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Yaroslav Igorovitch Soynikov
National University of Ukraine on Physical Education and Sport
jaroslavsojnikov@gmail.com
ORCID: https://orcid.org/0009-0001-6080-1024
Halyna Volodymyrivna Lukyantseva
National University of Ukraine on Physical Education and Sport
lukjantseva@gmail.com
ORCID: https://orcid.org/0000-0002-8054-0108

REACTIVE AND ADAPTIVE CHANGES OF THE CARDIOVASCULAR SYSTEM IN MEN IN RESPONSE TO DIFFERENT TYPES OF PHYSICAL EXERCISE: PHYSIOLOGICAL AND TRAINING CONTEXT

The article examines reactive and adaptive alterations of the cardiovascular system in men across various stages of ontogenesis under the influence of physical exercises of different orientations. ***Purpose.*** *To identify age-related features of reactive and adaptive changes in the cardiovascular system of men in response to exercise of different metabolic orientations and to characterize the mechanisms underlying hemodynamic responses and training-induced adaptations.* ***Methods.*** *A systematic analysis of contemporary scientific literature was conducted using PubMed, Scopus, Web of Science, and Google Scholar. More than 700 sources were initially screened using keywords related to age-dependent hemodynamic responses to various exercise types. Following multi-stage relevance assessment and full-text evaluation, 109 publications were included in the final synthesis.*

Main results. *Adolescence is characterized by predominant sympathetic reactivity and instability of baroreflex control. Men in early adulthood exhibit the highest degree of morphofunctional maturity of the heart and vasculature, demonstrating efficient training adaptations and an optimal autonomic balance. Older age is associated with reduced stroke volume, increased arterial stiffness, and delayed parasympathetic reactivation. Exercise modality significantly shapes the response profile: aerobic exercise enhances tissue perfusion, anaerobic training induces peak pressor responses, mixed exercise elicits alternating sympathetic and vasodilatory phases, while functional training improves intermuscular coordination and postural circulatory regulation.*

Scientific novelty. *Age-specific models of cardiovascular reactivity and adaptation have been systematized. Early adulthood is substantiated as the physiologically optimal period for achieving maximal training effects. Intracollective differences in hemodynamic responsiveness within adolescent and adult groups are identified and linked to the degree of cardiovascular and autonomic maturation.*

Conclusions and recommendations. *Age-related physiological characteristics necessitate individualized training strategies: adolescents require gradual load progression with emphasis on stabilizing autonomic regulation; adult men benefit most from combined and functional training modalities; older individuals should prioritize aerobic and low-intensity exercises with careful monitoring of hemodynamic parameters.*

Keywords: *circulatory system, heart, blood vessels, hemodynamics, physical exercise, reactivity, adaptation, men.*

Formulation of the problem. The cardiovascular system plays a central role in enabling the organism to adapt to physical and athletic loads, maintaining homeostasis under conditions of elevated metabolic demand [1–3]. Different types of physical exercise elicit complex hemodynamic responses involving changes in heart rate (HR), stroke volume (SV), cardiac output (CO), arterial blood pressure (BP), and the redistribution of peripheral vascular resistance (PVR) [4–6]. These reactions are mediated by neurohumoral mechanisms whose sensitivity and efficiency change with age [7, 8]. Men of different age groups show marked differences in hemodynamic reactivity due to age-related alterations in myocardial structure and function, vascular status, and autonomic regulation [9, 10]. Adolescence features dominant sympathetic activation and high rhythm variability, adulthood a more stable but less flexible response, and older age reduced reserves, slower regulatory adjustments, and increased risk of hemodynamic instability.The type of physical exercise also exerts a significant influence on the pattern of the hemodynamic response. Aerobic, anaerobic, mixed, and functional training loads activate distinct adaptive mechanisms operating within specific metabolic and neurovegetative contexts [13–15]. Investigating age-related features of cardiovascular reactivity and adaptation to muscular work is essential not only for sports physiology but also for the prevention of cardiovascular diseases and the development of effective individualised training programmes.

The purpose of the study. To determine the age-specific characteristics of reactive and adaptive changes in the cardiovascular system of men in response to physical exercises of different orientations and to characterise the mechanisms underlying hemodynamic responses and training adaptation.

