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The Effect of Training Load Regulation Based on Heart Rate Variability Using Wearable Devices on Heart Rate Variability and Estimated Maximal Oxygen Uptake in Weightlifters

Saleh Mahdi Mukhif[1]

[1] University of Baghdad, College of Physical Education and sport sciences.

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Abstract

This study aimed to test the effectiveness of a training program according to regulated training load using heart rate variability readings (HRV) and estimated VO_2max in weightlifters. The researcher employed an experimental design with two equivalent groups (experimental and control) using pre- and post-tests as this method was appropriate for the nature of the problem and the research objectives. The research population included of weightlifters at the Police Sports Club during the 2026 sports season totaling 12 athletes. The research sample comprised 10 athletes choose purposively and randomly assigned to two equivalent groups: five athletes in the experimental group and five in the control group. Two athletes were used for a pilot study. The research instruments included a Polar H10 device and the Kubios HRV software for measuring heart rate variabilit, as well as a 12-minute Cooper test for estimating VO_2max. The main trial lasted for eight weeks, comprising 24 training sessions. The experimental group adjusted their training load based on heart rate variability readings while the control group continued with the traditional training program. Statistical analysis using SPSS demonstrated improvements in both heart rate variability (from 34.80 to 48.60 ms) and the estimated maximum oxygen consumption (from 45.72 to 52.18 ml/kg/min) in the experimental group demonstrating statistically significant superiority over the control group (38.10 ms and 47.80 ml/kg/min, respectively) in the post-tests. The researcher determined that adjusting training load based on heart rate variability readings using wearable devices is an effective method for developing recovery, functional adaptation and the development of important physiological indicators in weightlifters.

Keywords: Wearable devices, heart rate variability, maximal oxygen consumption, weightlifting.

[1]University of Baghdad, College of Physical Education and sport sciences.

saleh.mahdi@cope.uobaghdad.edu.iq

Introduction

Training based on daily physiological indicators has become a modern trend in regulating training loads and heart rate variability (HRV) is one of the most commonly used indicators for determining an athlete's daily readiness and directing training load depending on each player's actual recovery status. Wearable devices used to measure HRV vary in terms of sensor technology and measurement accuracy. Some rely on photoelectric sensors (PPGs) integrated into smartwatches such as the Apple Watch. While these are easy to use their accuracy is affected by movement and the device's fit on the wrist which may decrease the accuracy of readings during daily measurements. Others use chest strap ECG devices such as the Polar H10 used in this study which records the heart's electrical signal directly from the chest surface at a high frequency (1000 Hz) giving it higher accuracy in extracting HRV indicators contrasted to devices based on photoelectric technology (Ho et al., 2022; Van Oost et al., 2025).

Heart rate variability (HRV) is a physiological variable that indicates the activity of the autonomic nervous system and the interaction of its sympathetic and parasympathetic branches in regulating heart rate. It is not measured directly but is deduced from a set of mathematical indicators derived from cardiac signal recordings including: SDNN which reflects the total variability; HF and LF which show parasympathetic and sympathetic activity respectively; the LF/HF ratio which indicates the balance between the two branches; and RMSSD which reflects the short-term variability and is connected to parasympathetic activity.

The RMSSD index was adopted in this study over other heart rate variability indices for many methodological reasons. First, RMSSD is less impacted by respiratory rate contrast with frequency indices such as HF and LF, making it more stable and reliable in repeated daily measurements outside the laboratory. Second the objective of the study is to guide the daily training load based on the recovery state and not to conduct a comprehensive and detailed assessment of the autonomic nervous system that demands a full spectral analysis. Third recent scientific literature confirms that RMSSD is the most suitable index for daily field monitoring in athletes due to its ease of calculation, relative stability and gradual development with physical adaptations (Plews et al., 2013; Esco et al., 2025).

The causal mechanism for using heart rate variability in training load regulation depends on a logical sequence that begins with measuring the RMSSD as an indicator of the athlete's autonomic neurological recovery during the rest period before a training session. High values reflect a physiological balance indicating complete recovery and readiness to endure loads while low values indicate the dominance of sympathetic activity and incomplete recovery. These readings are then translated into a daily training decision that involves increasing, maintaining or decreasing the load according to the athlete's actual condition.

