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Effect of pre-competition weight loss on onautonomic regulation and functional state qualified powerlifters

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Abstract

Background and Study Aim. Pre-competition weight loss is a common practice among powerlifters to compete in lower weight categories. However its impact on autonomic regulation and functional status in female powerlifters remains poorly understood. This study aimed to evaluate the effect of rapid weight loss on HRV in qualified female powerlifters, focusing on changes in sympathetic and parasympathetic activity. The hypothesis was that pre-competition weight loss would lead to a decrease in HRV, an increase in sympathetic activity, and a decrease in parasympathetic regulation, indicating physiological stress.

Material and methods. The study enrolled 31 qualified female powerlifters (candidates for master of sports). HRV was measured before and after a 5-10-day weight loss period using a portable cardiomonitor. Key HRV parameters were analyzed, including SDNN, rMSSD, LF, HF, and the LF/HF ratio. Statistical analysis was performed using a paired t-test in Statistica 11.0, with significance set at $p<0.05$.

Results. Significant decreases in SDNN ($p<0.001$), rMSSD ($p<0.001$), and HF ($p<0.01$) were found, indicating a decrease in parasympathetic activity. In contrast, LF ($p<0.001$) and the LF/HF ratio ($p<0.001$) increased, reflecting an increase in sympathetic activity. No significant changes in heart rate (HR) or RR intervals were found ($p>0.05$).

Conclusions. Pre-competition weight loss in skilled female powerlifters results in significant changes in HRV, characterized by increased sympathetic activity and decreased parasympathetic regulation. These changes indicate physiological stress and potential risks to cardiovascular health. The results highlight the need for individualized weight management strategies to minimize negative impacts on autonomic regulation and overall health.

Key words: heart rate variability, powerlifting, weight loss, autonomic nervous system, physiological stress.

Анотація

Вплив передзмагального зниження маси тіла на вегетативну регуляцію та функціональний стан кваліфікованих пауерліфтерів

Передумови та мета дослідження. Передзмагальне зниження маси тіла є поширеною практикою серед пауерліфтерів для участі у нижчій ваговій категорії, однак його вплив на вегетативну регуляцію функціональний стан у жінок-пауерліфтерів залишається недостатньо вивченим. Метою цього дослідження було оцінити вплив швидкого зниження маси тіла на ВСР у кваліфікованих пауерліфтерок, зосередившись на змінах у симпатичній та парасимпатичній активності. Гіпотеза полягала в тому, що передзмагальне зниження маси тіла призведе до зниження ВСР, підвищення симпатичної активності та зменшення парасимпатичної регуляції, що свідчитиме про фізіологічний стрес.

Матеріал і методи. У дослідженні взяли участь 31 кваліфікована пауерліфтерка (кандидатки в майстри спорту). ВСР вимірювали до та після періоду зниження маси тіла тривалістю 5-10 днів за допомогою портативного кардіомонітора. Аналізували ключові параметри ВСР, включаючи SDNN, rMSSD, LF, HF та співвідношення LF/HF. Статистичний аналіз виконували за допомогою парного t-критерію в програмі Statistica 11.0, рівень значущості встановлено на рівні p<0,05.

Результати. Виявлено значне зниження SDNN (p<0,001), rMSSD (p<0,001) та HF (p<0,01), що свідчить про зменшення парасимпатичної активності. Натомість LF (p<0,001) та співвідношення LF/HF (p<0,001) зросли, що відображає підвищення симпатичної активності. Значних змін у частоті серцевих скорочень (ЧСС) або R-R інтервалах не виявлено (p>0,05).

Висновки. Передзмагальне зниження маси тіла у кваліфікованих пауерліфтерок призводить до значних змін у ВСР, які характеризуються підвищенням симпатичної активності та зниженням парасимпатичної регуляції. Ці зміни свідчать про фізіологічний стрес та потенційні ризики для серцево-судинного здоров'я. Отримані результати підкреслюють необхідність індивідуалізованих стратегій управління масою тіла для мінімізації негативного впливу на автономну регуляцію та загальний стан здоров'я.

Ключові слова: варіабельність серцевого ритму, пауерліфтинг, зниження маси тіла, автономна нервова система, фізіологічний стрес.