Research materials and methods.The analysis of specialised scientific literature was conducted by reviewing sources indexed in PubMed, Scopus, Web of Science, Google Scholar, and the Cochrane Library over the past 10–15 years, with priority given to publications from 2020–2025. The literature search employed the following keywords: “cardiovascular reactivity”, “exercise-induced hemodynamic response”, “training adaptation”, “age-related cardiovascular changes”, “men”, “aerobic exercise”, “anaerobic exercise”, and “functional training”.

Using these search terms, over 700 records were identified. After removing duplicates and performing an initial title-based screening, 426 publications remained. Subsequent selection followed a stepwise algorithm: if the study topic aligned with the research focus, abstracts were analysed, and when appropriate, full texts were reviewed. The final analysis included publications that contained data on age-specific mechanisms of hemodynamic reactivity, adaptive changes in cardiac and vascular function under different types of physical exercise, and regulatory features of the cardiovascular system. Ultimately, 109 scientific works were included in the review, systematically organised and critically analysed.

Research results and their discussion. The cardiovascular system is a key target for examining reactive and adaptive responses to athletic loads. Circulatory reactivity is defined as the acute response to muscular work, manifested by rapid increases in heart rate (HR), stroke volume (SV), cardiac output (CO), and arterial blood pressure (BP), as well as the redistribution of blood flow between active and inactive muscle groups and internal organs [16, 17]. These reactions reflect the organism’s functional reserves, the speed of compensatory adjustments, and the ability to maintain dynamic homeostatic balance during physical activity.

Adaptive hemodynamic changes, in contrast to reactive shifts, develop gradually and have a chronic character, emerging as a consequence of regular training stimuli [17–19]. They include cardiac remodelling (increased SV, enhanced diastolic filling, and improved myocardial contractility) and vascular remodelling (greater arterial elasticity, increased skeletal muscle capillarisation, improved endothelial function, etc.) [18–20]. Such changes contribute to the economisation of cardiac work through reduced HR (physiological bradycardia) and enhanced pumping efficiency, as well as improved perfusion of working muscles during exercise.

Acute cardiovascular responses form the basis for long-term structural and functional adaptations, with their intensity and quality determining the direction and magnitude of the adaptive process [19, 20]. Alterations in CO during muscular work directly influence SV and oxygen transport, highlighting the importance of reactive mechanisms for subsequent adaptation [21]. Regular physical activity induces specific vascular adaptations that enhance the overall efficiency of the circulatory system [22]. Evidence also indicates differences in central hemodynamic reactivity following dynamic versus static exercise, which is essential for the individualisation of training programmes [23–25].

The physiological response of the circulatory system to muscular work results from the complex interaction of numerous internal and external factors that determine individual patterns of reactivity and adaptation. Key determinants include genetically mediated characteristics of the heart and vasculature, training status, age, sex, overall functional condition, as well as the type, intensity, duration, and specificity of exercise [26, 27]. Even within the same mode of muscular work, macro- and microhemodynamic parameters may vary substantially depending on individual adaptation level, neurohumoral regulatory efficiency, and peripheral vascular functionality [26, 28–30].

Exercise technique and training experience play a decisive role in shaping response variability by influencing the degree of morphofunctional remodelling of cardiac and vascular structures [31, 32]. Individuals with high aerobic fitness demonstrate a tendency toward greater cardiac economy, increased SV, and lower HR at comparable workloads [33, 34]. Conversely, untrained individuals or athletes subjected to chronic overload may exhibit reduced vascular reactivity and impaired restoration of hemodynamic indices, indicating dysfunction of regulatory mechanisms and diminished adaptive potential of the cardiovascular system [35–37]. Sex and age also substantially affect response dynamics: women typically show lower SV and higher HR compared to men under similar loads, whereas aging is associated with reduced vascular elasticity, altering BP responses during exercise [38, 39].

Thus, the individual circulatory response to different types of physical exercise represents a multifactorial process shaped by both life-long and training-related experience, reflecting the level of functional capacity and the potential for further adaptation. An analysis of these responses not only enables the optimisation of training strategies but also allows the early detection of overload, reduced tolerance, or emerging dysfunction within cardiac and vascular regulation.

