mm Hg	148,0	20,61	130,6***	10,84	-3,98	0,001
BP diastolic, mm Hg	100,8	14,75	85,6***	5,89	-5,07	0,001
HR, beats·min ⁻¹	77,4	18,37	72,4	5,87	-1,34	0,18
Average blood pressure, mm Hg	116,5	16,17	98,3**	2,75	-3,34	0,01

Note: Verification of significant differences in the student's parametric t-criterion for independent samples between the results of performing functional tests of military personnel of different sex groups, * $p < 0,05$; ** $p < 0,01$; *** $p < 0,001$.