Glossary:
HRV (Heart Rate Variability): The variation in the intervals between heart beats, reflecting the activity of the autonomic nervous system.
SDNN: Standard deviation of all RR intervals, showing the overall HRV.
rMSSD: Root mean square deviation of sequential differences, a marker of parasympathetic activity.
LF/HF Ratio: The ratio of low-frequency to high-frequency power, reflecting the balance between sympathetic and parasympathetic activity.
Autonomic regulation: The control of the autonomic nervous system over involuntary functions of the body.
Physiological stress: The body's response to external or internal stressors, often involving hormonal and autonomic changes.

Introduction

Heart rate variability (HRV) is a key indicator of the functional state of the cardiovascular system, reflecting the balance between the sympathetic and parasympathetic divisions of the autonomic nervous system. In sports physiology, HRV is widely used to assess the adaptive capabilities of athletes, the level of fatigue, and the efficiency of recovery after physical exertion [1, 2]. High heart rate variability is usually associated with good regulation of the autonomic nervous system, while its decrease may indicate overload, fatigue, or excessive stress [3].

Powerlifting is a weight-based sport where an athlete's body weight determines their competitive ability [4] Therefore, pre-competition weight loss is a common practice among powerlifters to move into a lighter weight category and gain a potential advantage in strength-to-weight ratio [5]. Methods used to do this include calorie control, dehydration, changing the intensity of the training process, and the use of saunas [6]. However, rapid weight loss can be accompanied by significant physiological changes, including fluid and electrolyte imbalances, metabolic shifts, and effects on cardiovascular function.

Of particular note is the effect of weight loss on heart rate variability in female powerlifters. Due to hormonal and physiological characteristics, the female body's response to stress factors, including weight change, may differ from that of men [7, 8], It is known that pre-competition changes in body weight can cause an imbalance between the sympathetic and parasympathetic divisions of the nervous system, which is manifested by changes in HRV [10, 11]. Such changes may indicate increased stress on regulatory mechanisms, which in turn may have an impact on athletic performance and the risk of cardiovascular complications [12].

Thus, studying the impact of pre-competition weight loss on heart rate variability in skilled powerlifters is important both for understanding adaptation mechanisms and for developing safe weight management strategies in this sport.

Existing studies demonstrate that rapid weight loss can significantly affect HRV by altering the balance between sympathetic and parasympathetic regulation of the cardiovascular system. There is a decrease in overall heart rate variability, which may indicate increased stress on regulatory mechanisms and reduced adaptive capacity of the athlete's body. In addition, changes in the ratio of low-frequency (LF) to high-frequency (HF) components of HRV indicate increased sympathetic nervous system activity in response to physiological stress caused by caloric restriction, dehydration, and intense training before competition.[3] Such adaptive responses may be temporary, but their long-term effects on the cardiovascular system remain a subject of debate in the scientific community.

Despite the significant number of studies analyzing the effects of body weight changes on HRV, most of them have focused on male athletes or combat sports participants [13]. Data on female powerlifters are limited, creating a significant gap in understanding the specific responses of the female body to pre-competition weight loss [14]. It is known that hormonal status and metabolic characteristics in women can affect the adaptive mechanisms that regulate the activity of the cardiovascular system. Accordingly, the results of studies obtained on male samples cannot be directly extrapolated to female powerlifters, which requires separate studies on female athletes [17, 18].

Despite the existence of general recommendations for weight management in sports practice, there are currently no clear standards regulating the process of pre-competition weight loss, taking into account its impact on HRV and the general condition of the cardiovascular system [8, 9]. This is particularly true in weight-based sports, such as powerlifting, where changes in body weight can be critical to an athlete's competitiveness. The lack of evidence-based recommendations for optimal weight loss strategies without negatively impacting functional status highlights the need for further research [15, 16]. In particular, the question remains important as to how HRV changes in female powerlifters in response to pre-competition changes in body weight and what mechanisms of autonomic heart rate regulation ensure adaptation to these conditions [19, 20].

The purpose of this study: evaluation of the impact of pre-competition weight loss on heart rate variability in qualified female powerlifters.

Materials and methods

Participants

The study involved 31 qualified powerlifters (candidates for master of sports), whose body weight ranged from 59.4 to 76.3 kg. All participants had at least 5 years of experience in powerlifting and regularly participated in competitions at the regional and national levels. Before the study began, all athletes provided written informed consent to participate in the study. The ethics committee of the Kharkiv State Academy of Physical Culture, where the study was conducted, approved the study protocol in accordance with the 2008 Declaration of Helsinki.

