The dynamics of cardiohemodynamic parameters during the development of strength abilities in 12-14-year-old weightlifters

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Abstract

This study examines the dynamics of key central cardiohemodynamic parameters in young weightlifters aged 12-14 during the targeted development of strength abilities throughout the preparatory stage of the annual training cycle. It was established that systematic strength training not only improves the functional state of the cardiovascular system but also causes a statistically significant increase in indicators that directly reflect the level of strength qualities, which are a leading physical ability in this sport. To assess the long-term effects of regular strength training, a follow-up examination was conducted after 10 months of continued targeted strength development. The results indicate sustained and partially enhanced positive adaptive changes in cardiohemodynamics.

Keywords: young weightlifters aged 12-14, cardiohemodynamics, strength abilities, strength training, preparatory period, cardiovascular adaptation.

Introduction

An analysis of contemporary scientific and methodological literature reveals that for a long period, the primary criteria for the effectiveness of the training process in weightlifting were indicators of athletes' physical development. These included anthropometric measurements (body height and weight, limb segment circumference, chest excursion), as well as the results of hand and back dynamometry [1,2]. In recent decades, however, powerlifting (the power triathlon) has been introduced to assess physical fitness. This has made it possible to evaluate an athlete's training not only from a purely aesthetic standpoint but also from the perspective of athletic preparation, which includes competitive elements and, consequently, targeted technical and functional training [3].

Methods

The purpose of this study was to examine the dynamics of cardiohemodynamic indicators during the development of strength abilities in young weightlifters aged 12-14 over a preparatory training period.

In accordance with this purpose, the following objectives were set for the study:</2>

1. To study the initial and final values of cardiohemodynamic parameters and strength capabilities in athletes of the specified age group.</3>

2. To assess the nature of changes in the studied indicators throughout the preparatory stage of training.</4>

3. To identify the specific effects of the prolonged training process on the cardiohemodynamics of young weightlifters during the development of their strength qualities.</5>

Results and discussion

To address the objectives of the study, a range of methods was employed: theoretical analysis and synthesis of literature sources, a pedagogical experiment (natural), instrumental methods for studying cardiohemodynamics, control tests (strength ability testing), and mathematical statistics for processing the numerical data.

Heart rate (HR, beats/min) was determined by palpation, by counting the number of pulse waves over 10 seconds and subsequently multiplying the resulting value by 6.

Systolic (SBP, mmHg) and diastolic (DBP, mmHg) blood pressure were recorded using the indirect auscultatory method of N.S. Korotkov with a standard tonometer and phonendoscope.

Stroke volume (SV, ml) was calculated using the formula:

$$SV = 100 + 0.5 \times PP - 0.6 \times DBP - 0.6 \times A,$$

where PP is the pulse pressure (mmHg), equal to the difference between SBP and DBP; A is the subject's age (years).

Cardiac output (CO, L/min) was determined by the formula:

$$CO = (SV \times HR) / 1000.$$

To assess the subjects' strength abilities, the following exercises were used: bench press

Fig 1. Cardiohemodynamic parameters of young weightlifters aged 12-14 at the beginning of the preparatory period (M±m)

Parameters	Beginning of the preparatory period
Heart rate, beats/min	75.12±1.10
SBP, mm Hg	120.75±1.30
DBP, mm Hg	78.46±3.00
Stroke volume, ml	71.33±1.15
Cardiac output, L/min	5.24±0.09
Robinson Index	88.29±1.08

(kg), squats with a barbell (kg), and the deadlift result (kg) was also recorded.

During data processing, the following values were calculated: M - arithmetic mean; m - standard error of the mean; t - Student's t-test for significance.

The experimental work consisted of three temporal cross-sections. The first assessment, conducted at the beginning of the preparatory period, established the baseline physiological (cardiohemodynamic) and physical (strength) parameters of the 12-14-year-old athletes. The second cross-section, performed at the end of this period, recorded the changes that had occurred. The third stage, a delayed follow-up, was aimed at identifying the cumulative effect of training - specifically, the degree to which strength gains influenced the long-term adaptation of the young weightlifters' cardiohemodynamics.

The study was conducted at the "Zhastar" Regional Children and Youth Sports School in Aktobe.

In line with the established goals and objectives, 12 young weightlifters aged 12-14 years (with 3-4 years of training experience) were examined during the first stage (from October 2024 to March 2025). To assess the extent of the long-term effect of systematic training, a follow-up examination of the participants was conducted 10 months after the study began (January 2026).

At all stages, the following cardiohemodynamic indicators were recorded for each young weightlifter: heart rate (HR, bpm), systolic (SBP, mmHg) and diastolic (DBP, mmHg) blood pressure, stroke volume (SV, ml) and cardiac output (CO, L/min), and the Robinson Index (RI, c.u.), which characterizes the efficiency of the circulatory system, was also calculated.

