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ABSTRACT

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THE RELATIONSHIP BETWEEN EXERCISE LOAD AND THE LEVEL OF FATIGUE, ANXIETY, AND AUTONOMIC NERVOUS SYSTEM FUNCTION IN INDIVIDUALS WITH OBESITY, HYPERTENSION, TYPE 2 DIABETES, AND ATHLETES IN THE CONTEXT OF PHYSICAL REHABILITATION

Physical activity plays a crucial role in the lives of individuals with type 2 diabetes, hypertension, and obesity, contributing – when maintained within healthy limits – to improved quality and longevity of life. Among athletes, physical activity is fundamental to professional performance, ensuring an adequate level of preparedness for achieving competitive results. Consequently, motivation for engaging in physical exercise varies considerably between populations. The willingness to participate in and regulate physical activity significantly influences its impact on human health. However, the effects of varying levels of training load on the human body remain insufficiently explored. The aim of this study was to examine the relationship between training load and levels of fatigue, anxiety, and autonomic nervous system dysfunction in individuals with obesity, hypertension, type 2 diabetes, and athletes in the context of physical rehabilitation.

Materials and Methods. A total of 61 participants were included in the study and divided into two groups: a patient group (9 individuals with type 2 diabetes, hypertension, and obesity) and a group of healthy athletes (52 participants). The physical rehabilitation program for patients included individualized aerobic and strength exercises. In the patient group, the average weekly training duration over the final two weeks was 6.56 ± 2.07 hours, corresponding to a satisfactory level of physical activity (≥ 150 minutes/week). Among athletes, this value was significantly higher, averaging 18.12 ± 4.98 hours per week. Weekly training duration and load volume were assessed. Fatigue was measured using the Fatigue Assessment Scale; well-being (as a component of

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quality of life) was assessed via the WHO-5 Well-Being Index; insomnia was evaluated using the Athens Insomnia Scale; daytime sleepiness using the Epworth Sleepiness Scale; and anxiety levels were determined using the Hospital Anxiety and Depression Scale.

Results. Physical activity had differing effects on the well-being and quality of life of both patients and athletes. If for the former it was a factor in reducing fatigue and improving well-being, then for athletes it was accompanied by a deterioration in psychophysiological indicators. The latter gives grounds to assume that in people with the most significant training load during the week, a decrease in the feeling of well-being may develop precisely as a result of overfatigue, which can be physical and mental-emotional. A similar picture was observed when studying the autonomic nervous system - with an increase in the volume and duration of the load, almost all indicators of heart rate variability improved, while in athletes such a pattern was not established. This is explained by the motivation of athletes to engage in such intensive training that can exceed the level of optimal adaptive capacity of the body, become excessive and be accompanied by the accumulation of fatigue and overtraining.

Conclusions. Thus, the findings indicate that the duration and volume of physical activity have a specific impact on well-being and autonomic regulation, varying according to the characteristics of the population studied. In individuals with type 2 diabetes, arterial hypertension, and obesity, training load duration and volume demonstrated an inverse relationship with subjective fatigue and a direct relationship with perceived well-being and the majority of heart rate variability (HRV) parameters. In contrast, among athletes, increased training load was associated with greater fatigue and reduced overall well-being, without significant correlation with HRV parameters. This may suggest the onset of subjective overfatigue as an early stage of overtraining, particularly in athletes with the highest training volumes.

Keywords: exercise load, fatigue, anxiety, autonomic nervous system, obesity, hypertension, type 2 diabetes, physical rehabilitation.