Procedure

The study was conducted in two stages: before the start of weight loss and after its completion immediately before the competition. The standard weight loss technique included calorie control, manipulation of water and electrolyte balance, and increased physical activity as part of the training process. The duration of weight loss was from 5 to 10 days. During this period, the athletes reduced their body weight by 5-7 kg each.

For the study of HRV, the mobile application "ResearchHRV" (copyright certificate No. 125199) and the Polar H10 chest heart rate monitor (https://www.polar-ukraine.com/shop/h10/). The application runs on iOS, written in Swift using the UIKit, CoreData, CoreBluetooth, AVFoundation, and Accelerate libraries. The program recorded RR intervals in the range of 400-1300 ms. To track artifacts, a median filter with a window of 5 consecutive points was used. If the RR interval value is greater than (mediana - 250 ms) and less than (mediana + 250 ms), then such a value will be recorded in the RR interval array. HRV recording was carried out in the morning hours in a sitting position, after a 5-minute rest. We measured HRV in the 300 s mode. Control processing of the research results

To verify the accuracy of the obtained HRV results, we compared the calculations of the author's mobile application "Research HRV" and the computer program "Kubios HRV Standart", Version 3.5.0. Kubios (www.kubios.com). The results of both software applications processed and presented by us in this article were identical.

HRV parameters were assessed according to international standards, including statistical and spectral indicators:

- The heart rate (HR, beats/min) – average heart rate over time
- registration period.
- The average RR interval (RRNN, ms) – the average duration of intervals between adjacent R-peaks.
- SDNN (ms) – standard deviation of all RR intervals, an indicator of overall HRV.
- rMSSD (ms) – root mean square deviation of consecutive differences between adjacent RR intervals, a marker of parasympathetic activity.
- pNN50 (%) – the proportion of consecutive RR intervals that differ by more than 50 ms, an indicator of vagal activity.
- AMo (%) – mode of distribution of RR intervals, reflecting sympathetic activity.
- The tension index (TI, UD) is an indicator of the activity of the sympathetic nervous system and the level of stress.
- The integral vegetative index (IVR, arbitrarily) – characterizes the total influence of the autonomic nervous system on the heart rhythm.

- The vegetative balance index (VBI, arbitrarily) is the ratio of sympathetic and parasympathetic activity.
- The parasympathetic active balance index (PAPR, sd. units) is a marker of the level of parasympathetic regulation of heart rate.
- VLF (ms²) is a very low-frequency component of the spectrum that reflects humoral-metabolic mechanisms of regulation.
- LF (ms²) is a low-frequency component that characterizes mixed sympathetic and parasympathetic activity.
- HF (ms²) is a high-frequency component, a marker of vagal regulation of heart rate.
- LF/HF (intellectual unit) – the ratio between low-frequency and high-frequency components, an indicator of the balance of the autonomic nervous system.
- TP (ms²) is the total power of the spectrum, reflecting the level of activity of the autonomic regulation of heart rate.

Statistical analysis

The analysis of the obtained data was carried out in the Statistica 11.0 software environment. To check the normality of the data distribution, the Shapiro-Wilk test was used. A comparison of mean values before and after weight loss was performed using the paired Student's t-test. The significance of differences was determined at a significance level of $p<0.05$. Data are presented as mean ($\overline{X}$) and standard error (m).

Results

Table 1 presents the dynamics of statistical and temporal indicators of heart rate variability before and after a 5-7 kilogram weight loss in qualified powerlifters. Analysis of these indicators allows us to draw conclusions about the nature of changes in understanding of the mechanisms of regulation of physiological functions, the general activity of regulatory mechanisms and neurohumoral regulation of the heart, the relationship between the sympathetic and parasympathetic divisions of the autonomic nervous system and the potential impact of pre-competition weight change on the functional status of female athletes.

The average heart rate (HR) in powerlifters before weight loss was 76.52±0.40beats×min^{-1}(range:73–81beats×min-1After weight loss, heart rate decreased slightly to 76.27±0.33beats×min-1(range: 73–82beats×min^{-1}). Statistical analysis ($t=0.47$, $p>0.05$) showed no significant changes. This indicates stability of heart rate during short-term weight loss, which may be a sign of high adaptation of the cardiovascular system to stress. However, it is possible that longer periods of calorie restriction or more stringent dietary interventions could affect this indicator.