Training modalities are commonly classified according to the predominant energy supply supporting muscular activity. Aerobic, anaerobic, combined, and functional training differ markedly in loading characteristics, recruitment of metabolic pathways, duration, intensity, and the orientation of adaptive changes.

Aerobic training is characterised by prolonged performance of moderate-intensity muscular work with dominant oxidative energy production, as seen in long-distance running, swimming, cycling, and race walking [18, 19]. The primary energy source is aerobic oxidation of carbohydrates and fats in the presence of oxygen within skeletal muscle mitochondria [19, 20].

Anaerobic training consists of exercises of high or near-maximal intensity, where oxygen delivery cannot meet metabolic demand, leading the organism to rely on anaerobic glycolysis or the phosphagen system — such as sprinting, heavy resistance training, jumping activities, or short intervals of high-intensity exercise [20, 21]. It is characterised by lactate production, high rates of energy turnover, and rapid depletion of energy stores [21, 40]. Adaptive responses include increased glycolytic capacity, enhanced muscle buffering potential, hypertrophy of fast-twitch fibres, and improved anaerobic tolerance.

Combined training integrates both aerobic and anaerobic components and aims to simultaneously develop several fitness qualities — endurance, strength, speed, and coordination [41, 42]. High-intensity interval training (HIIT) is a typical example, alternating short anaerobic bouts with aerobic recovery intervals. This modality produces multi-energy loading and induces adaptations across several systems, including cardiovascular, respiratory, and neuromuscular.

Functional training focuses on improving movement patterns applicable to daily activity, sport, or rehabilitation. Unlike traditional isolated exercises, functional training engages multiple muscle groups simultaneously, involving both central and peripheral mechanisms of motor regulation [43, 44, 45, 46]. This includes bodyweight exercises, unstable-surface training, TRX systems, and tasks requiring variable stabilization, balance, and movement trajectories. Physiologically, such training enhances intermuscular coordination, proprioception, flexibility, and balance.

The choice of training modality depends on the targeted objective, level of preparedness, and functional status of the individual. Aerobic and anaerobic components may be alternated or combined to develop comprehensive physical fitness, whereas functional approaches support the transfer of trained skills to specific movement tasks. Contemporary research underlines the importance of individualised exercise selection based on physiological responses and adaptive profiles.

Reactive and adaptive cardiovascular changes in men in response to different types of physical exercise vary substantially with age.

In late adolescence (17–21 years), the circulatory system undergoes the final stages of morphofunctional maturation, exhibiting high plasticity but still incomplete regulatory integration.

The heart attains nearly adult anatomical dimensions; however, the functional maturity of cardi hemodynamics develops gradually, particularly regarding the integration of central and peripheral regulatory circuits. Resting HR in adolescent males typically remains slightly elevated (approximately 70–75 bpm), driven by predominant sympathetic activity [47, 48]. SV and CO have not yet reached the optimal values characteristic of early adulthood, as the finalisation of myocardial inotropic function and full correspondence of diastolic filling are still in progress [15, 49]. PVR tends to be lower due to the high elasticity of the arterial tree. BP remains within age norms, though greater fluctuations may occur under physical or emotional stress because baroreflex control is not yet fully matured [5, 50]. Hyperreactive responses, including hypertension, may occasionally be observed.

Heart rate variability (HRV) serves as a key indicator of autonomic homeostasis. In adolescence, HRV remains relatively high, reflecting substantial adaptive reserves, although the balance between sympathetic and parasympathetic activity is not yet stable [51, 52]. This instability may result in disproportionate chronotropic and inotropic responses to changes in posture, temperature, or psycho-emotional state [52, 53]. From the standpoint of endothelial function, production of vasoactive mediators (nitric oxide, prostacyclin) is elevated, but vascular reactivity has not yet reached maximal sensitivity to metabolic stimuli — a factor of importance during high-intensity muscular work [54, 55]. At this age, structural remodelling of arteriolar smooth muscle also progresses, shaping the future adaptive capacity of the vascular system.

Hormonal regulation plays a particularly prominent role in this period, driven by elevated levels of testosterone, growth hormone, and IGF-1 [56, 57]. These hormones support anabolic stimulation of the myocardium, enhance energy metabolism, increase contractile performance, and contribute to the overall functional tone of the cardiovascular system.