Table 2. Strength indicators of young weightlifters aged 12-14 at the beginning of the preparatory period (M±m)

Strength Indicators	Beginning of the preparatory period
Bench press, kg	78.00±2.03
Deadlift, kg	131.52±2.42
Barbell squat, kg	90.48±2.25

The following tests were used to assess the strength abilities of the athletes: bench press (kg), barbell squats (kg), and deadlift (kg).

The development of the body's strength abilities is inextricably linked to changes occurring in the major physiological systems. The degree of harmony in the relationship between the increase in strength indicators and the dynamics of key functional parameters determines not only the overall functional state of the body but also the general level of health [4].

In this regard, we analyzed the nature of the relationship between the increase in strength indicators and changes in cardiohemodynamic parameters in young weightlifters aged 12-14 during the preparatory period. Table 1 presents the results of the examination of young weightlifters at the first stage of the experiment.

As the presented data show, at the beginning of the preparatory period, the following values of the studied indicators were recorded in the examined athletes: stroke volume (SV) was 71.33±1.15 ml, and cardiac output (CO) was 5.24±0.09 L/min, which

Table 3. Cardiohemodynamic indicators in young weightlifters aged 12-14 at the beginning and end of the preparatory period (M±m)

Indicators	Beginning of the preparatory period	End of the preparatory period
Heart rate, bpm	74.28±1.14	72.31±1.22
SBP, mm Hg	122.63±1.25	117.58±1.34*
DBP, mm Hg	76.58±3.02	70.65±1.89*
Stroke volume, ml	72.35±1.17	74.88±1.24
Cardiac output, L/min	5.27±0.08	5.24±0.09
Robinson Index	89.32±1.05	83.48±1.14*

characterizes the contractile function of the myocardium as satisfactory. At the same time, it should be noted that at the beginning of the preparatory period, the athletes registered slightly elevated values for heart rate (HR - 75.12±1.10 bpm), systolic (SBP - 120.75±1.30 mmHg), and diastolic (DBP - 78.46±3.00 mmHg) blood pressure. The Robinson index, which characterizes the overall efficiency of the circulatory system, was also quite high (88.29±1.08 c.u.).

These particular cardiohemodynamic indicators suggest that the young weightlifters examined showed signs of fatigue at the beginning of the preparatory period, which may have been caused by an imbalanced work and rest schedule during the absence of systematic training sessions.

Analysis of the indicators characterizing the strength abilities of the subjects (Table 2) showed that at the initial stage of the experiment, the results for the bench press were 78.00±2.03 kg, for barbell squats - 90.18±2.25 kg, and the deadlift result was 131.52±2.42 kg.

The data obtained from examining the athletes at the end of the preparatory period were quite interesting. As shown by the results presented in Table 3, by the end of the preparatory period, the young weightlifters exhibited a statistically significant decrease in systolic (to 117.58±1.34 mm Hg) and diastolic (to 70.65±1.89 mm Hg) blood pressure. Concurrently, a trend was observed towards a lower heart rate (to 72.31±1.22 bpm) and a higher stroke volume (to 74.88±1.24 ml).

Table 4. Strength indicators in young weightlifters aged 12-14 at the beginning and end of the preparatory period (M±m)

Strength indicators	Beginning of the preparatory period	End of the preparatory period
Bench press, kg	78.00±2.03	96.50±2.34*
Deadlift, kg	131.52±2.42	145.50±2.89*
Barbell squat, kg	90.48±2.25	103.57±2.64*

These changes resulted in stabilized blood pressure, economization of heart rate, and increased myocardial contractile function. A more optimal Robinson index value was also recorded, which significantly decreased to 83.48±1.14 c.u. by the end of the preparatory period. It is evident that an optimization of the athletes' circulatory system occurs during the training process.

Analysis of the data on the changes in strength indicators by the end of the preparatory period revealed (Table 4) that the athletes demonstrated a significant increase in their bench press results to 96.50±2.34 kg, barbell squats to 103.57±2.64 kg, and deadlifts to 145.50±2.89 kg.

Given the positive dynamics in cardiohemodynamic and strength parameters by the end of the preparatory period, a comparative analysis of their relative increases is of interest (Tables 5, 6).

As the data shows, the increases in circulatory parameters were not as significant. Specifically, heart rate decreased by 2.65%, systolic blood pressure by 7.74%, the Robinson index by 6.54%, stroke volume increased by 3.50%, and minute blood volume decreased by

Table 5. Relative increase values (in % of the initial level) of the studied indicators in young weightlifters aged 12-14 by the end of the preparatory period

Cardiohemodynamic indicators	% increase
Heart rate, bpm	-2.65
SBP, mmHg	-4.12
DBP, mmHg	-7.74
Stroke volume, ml	+3.50
Cardiac output, l/min	-0.57
Robinson index	-6.54

0.57%.

In contrast, the increase in strength indicators was more pronounced (Table 6). After 5 months of training, the increase in the bench press was +23.72%, in the barbell squat +14.47%, and in the deadlift +10.63%.