The average RRNN interval before weight loss was 784.78±4.10 ms (range: 744–827 ms), after weight loss – 787.10±3.33 ms (range: 734–828 ms). Statistical analysis ($t=0.43$, $p>0.05$) did not reveal any significant changes. This indicates that short-term weight loss did not affect the regularity of heart contractions. A slight increase in RRNN may indicate adaptation of the cardiovascular system to stress, emphasizing the stability of autonomic regulation in female athletes.

The SDNN before weight loss was 60.80±0.74 ms (range: 50–67 ms), after weight loss it was 45.88±0.99 ms (range: 31–52 ms). Statistical analysis ($t=12.16$, $p<0.001$) confirmed a significant decrease in SDNN. This indicates a decrease in overall heart rate variability, which may be a consequence of physiological stress due to calorie restriction and exhaustion. Such changes indicate a weakening of the functional reserves of the autonomic nervous system.

The rMSSD before weight loss was 46.67±0.63 ms (range: 33–59 ms), after weight loss – 40.45±0.81 ms (range: 21–39 ms). Statistical analysis ($t=4.72$, $p<0.001$) confirmed a

Table 1. **The value of statistical and temporal indicators of HRV in qualified powerlifters (n=31) before and after weight loss**

Indicator	$\overline{X}$±m	min	max	t	p	Age norms
Heart rate at the beginning, beats×min^{-1}	76.52±0.40	73	80	0.47	>0.05	60-90
Heart rate at the end, beats×min^{-1}	76.27±0.33	73	82			
RRNN at the beginning, ms	784.78±4.10	744	827	0.43	>0.05	700-900
RRNN at the end, ms	787.10±3.33	734	828			
SDNN at start, ms	60.80±0.74	50	67	12.16	<0.001	60-70
SDNN at the end, ms	45.87±0.99	31	56			
rMSSD at the beginning, ms	46.67±1.04	33	59	4.72	<0.001	30-60
rMSSD at the end, ms	40.45±0.81	31	52			
pNN50 at the beginning, %	7.41±0.26	4.36	10.72	2.46	<0.05	7.0±2.0
pNN50 at the end, %	8.57±0.39	2.77	11.42			
AMo at the beginning, %	33.44±0.46	28.83	39.23	1.57	>0.05	30-50
AMo at the end, %	34.51±0.52	28.10	40.17			

significant decrease. This indicates a weakening of parasympathetic activity, which may be a consequence of stress due to energy deficiency and reduced glycogen stores. The results obtained demonstrate the importance of controlling heart rate variability to prevent negative health consequences for female athletes.

Before weight loss, the pNN50 value was 7.41±0.26% (range: 4.36–10.72%), and after weight loss, it was 8.57±0.39% (range: 2.77–11.42%). Statistical analysis (t=2.46, p<0.05) confirmed a significant increase. This reflects a significant decrease in parasympathetic influence, which may be a consequence of reduced flexibility of the autonomic nervous system due to dietary restrictions and intensive training. The obtained data emphasize the high tension of regulatory mechanisms, which may lead to a deterioration of the body's recovery reserves.

Before weight loss, the AMo value was 33.44±0.46% (range: 28.83–39.23%), and after weight loss, it was 34.51±0.52% (range: 28.10–40.17%). The results demonstrate that excessive activation of the sympathetic system can lead to depletion of the body's reserves, which needs to be taken into account when planning training programs during the competitive preparation period.

Table 2 presents the dynamics of integral heart rate variability indicators before and after weight loss in qualified powerlifters.

Before weight loss, IVR was 106.62±6.04 standard units (range: 48.76–166.36 standard units), after weight loss – 171.92±9.70 standard units (range: 74.23–314.11 standard units). Statistical analysis (t=5.71, p<0.001) confirmed a significant increase. This reflects an increase in the activity of the autonomic regulation of the autonomic nervous system, in particular the sympathetic division, which is characteristic of states of physiological stress. The obtained data indicate an increase in the load on the cardiovascular system, which may reduce the adaptive capabilities of the body and require correction of training and nutritional programs.