The incomplete morphofunctional maturation of the circulatory system in adolescent males determines the specificity of their responses to different types of physical exercise. Hemodynamic reactions at this age develop against the background of not fully consolidated neurovegetative regulation, ongoing myocardial remodelling, and active hormonal transformation. During prolonged moderate-intensity cyclic exercise (running, swimming, cycle ergometry), adolescents exhibit a marked increase in HR, moderate growth in SV, and elevation of CO [58, 59]. The hemodynamic response is predominantly chronotropic, as inotropic and vasodilatory reserves are not yet fully developed. Following exercise cessation, delayed recovery of baseline HR and BP is often observed, indicating functional immaturity of baroreflex regulation [59, 60].

In response to anaerobic or static exercise (resistance training, isometric holds), the hemodynamic reaction is characterised by a sharp increase in systolic and diastolic BP, a substantial rise in HR, and elevated PVR [24, 61, 62].

This pattern results from the centralisation of circulation, activation of sympathetic pathways, and catecholamine release under conditions of insufficient vasodilatory compensation in active muscle groups. In adolescent males, these responses may be hyperreactive or labile, manifested by inadequate control of systemic BP and uneven blood distribution.

Mixed exercises (aerobic–anaerobic), such as high-intensity interval training, circuit training, or team sports, elicit a combined hemodynamic response in adolescents, involving alternating phases of sympathetic activation and reactive vasodilation [63, 64]. At this developmental stage, regulatory mechanisms lack full synchronisation, leading to marked HR variability, transient periods of increased cardiac loading, delayed stabilisation of venous return, and potential disturbances in BP regulation [63, 64, 65]. These factors necessitate careful dosage of exercise.

Functional training (e.g., TRX, unstable-surface exercises) requires substantial involvement of postural control, microcirculatory regulation, and hemodynamic plasticity. In adolescents, such training activates compensatory reserves of venous return, modifies deep stabiliser muscle tone, and enhances HRV, but may provoke orthostatic instability or BP fluctuations due to incomplete integration of autonomic responses [66, 67]. Despite this, functional training is regarded as a promising modality for developing autonomic balance in youth.

Thus, in adolescent males, the circulatory system remains in a transitional stage between completed anatomical development and full functional maturity, which underlies its sensitivity to external stimuli, high reactivity, and variability of adaptive responses. These factors must be taken into account when interpreting exercise reactions, designing individual training programmes, and preventing cardiovascular dysfunction.

The period of early adulthood in men is characterised by the highest stability and functional completeness of the circulatory system.

An optimal relationship between myocardial structural maturity and functional efficiency provides favourable conditions for adaptation to physical and psycho-emotional loads [68, 69]. At this ontogenetic stage, the heart exhibits its best contractile performance: SV, contraction and relaxation rates, and overall systolic–diastolic function fall within the upper physiological range [13, 25, 70]. Cardiac output adequately supports elevated metabolic demands, particularly during physical activity. Hemodynamic parameters are stable and demonstrate clear autoregulation with rapid adaptive adjustment [13, 24, 71].

The vascular system of young adult men is likewise in a phase of maximal functional activity. Arteries maintain high elasticity, ensuring effective dampening of the pulse wave and regulation of peripheral resistance [72, 73]. Capillary density is maximal, providing optimal oxygen and substrate delivery [32, 33]. The venous system demonstrates efficient venous return with minimal signs of venous stasis even during prolonged muscular work [23, 62].

Cardiovascular regulation at this age is maintained by a balanced interaction between sympathetic and parasympathetic divisions. High resting HRV reflects substantial adaptive reserves, while adequate visceral responses to load confirm the effectiveness of rapid regulatory mechanisms [62, 74]. Central hemodynamic regulation is also well coordinated: the hypothalamic–pituitary–adrenal axis maintains homeostasis efficiently under stress and physical exertion.

Endothelial function remains highly sensitive to vasoactive stimuli. Synthesis of nitric oxide and other vasodilators meets physiological demands, supporting efficient tissue perfusion and preventing endothelial dysfunction [37, 75]. Anti-atherogenic properties of the endothelium remain strong, limiting early vascular pathology. BP stability is characteristic of this age group in the absence of risk factors, while vascular tone is effectively supported by neurohumoral mechanisms with high sensitivity to exercise [15, 76]. Rapid post-exercise recovery of homeostatic parameters reflects robust stress-response and adaptation systems.