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РЕЗЮМЕ

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ЗВ'ЯЗОК НАВАНТАЖЕННЯ З РІВНЕМ ВТОМИ, ТРИВОЖНОСТІ ТА ПОКАЗНИКАМИ ФУНКЦІЇ ВЕГЕТАТИВНОЇ НЕРВОВОЇ СИСТЕМИ У ОСІБ З ОЖИРІННЯМ, АРТЕРІАЛЬНОЮ ГІПЕРТЕНЗІЄЮ, ЦУКРОВИМ ДІАБЕТОМ 2 ТИПУ ТА СПОРТСМЕНІВ У КОНТЕКСТІ ФІЗИЧНОЇ РЕАБІЛІТАЦІЇ

Фізичне навантаження відіграє важливу роль для життя людей з цукровим діабетом 2 типу, артеріальною гіпертензією та ожирінням, дозволяючи, якщо воно в здорових межах, покращувати якість та тривалість життя. У спортсменів воно відіграє основну роль в професійній діяльності, забезпечуючи відповідний рівень підготовки для досягнення спортивного результату. Отже, значною мірою відрізняється мотивація людей займатися фізичними вправами. Саме бажання займатися ними, дозувати їх, багато в чому визначає їх вплив на здоров’я людини.

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Разом з цим, питання впливу різного рівня тренувального навантаження на організм людини до кінця не вивчено. Метою нашого дослідження, було вивчення його зв'язку з рівнем втоми, тривожності та порушеннями регуляції вегетативної нервової системи у осіб з ожирінням, артеріальною гіпертензією, цукровим діабетом 2 типу та спортсменів у контексті фізичної реабілітації.

Матеріали та методи. Всього у дослідженні взяли участь 61 учасник, які були розподілені на групу хворих (9 осіб з цукровим діабетом 2 типу, артеріальною гіпертензією та ожирінням) та здорових спортсменів (52 учасники). Програма фізичної реабілітації для осіб з цукровим діабетом 2 типу, артеріальною гіпертензією та ожирінням включала індивідуалізовані фізичні навантаження аеробного та силового характеру, тривалість щотижневих тренувань в групі хворих протягом останніх двох тижнів складала у середньому 6,56 (2,07) год./тиж. та відповідав рівню задовільної фізичної активності (≥ 150 хв./тиж.), у спортсменів вона була значно вищою і складала відповідно 18,12 ± 4,98 год. Проводилися оцінка тижневих тривалості та обсягу навантажень, визначення рівня втоми за шкалою Fatigue Assessment Scale, показника WHO-5, що відображає благополуччя (якість життя), кількісну оцінку безсоння проводили за Athens Insomnia Scale, сонливості за Epworth Sleepiness Scale, рівень тривожності визначали за Hospital Anxiety and Depression Scale.

Результати. Фізичне навантаження по різному впливало на самопочуття та якість життя хворих людей і спортсменів. Якщо у перших воно було фактором зменшення втоми та покращення благополуччя, то у атлетів супроводжувалося погіршенням психофізіологічних показників. Останнє дає підстави припустити, що у осіб з найбільш значним тренувальним навантаженням протягом тижня зменшення відчуття благополуччя може розвиватися саме внаслідок перевтоми, яка може бути фізичною і психоемоційною. Подібну картину спостерігали при вивченні вегетативної нервової системи – при зростанні обсягу та тривалості навантаження покращувалися практично всі показники варіабельності серцевого ритму, в той час, як у спортсменів такої закономірності встановлено не було. Зазначене пояснюється мотивацією спортсменів займатися такими інтенсивними тренуваннями, що можуть перевищувати рівень оптимальної адаптаційної здатності організму, ставати надмірними та супроводжуватися накопиченням втоми та перетренованості.

Висновки. Таким чином, показано, що тривалість і обсяг фізичного навантаження справляють специфічний вплив на самопочуття та показники вегетативної регуляції, який варіює залежно від характеристик контингенту. В осіб із цукровим діабетом 2 типу, артеріальною гіпертензією та ожирінням тривалість і обсяг тренувального навантаження мали зворотний зв’язок із рівнем суб’єктивної втоми, та прямий з показниками відчуття благополуччя та переважною більшістю параметрів варіабельності ритму серця. Натомість, у спортсменів збільшення навантаження асоціювалося з посиленням втоми та погіршенням загального самопочуття, без кореляції з параметрами варіабельності ритму серця, це може вказувати, на розвиток суб’єктивної перевтоми, як початкової стадії перетренованості у атлетів з найвищим його рівнем.