Before weight loss, the VPR was 8.14±0.21 standard units (range: 5.26–10.73 standard units), after weight loss – 9.11±0.21 standard units (range: 6.77–11.83 standard units). Statistical analysis (t=3.23, p<0.01) confirmed a significant increase. This indicates an increase in sympathetic influence compared to parasympathetic, which is a reaction to stress factors. The results obtained indicate the dominance of resource activation over recovery, which may increase the risk of overloading adaptive mechanisms and reduce the effectiveness of recovery.

At the beginning of the study, PAPR was 53.29±0.29 standard units (range: 50.01–56.00 standard units), after weight loss it was 53.31±0.54 standard units (range: 45.21–57.20 standard units). Statistical analysis (t=0.03, p>0.05) did not reveal any significant changes. This indicates the stability of parasympathetic activity, which may indicate a high adaptive capacity to physiological stress. The obtained data emphasize the importance of this stability for maintaining recovery processes and the functional state of the body.

Before weight loss, the IN was 93.92±7.39 standard units (range: 59.92–121.27 standard units), after weight loss – 138.85±6.52 standard units (range: 45.86–235.86 standard units). Statistical analysis (t=6.33, p<0.001) confirmed a significant increase. This reflects an increase in the intensity of regulatory mechanisms, which is a reaction to stressful conditions associated with weight loss. The results obtained indicate an increase in sympathetic activity, which can lead to a decrease in adaptive reserves and the risk of exhaustion of the body.

VLF, which reflects the activity of humoral-metabolic mechanisms of heart rate regulation, had an average value of 454.52±15.93 ms² before the start of weight loss, with a minimum value of 264.96 ms² and a maximum of 601.18 ms². After weight loss, the average VLF index significantly increased to 767.67±26.02 ms², with a minimum value of 510.24 ms² and a maximum of 1188.84 ms². Statistical analysis (t=10.26, p<0.001) indicates a significant increase in this index.

The increase in VLF after weight loss indicates an increase in the humoral-metabolic component of regulation, which is likely activated in response to stressful conditions, such as calorie restriction

Table 2. **Values of integral HRV indices of qualified powerlifters (n=31) before and after weight loss**

Indicator	$\overline{X}$±m	min	max	t	p	Age norms
IVR at the beginning, um.unit.	106.62±6.04	48.76	166.36	5.71	<0.001	100-300
IVR at the end, um.unit.	171.92±9.70	74.23	314.11			
VPR at the beginning, modal unit.	8.14±0.21	5.26	10.73	3.23	<0.01	7.1-9.3
VPR at the end, modal unit.	9.11±0.21	6.77	11.83			
PAPR at the beginning, modal.	53.29±0.29	50.01	56.00	0.03	>0.05	35-70
PAPR at the end, um.unit.	53.31±0.54	45.21	57.32			
IN at the beginning, accusative singular	93.92±2.79	59.92	121.27	6.33	<0.001	70-140
IN at the end, accusative singular	138.85±6.52	45.86	215.37			

Table 3. Values of HRV spectral indices of qualified powerlifters (n=31) before and after weight loss

Indicator	$\overline{X}\pm m$	min	max	t	p	Age norms
VLF at the beginning, ms²	454.52±15.93	264.96	601.18	10.26	<0.001	310-1117
VLF at the end, ms²	767.67±26.02	510.24	1188.84			
LF at the beginning, ms²	755.28±31.13	430.96	1064.16	6.25	<0.001	448-1058
LF at the end, ms²	1055.19±36.45	773.18	1559.26			
HF at the beginning, ms²	585.15±22.44	359.38	787.11	3.47	<0.01	95-486
HF at the end, ms²	487.42±16.96	276.21	768.24			
LF/HF at the beginning, standard unit	1.34±0.07	0.64	2.27	7.39	<0.001	0.5-4.2
LF/HF at the end, standard unit	2.23±0.10	1.14	3.64			
TP at the beginning, ms²	*2310.28±44.06*	1894.51	2935.23	8.15	<0.001	1937-4590
TP at the end, ms²	1794.94±45.29	1265.53	2163.33			

and intensive training. Such an increase may be associated with the mobilization of the body's adaptive reserves aimed at maintaining homeostasis in conditions of energy deficiency. A high level of VLF is a marker of the tension of the regulatory system, which requires attention to prevent its overload.

LF which reflects both sympathetic and parasympathetic activity, but with a predominance of sympathetic regulation, before the start of weight loss was 755.28±31.13 ms², with a minimum value of 430.96 ms² and a maximum of 1064.16 ms². After weight loss, the average LF index significantly increased to 1055.19±36.45 ms², with a minimum value of 773.18 ms² and a maximum of 1559.26 ms². Statistical analysis (t=6.25, p<0.001) confirmed a significant increase in this index.