The hormonal profile of men in early and mid-adulthood plays a crucial role in maintaining optimal cardiovascular function. Testosterone, growth hormone, and IGF-1 enhance myocardial contractility, cardiomyocyte metabolism, and vascular regulation [77, 78]. This hormonal milieu supports healthy anabolic processes in skeletal muscle and myocardium and prevents early dystrophic changes [35, 79].

The physiological optimum of this age allows the use of intensive training regimes with minimal cardiovascular risk, provided principles of progression, safety, and individualisation are followed [80, 81]. This period enables the greatest training effect, as morphological and functional adaptations are expressed rapidly and fully. Nevertheless, within both adolescent and early adult groups, interindividual differences in hemodynamic reactivity persist, influenced not only by training status but also by age-specific features of cardiovascular functional maturity [18, 19, 24, 82].

In men of early adulthood, the hemodynamic response to physical exercise—particularly anaerobic or mixed modalities—is often accompanied by a more pronounced increase in HR and BP due to predominant sympathetic activation [5, 23, 25].

This is associated with the incomplete maturation of autonomic regulatory mechanisms, relatively lower vascular elasticity, and reduced stroke efficiency of the heart [15, 75, 83–85]. With advancing age, these responses become better balanced due to improved baroreceptor control, stabilised cardiac rhythm, increased stroke volume, and reduced dependence of cardiac output on HR [86, 87].

Aerobic exercise in men of early adulthood induces smaller BP fluctuations and a more economical HR response compared with younger individuals [9, 88, 89]. In resistance or interval exercise, significant differences are observed in vasoconstrictor responses and recovery dynamics: in individuals under 20 years, these processes are less stable, and the return to baseline may be delayed [5, 15, 24, 62].

In the context of aging, the circulatory system undergoes a complex set of morphofunctional changes that define a hemodynamic profile dominated by compensatory rather than adaptive mechanisms [90, 91].

Older age in men is characterised by the onset and progression of cardiovascular pathologies, further exacerbated by the diminished cardioprotective influence of testosterone [91, 92]. Within the central circulatory component, progressive reductions in myocardial elasticity, decreased β-adrenergic receptor density, and weakened inotropic responses are observed [93, 94]. Left ventricular contractility declines both at rest and—more markedly—during physical exertion, limiting increases in SV and CO. Although ejection fraction may remain within a relatively normal range through compensatory redistribution, reduced diastolic compliance and impaired early diastolic filling are typical features of the aging heart [94, 95].

Resting HR in older men is generally lower compared to younger groups, yet the adaptive HR rise during exercise is slower and less pronounced [86, 95]. This is attributed to attenuated sympathoadrenal responsiveness, reduced baroreceptor sensitivity, and diminished HRV reserves [96, 97]. Consequently, the cardiovascular system’s ability to respond rapidly to changing conditions is limited, predisposing older men to orthostatic hypotension, tachycardia, or ischemia.

Additionally, myocardial energetic potential declines with age due to impaired mitochondrial metabolism, oxidative stress, and reduced activity of electron transport chain enzymes [98]. Combined with degenerative alterations in the cardiac conduction system, this increases the risk of arrhythmias, lowers exercise tolerance, and heightens the probability of heart failure even under moderate loads. Age-related myocardial changes—such as fibrosis and fatty infiltration—further reduce contractile performance and pumping capacity [99]. The accumulation of atherosclerotic plaques in the coronary arteries may lead to the development of ischemic heart disease, compromising myocardial trophism and impairing its physiological function [90, 100].