Ключові слова: фізичне навантаження, втома, тривожність, вегетативна нервова система, ожиріння, гіпертензія, діабет 2 типу, фізична реабілітація.

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INTRODUCTION

Such widespread "diseases of civilization" as type 2 diabetes, arterial hypertension, and obesity have a detrimental effect not only on life expectancy and hospitalization rates but also on patients' quality of life, particularly when these conditions are combined [1]. It is well known that physical activity can influence quality of life in such patients [2, 3]. An individual is considered physically active if they perform aerobic exercises – such as walking, jogging, swimming, cycling, or participating in team sports – for 30–60 minutes, five days per week, in addition to strength training 2–3 times per week for 30–45 minutes [4]. Physical activity, especially a combination of aerobic and resistance exercises, contributes to lowering blood pressure, improving insulin sensitivity, and reducing body weight – effects that are particularly beneficial in the context of diabetes, hypertension, and obesity. According to 2021 data, such combined exercise programs are the most effective in improving glycemic control, blood pressure, and insulin resistance in adults with type 2 diabetes who are overweight or obese [5].

However, the relationship between this combination of chronic conditions and symptoms such as fatigue, well-being, anxiety, and sleep disturbances has been studied to a much lesser extent. According to the literature, patients with type 2 diabetes, obesity, and arterial hypertension frequently experience elevated fatigue and reduced overall well-being, often accompanied by symptoms of anxiety. These manifestations may occur even in the early stages of chronic illness and tend to progress over time. Studies indicate that psychological and physiological symptoms are closely intertwined, forming a multifactorial mechanism that contributes to the deterioration of a patient's condition. These effects are further exacerbated by frequent sleep disturbances, including poor sleep quality and instability, which in turn intensify fatigue and diminish quality of life. Anxiety, which is commonly observed in this patient population, negatively affects sleep perception and overall well-being, creating a vicious cycle in which chronic disease perpetuates sleep disorders, and poor sleep worsens the individual's mental-emotional state [6, 7, 8].

The impact of physical activity duration and training load volume on the previously noted symptoms remains insufficiently explored in the literature. This gap applies not only to physically active individuals with type 2 diabetes, hypertension, and obesity but also to athletes, in whom fatigue is an expected physiological response associated with the supercompensation process that underlies performance adaptation [9]. The specific effects of exercise intensity on the autonomic nervous system also remain unclear in both patients and athletes. In the latter individuals, overload is a common phenomenon that can lead to the development of overtraining syndrome and impaired autonomic regulation. Excessive physical load negatively affects heart rate variability (HRV), reducing its parameters, which reflects diminished parasympathetic activity and increased physiological stress. Furthermore, a relationship has been established between prehypertension and myocardial repolarization abnormalities [10, 11]. These changes can impair recovery, reduce physical performance, and increase the risk of injury [9]. In contrast, the response to intense physical activity in patients with type 2 diabetes, arterial hypertension, and obesity may follow different patterns, as this population typically lacks the competitive motivation characteristic of athletes. The aim of this study was to examine the relationship between weekly exercise duration and training load with levels of fatigue, anxiety, and autonomic nervous system dysfunction in physically active individuals with obesity, hypertension, type 2 diabetes, and in athletes. The aim of this study was to examine the relationship between training load and levels of fatigue, anxiety, and autonomic nervous system dysfunction in individuals with obesity, hypertension, type 2 diabetes, and athletes in the context of physical rehabilitation.

MATERIALS AND METHODS

The study involved 9 individuals with a confirmed diagnosis of type 2 diabetes, arterial hypertension, and obesity (patient group, PG) and 52 track and field athletes (healthy group, HG). Assessments were conducted at the Sports Medicine Center of Sumy State University. The mean age of participants in the HG was 22.35 ± 3.28 years, of whom 20 (38.5 %) were female. In the PG, the mean age was significantly higher at 46.22 ± 7.38 years.