The increase in LF indicates the activation of the sympathetic nervous system in response to the physiological stress associated with weight loss. This may be a consequence of the mobilization of the body to increased loads in the pre-competition period. A high level of LF after weight loss also indicates adaptive changes aimed at maintaining the stability of the cardiovascular system, but at the same time it is a sign of increased tension of regulatory mechanisms. An excessive increase in this indicator may signal the risk of depletion of adaptation reserves, which requires careful monitoring.

HF, which reflects the activity of the parasympathetic nervous system and is an indicator of vagal regulation of heart rate, before the start of weight loss was 585.15±22.44 ms², with a minimum value of 359.38 ms² and a maximum of 787.11 ms². After weight loss, the average HF decreased to 487.42±16.96 ms², with a minimum value of 276.21 ms² and a maximum of 768.24 ms². Statistical analysis (t=3.47, p<0.01) showed a significant decrease in this indicator.

The decrease in HF after weight loss indicates a weakening of parasympathetic regulation of heart rate. This may indicate a decrease in recovery processes and a dominance of sympathetic activity. The decrease in HF also reflects a reduction in the adaptive capacity of the parasympathetic nervous system, which may be a critical factor in maintaining the overall functional state of female athletes in the pre-competition period.

The LF/HF ratio, which is a marker of the balance between sympathetic and parasympathetic activity, was 1.34±0.07 conventional units before the start of weight loss, with a minimum value of 0.64 conventional units and a maximum of 2.27 conventional units. After weight loss, the average LF/HF value significantly increased to 2.23±0.10 conventional units, with a minimum value of 1.14 conventional units and a maximum of 3.64 conventional units. Statistical analysis (t=7.39, p<0.001) confirmed a significant increase in this indicator.

An increase in the LF/HF ratio after weight loss indicates a significant predominance of sympathetic activity over parasympathetic. An increase in this indicator may indicate an imbalance in the functioning of the autonomic nervous system, which is a signal of increased tension of regulatory mechanisms. An excessive increase in the LF/HF ratio may lead to the depletion of adaptive reserves.

The total spectrum power (TP), which is an integral indicator of the overall activity of the autonomic nervous system, before the start of weight loss was 2310.28±44.06 ms², with a minimum value of 1894.51 ms² and a maximum of 2935.23 ms². After weight loss, the average TP value significantly decreased to 1794.94±45.29 ms², with a minimum value of 1265.53 ms² and a maximum of 2163.33 ms². Statistical analysis (t=8.15, p<0.001) confirmed a significant decrease in this indicator. Low values are an unfavorable sign and indicate low stress resistance and insufficient adaptive capabilities of the CNS when using the generally accepted approach of specialists to weight loss.

Discussion

The results of the study confirm that a pre-competition weight loss of 5-7 kg in qualified female powerlifters is accompanied by significant changes in heart rate variability (HRV), indicating an increase in the tension of the autonomic regulation of the cardiovascular system. Although the average heart rate (HR) remained relatively stable ($p>0.05$), indicating the maintenance of overall cardiovascular stability, detailed analysis of HRV revealed a decrease in SDNN, rMSSD and pNN50 ($p<0.001$), which is a characteristic sign of a decrease in parasympathetic influence and an increase in the level of physiological stress.

These changes are consistent with other studies demonstrating that weight loss, particularly through manipulation of fluid and electrolyte balance, can lead to a reduction in overall heart rate variability and a decrease in parasympathetic activity [21]. The increase in tension index (TI) ($p<0.001$) and AMo mode ($p<0.05$) further confirms the activation of the sympathetic nervous system in response to the weight loss process. Similar changes have been recorded in combat sports athletes after rapid weight loss (6 kg in 8 days) before competitions [5,22].

Spectral analysis of HRV also confirmed the predominance of sympathetic activity: the LF value increased significantly ($p<0.001$), while HF significantly decreased ($p<0.01$), indicating the suppression of parasympathetic regulation. As a result, the LF/HF ratio increased significantly ($p<0.001$), indicating a shift towards sympathicotonia. The increase in total spectral power (TP) may also reflect the increase in autonomic nervous system activity under physiological stress [23,24].