Thus, the presented materials indicate the ambiguous nature of the changes in the studied parameters among young weightlifters during the preparatory period. The lag in the growth of cardiohemodynamic parameters behind the changes in the young men's strength abilities should be regarded as an incomplete adaptation process of their bodies to increased training loads. The identified facts must be taken into account when organizing the training process for young weightlifters of this age group to avoid manifestations of acute and chronic overstrain of the body's functional state.

In accordance with the main objective of the second year of the experiment, we conducted an examination of 12-14-year-old weightlifters 10 months after the completion of the one-year experiment (January 2026).

As can be seen from the results presented in Table 7, a pronounced trend toward further optimization of the main parameters of central hemodynamics was registered in the examined athletes.

Table 6. Relative increase (as a % of the baseline level) of cardiohemodynamic indicators in young weightlifters aged 12-14 at the end of the preparatory period

Strength indicators	End of the preparatory period
Bench press, kg	+23.72
Deadlift, kg	+10.63
Barbell squat, kg	+14.47

Suffice it to say that by the end of the second year of systematic strength training, the subjects showed a statistically significant decrease in heart rate from 72.31±1.22 bpm to 67.29±1.14 bpm, a reduction of 6.94%

Table 7. Cardiohemodynamic indicators in young weightlifters aged 12-14 at the beginning and end of the preparatory period of the second year of the experiment (M±m)

Indicators	End of 1st year of experiment	End of 2nd year of experiment	% change
Heart rate, bpm	72.31±1.22	67.29±1.14*	-6.94
SBP, mmHg	117.58±1.34	112.32±1.41*	-4.47
DBP, mmHg	70.65±1.89	69.84±1.38	-1.14
Stroke volume, ml	74.88±1.24	78.91±1.13*	+5.38
Cardiac output, L/min	5.24±0.09	5.58±0.11*	+6.49
Robinson Index	83.48±1.14	77.49±1.24*	-7.17

Table 8. Indicators of strength abilities in young weightlifters aged 12-14 at the end of the first and second years of the experiment (M±m)

Strength Indicators	End of 1st year of experiment	End of 2nd year of experiment	% increase
Barbell bench press, kg	96.50±2.34	102.31±2.12*	+6.02
Deadlift, kg	145.50±2.89	154.28±2.41*	+6.03
Barbell squat, kg	103.57±2.64	109.25±2.07*	+5.48

compared to the values recorded at the end of the first year of the study. The absolute value of systolic blood pressure also decreased significantly - from 117.58±1.34 mmHg to 112.32±1.41 mmHg, or by 4.47% - with no significant changes in diastolic blood pressure. The nature of the changes in SBP and DBP suggests a certain stabilization of these homeostatic indicators by the end of the second year of the experiment.

The study also revealed significant transformations in such important parameters of central hemodynamics as systolic and minute blood volumes. An increase in their absolute values (systolic volume from 74.88±1.24 ml to 78.91±1.13 ml, or by 5.38%, and minute volume from 5.24±0.09 L/min to 5.58±0.11 L/min, or by 6.49%) indicated an improvement in myocardial contractile function. This was further confirmed by a significant decrease in the Robinson index from 83.48±1.14 c.u. to 77.49±1.24 c.u., or by 7.17%.

Thus, the presented data convincingly demonstrate that the athletes examined experienced a pronounced optimization of the main indicators of the circulatory system under the influence of systematic strength training.

Analysis of the strength training test results of young weightlifters aged 12-14 also showed an increase in the main indicators that characterize this physical quality.

As shown in Table 8, by the end of our study, young weightlifters aged 12-14 demonstrated a significant increase in their results for the bench press (from 96.50±2.34 kg to 102.31±2.12 kg, or 6.02%), the deadlift (from 145.50±2.89 kg to 154.28±2.41 kg, or 6.03%), and barbell squats (from 103.57±2.64 kg to 109.25±2.07 kg, or 5.48%) compared to the data from the end of the first year of the experiment. It is evident that, as a result of strength training, the surveyed athletes showed not only an improvement in the functional state of their cardiovascular system but also an increase in performance indicators directly related to strength, one of the most important physical qualities. Also of great importance is the fact that while the growth rate of strength indicators significantly outpaced the corresponding increases in central hemodynamic parameters during the first year of the study, their changes were practically synchronous during the second year of the experiment.

Conclusion

At the start of the preparatory period in the first year of the experiment, the young weightlifters examined showed slightly elevated values for heart rate (HR), blood pressure (BP), and the Robinson index, indicating a certain strain on the circulatory system. By the end of the preparatory period, the athletes demonstrated improvements in their cardiohemodynamic and strength parameters. The inconsistent nature of the changes in the studied indicators during the first year of the experiment, characterized by a more significant increase in strength parameters, suggests that the body's adaptive adjustments to the increased physical loads were incomplete. In the second year of the experiment, a virtually synchronous development of strength indicators and the main parameters of the circulatory system was observed.

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