This precise regulation is expected to improve the quality of adaptive responses and improve functional performance in the long term. The estimated VO_2max value is a functional indicator whose connection to weightlifting may seem indirect at first glance as this sport relies primarily on the anaerobic system for energy production to execute snatch and clean and jerk movements that need high explosive power over short periods. However increased aerobic efficiency contributes to faster recovery between training sets and increases overall training volume tolerance. Higher oxygen consumption during rest periods accelerates the removal of

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inorganic phosphates and the resynthesis of phosphagen (ATP-PCr), as well as speeding up the elimination of lactate accumulated after consecutive sets. This enables for greater training loads and higher quality training over weeks which give positive impacts neuromuscular adaptations and maximal strength in the long term (Bourdon et al., 2017). Moreover improving the estimated value of maximum oxygen consumption in four-wheel weightlifters is not intended to develop aerobic performance per se but rather it is a means to improve recovery efficiency and increase the capacity to withstand and absorb the total training volume which is the main driver of strength adaptations in this sport.

In reviewing previous studies numerous researchers have explored the use of heart rate variability in training regulation for endurance and ball sports such as Kiviniemi et al. (2007), Schmitt et al. (2015), and Olmos et al. (2024). Some systematic reviews have also demonstrated the potential use of wearable devices for field-based estimation of maximal oxygen consumption (MOOCs) (Železnik Mežan, 2025; Xie et al., 2025). However to the best of our knowledge, no study has investigated the correlation between training load regulation based on daily HRV readings and estimated MOOCs as causally related variables within the context of weightlifting. In other words, it has not been previously examined whether daily training load regulation based on RMSSD can improve estimated MOOCs in weightlifters by enhancing recovery efficiency and increasing training volume tolerance. This demonstrates the knowledge gap that current research seeks to bridge.

The importance of this research lies in its provision of a practical framework for using a particular technique (the Polar H10 chest strap) and a specific physiological indicator (RMSSD) to regulate the daily training load for weightlifters. This method moves away from traditional methods that rely on pre-set training schedules without considering the daily physiological variations among athletes. Furthermore, the research provides coaches with scientific evidence linking load regulation based on neuroendocrine recovery to improved aerobic recovery efficiency as measured by the estimated value of maximum oxygen consumption. This contributes to more accurate training decisions and reduces the likelihood of overexertion. The research also enriches scientific knowledge in the field of sports training physiology and opens avenues for future studies exploring the applications of load regulation according to daily physiological indicators in weightlifting.

Through his assessment of weightlifting training practices the researcher noted that most coaches rely on traditional methods of regulating training loads without fully using modern technologies that provide real-time physiological information about the athlete's condition and response to training. Furthermore neglecting individual differences in recovery and adaptation can lead to decreased training efficiency or excessive fatigue. Therefore the research problem can be summarized in the following question:

Does training guided by wearable devices impact heart rate variability and maximal oxygen consumption in four-wheel weightlifters?

The research objectives to develop a training program based on regulating the training load according to heart rate variability readings using wearable devices for four-wheel weightlifters and to identify the effect of this program on heart rate variability (HRV) and the estimated value of maximum oxygen consumption (VO_2max).

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The research suggests that there are statistically significant differences between the pre-test and post-test for the experimental group in the variables of heart rate variability and the approximate value of maximum oxygen consumption in favor of the post-test. In addition there are statistically significant differences between the experimental and control groups in the post-tests in favor of the experimental group.

Methodology and Tools

Study Design

The researcher adopted a randomized experimental design with two parallel groups using pre- and post-testing, as it was suitable for the nature of the research problem and its objectives which were to establish the effect of regulating training load according to heart rate variability using wearable devices on heart rate variability and the estimated value of maximum oxygen consumption in weightlifters.

Research Population and Sample

The research population was defined as advanced weightlifters at the Police Sports Club during the 2026 sports season in the middleweight category (81-89 kg). The researcher particularly chose this category because it demonstrates one of the middleweight categories characterized by related homogeneity in the physical and functional characteristics of its athletes. Furthermore, there was a sufficient number of athletes belonging to this category at the club to allow for the application of the randomized experimental design with two parallel groups totaling (12) athletes. The researcher chosen the research sample purposively from the same research population, comprising (10) players representing (83.33%) of the total population. These players were randomly separated into two parallel groups: (5) players for the experimental group and (5) players for the control group. The remaining two players were excluded from the main experiment and used in the pilot study to verify the validity of the tests, equipment and tools before the main experiment was implemented. Before commencing the training program the researcher performed a equivalence test between the two research groups in terms of the study variables to make sure their statistical equivalence and the absence of any significant differences between them as shown in Table 1.