This group included 5 women, accounting for 55.6 %, with no statistically significant difference in sex distribution compared to the HG (p = 0.355). The mean values of the PG group before the start of the study were as follows: glucose level 7.2 (0.8) mmol/L, HbA1c 6.8 (0.5) %, systolic BP 140 (8) mmHg, diastolic BP 90 (5) mmHg, BMI 34.5 (3.5) kg/m² Participants were eligible for inclusion if they provided informed consent, had diabetes mellitus, arterial hypertension, and obesity, and had a level of physical fitness that allowed them to perform the proposed physical therapy program.

The rehabilitation program for individuals with type 2 diabetes, arterial hypertension, and obesity included individualized aerobic and resistance training aimed at improving metabolic parameters, cardiovascular function, and reducing body weight. Participants engaged in moderate-intensity aerobic exercises – such as walking, jogging, cycling, stationary biking, and swimming – performed for 30–45 minutes, 3–5 times per week. Strength training sessions were conducted 2–3 times per week, targeting major muscle groups with gradually increasing loads to enhance metabolism, muscle mass, and insulin sensitivity. The program was supplemented by educational interventions, lifestyle modification strategies, and psycho-emotional support to improve recovery outcomes and prevent complications. In the patient group (PG), the average weekly training duration during the final two weeks was 6.56 ± 2.07 hours, corresponding to a satisfactory level of physical activity (≥ 150 minutes/week). All patients were on stable therapy, including metformin (500–1000 mg/day), ACE inhibitors (in moderate therapeutic doses) for at least 3 months prior to study inclusion. The risk of hypoglycemia was managed by monitoring blood glucose levels after exercise and individualizing the exercise intensity, considering the patient's existing risk factors.

Track and field athletes (healthy group, HG) were assessed during the preparatory phase of their annual macrocycle. All had undergone mandatory yearly medical evaluations and were declared healthy by a sports physician. In the HG, the average weekly training duration during the final two weeks was 18.12 ± 4.98 hours, with training taking place 5–6 days per week. Among them, 20 individuals (38.5 %) specialized in endurance-based athletic disciplines. The study was conducted in accordance with the principles of the Declaration of Helsinki, and all participants provided written informed consent.

Based on participants' subjective assessment of the average perceived training intensity over the past two consecutive weeks using the 10-point Session-RPE scale, weekly training load (TL) was calculated as the product of the Session-RPE score and the total weekly duration of physical activity [12]. All participants also completed the Fatigue Assessment Scale to evaluate fatigue levels [13], the WHO-5 Well-Being Index to assess quality of life [14], the Athens Insomnia Scale (AIS) for insomnia severity [15], the Epworth Sleepiness Scale (ESS) for daytime sleepiness [13], and the Hospital Anxiety and Depression Scale (HADS) to determine anxiety levels [13]. Autonomic nervous system function was evaluated through heart rate variability (HRV) analysis, based on a 4–6 minutes, electrocardiogram recorded using the automated diagnostic system "Cardio+." The following indicators were studied: SDNN (ms) - standard deviation of NN intervals, RMSSD (ms) - root mean square of successive differences, PNN50 (%) - percentage of successive NN intervals differing by more than 50 ms, LF (ms²) - low-frequency power, HF (ms²) - high-frequency power, LF/HF Ratio - ratio of low- to high-frequency power, SD1 (ms) - standard deviation perpendicular to the line of identity. Time-domain HRV parameters included RMSSD, SDNN, and PNN50%. Frequency-domain analysis was conducted using fast Fourier transform (FFT), measuring the power of key spectral bands – high-frequency (HF, 0.15–0.40 Hz), low-frequency (LF, 0.04–0.15 Hz), total spectral power, and the LF/HF ratio. Additionally, the nonlinear geometric HRV indicator SD1, representing the standard deviation perpendicular to the line of identity in the Poincaré plot, was calculated to further characterize autonomic regulation [16].