At the peripheral level, substantial age-related alterations occur within the vascular wall. An increase in collagen content, a reduction in elastic fibres, and calcification of the intima and media lead to a progressive rise in arterial stiffness [100, 101]. Consequently, systolic BP increases, producing the isolated systolic hypertension typical of advanced age. Peripheral vascular resistance also tends to rise, further complicating the heart’s pumping function. Elevated thrombotic risk—resulting from age-related changes in coagulation homeostasis—is an additional contributor to the development of arterial hypertension [101]. Endothelial dysfunction, characteristic of older men, manifests as reduced NO production, impaired vasodilatory capacity, and increased activity of pro-inflammatory cytokines [101, 102]. These changes play a central role in the development of atherosclerotic lesions, endothelial injury, and microcirculatory impairment, especially in the presence of metabolic comorbidities (type 2 diabetes, dyslipidaemia, etc.) [102, 103].

Thus, the hemodynamic profile of older men is energetically costly, low-reserve, and multifactorially compromised, necessitating caution in prescribing physical exercise and requiring continuous monitoring of cardiovascular function. In older men, physical activity remains a key determinant of cardiovascular functional capacity.

However, aging affects not only baseline hemodynamic parameters but also the nature of both acute and chronic responses to exercise. After moderate-intensity cyclic exercise (walking, light running, swimming), older men exhibit moderate increases in HR and CO, yet the rise in SV is substantially smaller compared with younger individuals [104]. This is caused by reduced diastolic function and diminished venous return due to decreased venous wall tone. PVR does not always adequately decrease, limiting vasodilatory mechanisms. Post-exercise hemodynamic recovery is slowed, reflecting reduced autonomic plasticity and delayed parasympathetic reactivation [88, 104].

In the long term, regular aerobic training contributes to reductions in pulse pressure, improved endothelial sensitivity to NO, enhanced microcirculation, and partial normalisation of HRV; however, structural vascular changes remain limited because of fibrotic–calcific arterial transformation [105].

Resistance exercise in older men induces marked increases in systolic and diastolic BP, driven by sympathoadrenal activation and peripheral vasoconstriction [105, 106]. Acute elevations in PVR combined with reduced arterial elasticity create conditions for excessive pressure loading on the left ventricle [106, 107]. In some individuals, transient myocardial ischemia or arrhythmias may occur, particularly with improper breathing or underlying subclinical atherosclerosis. With long-term, appropriately dosed resistance training, improvements in venous return, increased muscle capillarisation, and stabilisation of afterload are possible; nonetheless, hemodynamic adaptation requires extended time and strict individualisation.

During interval or circuit-based mixed training, older men demonstrate unstable hemodynamic patterns, characterised by rapid HR increase, inconsistent vascular responses, and insufficient SV augmentation [108]. Autonomic regulation loses its rapid adaptive capacity, impairing effective switching between sympathetic and parasympathetic dominance. With adaptation, improvements in parasympathetic reactivity, better autonomic balance, and more stable exercise HR may occur, but only with careful monitoring of BP, pulse, and HR recovery.

Functional exercises (e.g., TRX, unstable-surface tasks) require high multisystem coordination, activation of deep stabiliser muscles, and dynamic redistribution of blood flow [108, 109]. In older men, such activity elicits significant fluctuations in HR, BP, and HRV, reflecting increased reliance on sympathetic reserves. During recovery, hypotensive responses or orthostatic instability are common due to impaired venous tone and delayed parasympathetic reactivation [109]. Adaptively, functional training may improve postural hemodynamic control, enhance afferent sensitivity, normalise venous return, and potentially reduce the need for antihypertensive correction, though benefits depend on intensity, duration, and training experience.

Thus, in older men, the reactive hemodynamic response to physical exercise is characterised by limited reserves, delayed regulatory adjustment, and potential hyperreactivity of the pressure component.

Adaptive changes operate within a narrow physiological window, necessitating a high level of individualisation. Aerobic and functional exercise modalities offer the most favourable profile when progressed gradually, whereas anaerobic and mixed modes require increased caution.

Conclusion. Age-related morphofunctional characteristics of the heart, vascular system, and autonomic regulation determine the hemodynamic responses to various types of physical exercise (aerobic, anaerobic, mixed, and functional). In adolescence, sympathetic reactivity predominates, providing high adaptability yet contributing to unstable BP regulation. In mature men, responses are balanced, with optimal adaptive reserves. Older age is defined by reduced HRV, diminished SV, arterial stiffness, and decreased efficiency of neurohumoral responses.