Table1. Equivalence of the two research groups in terms of the study variables

variables	Unit of Measurement	Experimental Group		Control Group		t-value	Significance Value	Significance Level
		M	Sd	M	Sd			
Heart Rate Variability (HRV)	ms	34.80	3.11	35.20	2.94	0.209	0.840	Not significant
Maximum Oxygen Consumption (VO_2max)	ml/kg/min	45.72	2.41	46.10	2.28	0.257	0.804	Not significant

Significant at a significance level of less than 0.05 and 8 DF *

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Research Instruments

* Polar H10 records RR intervals at 1000 Hz.
* Kubios HRV app for analyzing heart rate variability data.
* Sports watch compatible with Polar H10.
* Laptop for data processing.
* Legal weightlifting equipment and weights.
* Measuring tape.
* Electronic medical scale.
* Data entry forms.
* Timer.
* Support team.

Tests used in the research

Heart rate variability (HRV) test (Plews et al., 2013)

Test name: Heart rate variability test using the (RMSSD) index

The purpose of the test: to measure the level of recovery and functional adaptation of the autonomic nervous system.

Tools used: Polar H10 device, Kubios HRV app

Procedure: The player wears a Polar H10 device and sits in a resting position for (5) minutes. Then the cardiac signals are recorded and analyzed using Kubios HRV software to extract the RMSSD value.

Recording Method: The RMSSD value displayed by the Kubios HRV software is recorded in milliseconds (ms) and this value demonstrate the indicator used in the study. Higher values reflect a better level of recovery and autonomic nervous system balance while lower values indicate increased stress or a decrease level of recovery.

Maximum oxygen consumption (VO_2max) test (Cooper, 1968)

Test name: Cooper's 12-minute test.

The purpose of the test: to measure the maximum oxygen consumption.

Equipment used: Running track, stopwatch, measuring tape to determine distance traveled, findings recording form.

Performance procedure: The player stands at the starting line and upon receiving the starting signal, runs or sprints as far as possible within (12) continuous minutes, allowing them to regulate their speed according to their physical ability. When the allotted time expires, the player stops and the total distance covered is recorded in meters.

Recording method: The distance traveled during (12) minutes is recorded in meters then the value of maximum oxygen consumption (VO_2max) is calculated using the following Cooper equation:

VO_2max (ml/kg/min) = (distance traveled in meters - 504.9) ÷ 44.73

The resulting value in (ml/kg/min) is adopted as an indicator of the maximum oxygen consumption.

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Exploratory experiment

The researcher conducted the exploratory experiment on (1/3/2026) on two players from the research community and outside the main sample in the closed weightlifting hall of the Police Club, in order to ensure the suitability of the equipment and tools used and to establish the possible obstacles that the researcher may face during the implementation of the tests and the main experiment as well as to determine the time needed to conduct the tests and to ensure the efficiency of the assisting work team.

Pre-test

The researcher conducted the pre-tests for the research sample on (2/3/2026) in the closed weightlifting hall of the Police Club before starting to implement the training program in order to identify the initial levels of the sample members in the two variables of heart rate variability (HRV) and maximum oxygen consumption (VO_2max). The researcher was keen to offer the same conditions for all members of the sample in terms of the place and time of the tests the devices and tools used and the assisting work team as well as standardizing the instructions and measurement procedures in order to ensure the precision of the findings and reach the principle of equal opportunities between the members of the experimental and control groups before implementing the primary experiment.