Statistical analysis was performed using the online service http://socscistatistics.com. The Kolmogorov–Smirnov test was used to assess the normality of data distribution. Continuous variables were presented as the mean and standard deviation (M ± SD) for normally distributed data, or as the median and interquartile range (Me [IQR]) for non-normally distributed data. Categorical variables were reported as percentages. To assess statistically significant differences between groups, a two-tailed t-test was applied for normally distributed data, while the Mann–Whitney U test was used when normality was not met in at least one group. Frequencies were compared using the chi-square (χ^2) test with Yates' correction. Correlation analysis was performed using Pearson's correlation coefficient. Statistical significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

We intentionally selected two highly contrasting groups in terms of health status and training intensity: the patient group (PG), engaged in physical rehabilitation, and the healthy group (HG), consisting of athletes. As expected, significant differences were observed in weekly training duration, perceived exertion, and resulting training load between the groups ($P < 0.001$). Despite chronic conditions such as type 2 diabetes, arterial hypertension, and obesity, the level of physical activity in the PG exceeded the recommended minimum and averaged 6.56 ± 2.07 hours per week. The lowest weekly training duration among PG participants was 3 hours, with a corresponding training load of 540 arbitrary units (AU). In comparison, athletes engaged in speed–strength disciplines reported a minimum of 6 hours per week and a training load of 600 AU, while those specializing in endurance disciplines trained at least 8 hours per week with training loads reaching 2400 AU. Notably, this highest training load observed among endurance athletes matched the maximum recorded in the PG, where one participant trained for 10 hours per week.

When comparing psychophysiological parameters between groups, the healthy athletes (HG) demonstrated consistently more favorable outcomes, as expected (Table 1). This included significantly lower levels of chronic fatigue ($P = 0.025$), better well-being ($P < 0.001$), lower anxiety scores ($P < 0.001$), and fewer insomnia symptoms ($P = 0.004$). No statistically significant difference was found in daytime sleepiness as measured by the Epworth Sleepiness Scale ($P = 0.110$). The proportion of individuals reporting persistent fatigue was notably higher in the patient group (PG), with 6 participants (66.7 %) affected, compared to 11 participants (21.2 %) in the HG ($P = 0.015$). Clinically relevant anxiety was also more prevalent in the PG, observed in 4 participants (44.4 %), whereas only 5 individuals (9.6 %) in the HG met the threshold, a statistically significant difference ($P = 0.027$). Overall, the majority of psychophysiological indicators were significantly poorer among individuals with chronic conditions, reflecting the detrimental impact of underlying pathology on their psycho-emotional well-being.

Table 1. Indicators of fatigue, well-being, anxiety, and sleep status in healthy and chronically ill participants

Parameter	Patients (PG)	Healthy (HG)	P-value
Weekly training duration (hours/week)	6.56 (2.07)	18.12 (4.98)	< 0.001
Perceived exertion (Session-RPE score)	3.67 (0.50)	5.94 (1.13)	< 0.001
Training load (arbitrary units)	1473.3 (577.9)	6223.9 (2190.7)	< 0.001
Fatigue (FAS scale)	24.0 (7.16)	19.65 (4.82)	0.025
Well-being (WHO-5 index)	16.56 (4.00)	20.63 (2.66)	< 0.001
Anxiety (HADS)	11.33 (3.32)	7.23 (3.05)	< 0.001
Insomnia (AIS)	6.67 (3.12)	3.60 (2.79)	0.004
Sleepiness (ESS)	8.44 (4.28)	6.27 (3.62)	0.110

Table 2 presents the results of the analysis of the strength and direction of correlations between training duration and training load with indicators of fatigue, well-being, anxiety, and sleep quality. It was shown that, in patients with chronic illness, the number of training hours per week was negatively associated with fatigue and positively associated with well-being. In athletes, however, no significant associations between training duration and psychophysiological indicators were found. As for training load, in patients it was even more strongly associated with fatigue ($p = 0.002$) and well-being ($p < 0.001$), with the direction of these correlations being consistent with those found for training duration. In athletes, training load was also significantly associated with prolonged fatigue ($p = 0.014$) and well-being ($p = 0.007$). However, unlike in patients, the direction of these associations was unfavorable – positive with fatigue and negative with well-being.