These results have important practical implications, as they indicate the potential risks associated with pre-competition weight loss in female powerlifters. Although competitive practice in weight categories involves weight control, the data indicate the need for more controlled and individualized weight loss strategies. In particular, the impact of different weight loss methods on the functional state of female athletes should be considered and the risks of excessive sympathetic nervous system activation should be minimized.

The results of our study are consistent with other scientific studies that indicate that rapid weight loss can lead to significant changes in the functioning of the autonomic nervous system. For example, a study [5] showed that weight loss in judo athletes leads to a decrease in parasympathetic activity and an increase in sympathetic influence, which significantly affects their physiological stability. The authors found that a 5-10% weight loss over five days leads to a decrease in heart rate variability (HRV) indices, such as SDNN and rMSSD, indicating an increase in the tension of regulatory mechanisms. These results confirm our data, where we also observed a decrease in SDNN and rMSSD after pre-competition weight loss [5].

Similar results were obtained in a study [25], where it was found that a 5 kg weight loss in 6 days in combat sports athletes is accompanied by an increase in stress levels and a decrease in the body's adaptive capabilities. The study emphasizes that weight loss due to dehydration and calorie restriction can lead to a violation of water and electrolyte balance, which negatively affects the functioning of the cardiovascular system. These data confirm our results, where we observed an increase in the tension index (IN) and a decrease in parasympathetic activity (HF).

In addition, research [26] showed that weight loss in judo athletes before competition leads to a decrease in total heart rate variability (SDNN) and an increase in sympathetic activity (LF), which is consistent with our results. The authors also emphasized that such changes may be temporary, but their impact on the overall health of athletes requires further study.

Our results also highlight the specificity of the female body, which may differ from that of the male in its response to stressors such as weight loss. For example, studies [12], showed that hormonal changes associated with the menstrual cycle can affect the adaptive mechanisms of the cardiovascular system. In particular, a decrease in estrogen levels can lead to a decrease in parasympathetic activity and an increase in sympathetic influence, which may explain the more pronounced changes in HRV in female athletes compared to men.

Research [27] also highlighted that rapid weight loss may have long-term health consequences for athletes, including reduced immune function and increased risk of cardiovascular disease. The authors recommended developing safer weight loss strategies that would minimize the negative impact on the body. These recommendations are also relevant to our study, as we found significant changes in HRV after pre-competition weight loss in female powerlifters.

In addition, research [28] showed that weight loss can lead to reduced athletic performance due to reduced energy reserves and impaired functioning of the autonomic nervous system. The authors emphasized that weight loss through calorie restriction can lead to reduced muscle glycogen levels, which negatively affects physical endurance and strength. These data confirm our results, where we observed a decrease in parasympathetic activity (HF) and an increase in sympathetic influence (LF), which may indicate a decrease in the body's adaptive capabilities.

Our study complements the existing evidence on the effects of weight loss on HRV, but has some limitations. First, the sample consisted only of female powerlifters, which limits the possibility of extrapolating the results to other sports. Second, the study did not consider the long-term effects of post-competition HRV changes, which requires further research. Despite this, the results obtained make a significant contribution to the understanding of the adaptive mechanisms of the cardiovascular system in response to pre-competition weight loss in female power athletes.

The results of our study are consistent with other scientific studies indicating that rapid weight loss can lead to significant changes in the functioning of the autonomic nervous system [29] However, our results also highlight the specificity of the female body, which may differ from that of the male in response to stressors such as weight loss. This highlights the need for further research aimed at studying the specificity of female adaptation to stressful conditions in sports.

*Research limitations.*One of the main limitations of the study is the lack of long-term monitoring of the athletes' condition after competition. Although we found significant changes in HRV after pre-competition weight loss, it is necessary to investigate how these changes affect recovery and overall health in the athletes in the long term. In addition, the study did not take into account individual characteristics of the athletes, such as the level of fitness, the duration of the training process and other factors that may affect the adaptive capabilities of the body.

Conclusions

The results of the study confirm that pre-competition weight loss in qualified female powerlifters is accompanied by significant changes in heart rate variability, which indicates an increase in the tension of the autonomic regulation of the cardiovascular system. These changes may have a negative impact on the adaptive capabilities of the body and the general health of female athletes. Therefore, it is important to develop individualized weight loss strategies that minimize health risks and maintain an optimal functional state of the body.

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