The synthesis of available data indicates a clear need for age-specific individualisation of training programmes in men, accounting for hemodynamic reactivity, cardiovascular risk, and physical fitness level. Further research should refine effective and safe exercise strategies to maintain cardiovascular health across the male lifespan.

Perspectives for future research. Future studies should clarify the underlying mechanisms of age-related differences in reactive and adaptive cardiovascular responses to different exercise types, particularly focusing on endothelial function markers, HRV metrics, and arterial stiffness. Investigating the roles of neurohumoral regulation and baroreceptor sensitivity in modulating acute and chronic hemodynamic changes across age groups is especially promising.

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Сойніков Я. І., Лук'янцева Г. В.

РЕАКТИВНІ ТА АДАПТИВНІ ЗМІНИ СЕРЦЕВО-СУДИННОЇ СИСТЕМИ ЧОЛОВІКІВ У ВІДПОВІДЬ НА РІЗНІ ВИДИ ФІЗИЧНИХ ВПРАВ: ФІЗІОЛОГІЧНИЙ ТА ТРЕНУВАЛЬНИЙ КОНТЕКСТ

Постановка проблеми. Гемодинамічні зміни, викликані фізичними вправами, є ключовим механізмом підтримки гомеостазу під час м'язової активності. Однак реактивні та адаптивні серцево-судинні реакції суттєво варіюються залежно від віку, статусу тренування та характеру фізичного навантаження. Існуючі дані, що описують, як аеробні, анаеробні, змішані та функціональні методи тренувань впливають на центральну гемодинаміку, вегетативну регуляцію та структурно-функціональні характеристики серця в різні вікові періоди, залишаються недостатньо систематизованими. Це обмежує розробку індивідуалізованих тренувальних програм, заснованих на віково-специфічних фізіологічних закономірностях.

Мета. Визначити вікові особливості реактивних та адаптивних змін серцево-судинної системи чоловіків у відповідь на фізичні вправи різної метаболічної спрямованості та охарактеризувати механізми, що лежать в основі гемодинамічних реакцій та адаптацій, викликаних тренуванням.

Методи. Було проведено систематичний аналіз сучасної наукової літератури з використанням баз даних PubMed, Scopus, Web of Science та Google Scholar. Спочатку було перевірено понад 700 джерел з використанням ключових слів, пов'язаних з віковими гемодинамічними реакціями на різні типи фізичних вправ. Після багатоетапної оцінки релевантності та повнотекстової оцінки, до остаточного синтезу було включено 109 публікацій.

Основні результати. Підлітковий вік характеризується переважною симпатичною реактивністю та нестабільністю барорефлексного контролю. Чоловіки в ранньому дорослому віці демонструють найвищий ступінь морфофункціональної зрілості серця та судин, демонструючи ефективну адаптацію до тренувань та оптимальний вегетативний баланс. Старший вік пов'язаний зі зниженням ударного об'єму, підвищенням жорсткості артерій та затримкою парасимпатичної реактивації. Модальність фізичних вправ значно формує профіль реакції: аеробні вправи посилюють перфузію тканин, анаеробні тренування викликають пікові пресорні реакції, змішані вправи викликають чергування симпатичних та

вазодилататорних фаз, тоді як функціональні тренування покращують міжм'язову координацію та постуральну регуляцію кровообігу.

Наукова новизна. Систематизовано вікові моделі серцево-судинної реактивності та адаптації. Обґрунтовано ранній дорослий вік як фізіологічно оптимальний період для досягнення максимального тренувального ефекту. Виявлено внутрішньоколективні відмінності в гемодинамічній чутливості в підлітковій та дорослій групах та пов'язано їх зі ступенем серцево-судинної та вегетативної зрілості.

Висновки та рекомендації. Вікові фізіологічні характеристики вимагають індивідуалізації тренувальних стратегій: підлітки потребують поступового збільшення навантаження з акцентом на стабілізацію вегетативної регуляції; дорослі чоловіки отримують найбільшу користь від комбінованих та функціональних тренувальних методів; старші люди повинні надавати пріоритет аеробним та низькоінтенсивним вправам з ретельним моніторингом гемодинамічних параметрів.

Ключові слова: система кровообігу, серце, кровоносні судини, гемодинаміка, фізичні вправи, реактивність, адаптація, чоловіки.

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