Thus, physical activity had differing effects on the well-being and quality of life of patients and athletes. For patients, it acted as a factor reducing fatigue and improving well-being, whereas in athletes, it was associated with a deterioration in psychophysiological indicators. This suggests that among individuals with the highest weekly training loads, a decrease in the sense of well-being may develop due to overfatigue, which can be both physical and mental-emotional. Physical overfatigue is primarily caused by an imbalance in the autonomic nervous system, the confirmation of which requires objective diagnostic methods. One of the most informative and convenient ways to assess autonomic dysfunction is through heart rate variability (HRV) analysis, which was the focus of the second part of our study.

The average heart rate variability (HRV) parameters were higher in the healthy athlete group compared to the patient group; however, statistical significance was reached only for the power of the high-frequency (HF) band ($p = 0.044$) (Table 3). Additionally, the athletes exhibited a lower heart rate ($p = 0.003$), further confirming the predominance of parasympathetic tone in this group.

Table 2. Correlations between weekly training duration and training load with indicators of fatigue, well-being, anxiety, and sleep quality in healthy and patient groups (Pearson's r)

Indicator	Training Duration (hours/week)				Training Load (a.u.)			
	HG	p	PG	p	HG	p	PG	p
Fatigue (FAS-scale)	- 0.009	0.950	- 0.760	0.017	0.340	0.014	- 0.881	0.002
Well-being	- 0.019	0.894	0.848	0.004	- 0.370	0.007	0.912	< 0.001
Anxiety (HADS)	- 0.052	0.715	- 0.214	0.580	0.009	0.950	- 0.214	0.580
Insomnia	- 0.028	0.844	- 0.401	0.201	- 0.244	0.110	- 0.525	0.147
Sleepness	- 0.001	0.994	- 0.795	0.010	0.212	0.131	- 0.826	0.006

Table 3. Variability of the heart rhythm in the examined subjects

Parameter	Healthy (Mean ± SD)	Patients (Mean ± SD / Median (IQR))	p-value
Heart Rate (bpm)	59.69 (9.88)	71.11 (12.73)	0.003
SDNN (ms)	64.46 (17.87)	61.89 (18.86)	0.694
RMSSD (ms)	41.79 (11.25)	39.56 (12.30)	0.589
PNN50 (%)	10.85 (3.01)	9.33 (3.64) %	0.182
LF (ms²)	708.48 (187.67)	669.1 (209.8)	0.570
HF (ms²)	510.67 (184.0)	318 (523.5 – 256.5) (Median, IQR)	0.044
LF/HF Ratio	1 (1–2) (Median, IQR)	1.56 (0.53)	0.150
SD1 (ms)	30.54 (8.25)	28.67 (9.14)	0.538

The strongest associations between physical activity – both its duration and volume – and heart rate variability (HRV) parameters were observed in the patient group, where all correlations were strong and positive (Table 4). Specifically, this relationship held true for all measured HRV indices except for the LF/HF ratio, which showed no significant correlation with either duration ($p = 0.403$) or volume ($p = 0.336$) of physical activity. These findings highlight a close link between the intensity of physical exertion and autonomic regulation of heart rate specifically in this patient population. In athletes, no significant correlation was found between the intensity of physical activity and heart rate variability parameters, although there was a somewhat stronger association with the overall training load volume. Thus, the link between training load, fatigue, and well-being in athletes does not appear to be mediated by autonomic dysfunction, suggesting that overfatigue in athletes with maximum training loads is more likely of a mental-emotional nature.

Table 4. Relationship between weekly training duration and training load with heart rate variability in the Patient and Healthy Groups

Parameter	Training Duration (hours/week)				Training Load (a.u.)			
	HG	p	PG	p	HG	p	PG	p
Heart Rate	0.009	0.950	0.448	0.227	0.017	0.905	0.531	0.141
SDNN	0.066	0.642	0.864	0.003	0.016	0.910	0.821	0.007
RMSSD	0.046	0.746	0.856	0.003	0.015	0.930	0.808	0.008
PNN50	0.029	0.838	0.886	0.001	- 0.078	0.583	0.853	0.003
LF	0.055	0.699	0.864	0.003	0.002	0.989	0.820	0.007
HF	0.029	0.838	0.849	0.004	- 0.061	0.667	0.829	0.006
LF/HF	0.050	0.725	- 0.319	0.403	0.206	0.143	- 0.364	0.336
SD1	0.053	0.709	0.858	< 0.001	0.011	0.938	0.811	0.008

Thus, the data obtained indicate a positive effect of physical activity on fatigue severity, overall well-being, and particularly on autonomic nervous system function in patients with type 2 diabetes mellitus, arterial hypertension, and obesity. This is evidenced by an increase in most heart rate variability (HRV) parameters, which can be considered a marker of improved physical conditioning and a protective factor against secondary complications, ultimately contributing to increased life expectancy and reduced healthcare costs. A key element of this beneficial effect is the appropriately and individually tailored level of physical activity, which not only optimizes autonomic regulation but also serves as a powerful motivational factor encouraging patients to maintain their health and improve their overall quality of life. For this patient population, the primary outcome of physical activity is health improvement rather than competitive success or athletic achievement.

The motivational focus of athletes is primarily directed toward achieving leading positions, surpassing average performance levels, and gaining a competitive advantage. This drive necessitates regular, high-intensity training sessions, often accompanied by overload and the development of acute stress. Throughout their professional careers, athletes face numerous challenges that deplete their psychological and emotional resources, including strict adherence to a sports regimen, constant social interaction within the team, the inevitability of defeats, the risk of professional injuries, frequent transfers, and uncertainty about the future. These factors underscore the need for a comprehensive approach to post-exertional recovery, incorporating pedagogical, psychological, and medico-biological support strategies. Our results demonstrated that increased training load was associated with worsening well-being and heightened subjective fatigue, highlighting the crucial role of training load as a factor in the development of overtraining syndrome, particularly its psycho-emotional component. At the same time, no significant impact of training load on objective measures of autonomic nervous system function was observed. This suggests that heart rate variability parameters, and consequently the balance between sympathetic and parasympathetic autonomic activity, are only partially influenced by physical load per se. Individual athlete characteristics – such as training status, experience, effectiveness of recovery methods, organization of non-training time, and history of rehabilitation interventions – likely exert a greater influence on cardiac autonomic regulation.

CONCLUSIONS

The duration and volume of physical activity exert specific effects on well-being and autonomic regulation indicators, which vary depending on the characteristics of the population studied. In individuals with type 2 diabetes mellitus, arterial hypertension, and obesity, the duration and volume of training load were inversely correlated with subjective fatigue levels and positively correlated with well-being scores and most heart rate variability parameters. In contrast, among athletes, increased training load was associated with heightened fatigue and deterioration of overall well-being, without significant correlations with heart rate variability metrics. This suggests the development of subjective fatigue, potentially representing an early stage of overtraining syndrome in athletes exposed to the highest training loads.

PROSPECTS FOR FUTURE RESEARCH

Our findings emphasize the importance of individualizing physical load according to the specific characteristics of the target group. Therefore, there is a clear need for further research into the effects of physical load on health indicators across different populations — both among individuals for whom physical activity serves a rehabilitative purpose and among athletes whose performance is evaluated based on sporting success.

AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

ARTIFICIAL INTELLIGENCE DISCLOSURE

The authors declare that no artificial intelligence (AI) technologies were used during the writing or editing of the manuscript.

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