Main Experiment:

After finishing the pre-tests and ensuring the equivalence of the two research groups in the study variables the researcher proceeded to conduct the main experiment in the indoor weightlifting hall of the Police Club. The experiment lasted for eight consecutive weeks from March 3, 2026, to May 3, 2026, with three training sessions per week on Saturdays, Mondays, and Wednesdays, totaling 24 training sessions. Each training session lasted 90 minutes including a 10-minute warm-up, a 70-minute main session and a 10-minute cool-down. Each training session included of three exercises performed in the following order: the first exercise (the main Olympic lift: snatch or clean and jerk) followed by the second exercise (front or back squat) and then the third exercise (a pull-up or assisted exercise). A rest period of 3-5 minutes separated each exercise while the rest periods between sets within each exercise ranged from 2-5 minutes. According to the intensity of the load as shown in Table (2). The speed of performance was determined so that snatch and clean lifts were performed at a maximum explosive speed in order to achieve maximum acceleration of the bar while squat exercises were performed at an explosive contraction speed with a controlled descent phase while pull exercises were performed at an accelerated transition speed that focused on the second phase of the pull.

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Table2. Proposed training program for the experimental group with details of the load

Week

Week	Unity	Exercises in order	Intensity (%1RM)	Sets	repetitions	Comfort between sets	Speed of performance
	1	Snatch → Back Squat → Pull Snatch	70%	4	6	2–3 minutes	Maximum explosive ← Contractionary explosive ← Accelerated transition
1	2	Nerd → Front Squat → Shoulder Press	70%	4	6	2–3 minutes	Maximum explosive ← Contractile explosive ← Controlled
	3	Snatched from the comment ← Pulled net	72%	4	5	2–3 minutes	Extreme explosive → accelerated transition
	4	snatch ← rear squat	75%	4	5	3 minutes	Maximum explosive force → Contractile explosive force
2	5	Neter → Front Squat	75%	4	5	3 minutes	Maximum explosive force → Contractile explosive force
	6	Snatch from comment ← Pull snatch	77%	4	5	3 minutes	Extreme explosive → accelerated transition
	7	Complete kidnapping	80%	5	4	3–4 minutes	extreme explosive
3	8	Full net	80%	5	4	3–4 minutes	extreme explosive
	9	Back squat ← Pull-up	82%	5	4	3–4 minutes	Explosive systolic → Transitional accelerated

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4	10	Complete kidnapping	85%	5	3	4 minutes	extreme explosive
	11	Full net	85%	5	3	4 minutes	extreme explosive
	12	back squat	87%	5	3	4 minutes	explosive contraction
5	13	Complete kidnapping	88%	5	3	4 minutes	extreme explosive
	14	Full net	88%	5	3	4 minutes	extreme explosive
	15	Front squat ← Pull snatch	90%	5	2–3	4 minutes	Explosive systolic → Transitional accelerated
6	16	Complete kidnapping	90%	5	2	4–5 minutes	extreme explosive
	17	Full net	90%	5	2	4–5 minutes	extreme explosive
	18	back squat	92%	5	2	4–5 minutes	explosive contraction
7	19	Complete kidnapping	85%	4	3	4 minutes	extreme explosive
	20	Full net	85%	4	3	4 minutes	extreme explosive
	21	Special skill exercises	80%	4	4	3 minutes	extreme explosive
8	22	Complete kidnapping	80%	3	3	3 minutes	extreme explosive
	23	Full net	80%	3	3	3 minutes	extreme explosive
	24	Light recovery training session	70%	3	—	—	Light exercise with focus on recovery

Heart Rate Variability (HRV) Measurement Protocol

Heart rate variability was measured daily before the start of each training session according to the following protocol: The athlete arrived at the measurement location 15 minutes before training and sat in a relaxed position on a chair with a straight back in a quiet room at a temperature of 22-24°C. They remained in this position for 5 minutes as an initial stabilization period to minimize the impact of transitions and environmental disturbances on the cardiac signal.

The Polar H10 device was then attached to the chest based on the manufacturer's instructions and the electrical signal of the heart was recorded continuously for 5 minutes at a sampling frequency of 1000 Hz. After recording the data was transferred to a laptop and analyzed using Kubios HRV software (version 10) to calculate the RMSSD value in milliseconds. A personal reference average was calculated for each athlete based on the moving average of the

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previous 7 days of measurements. This average was updated daily after each new measurement and the daily RMSSD value was contrast with this moving average to inform training decisions.

Training Load Adjustment Mechanism Based on RMSSD Readings

The researcher adopted a specific quantitative mechanism to modify the daily training load based on the relative deviation of the daily RMSSD value from the personal moving average of the last (7) days, according to the criteria shown in Table 3.

Table3. Training Load Adjustment Mechanism Based on Daily Changes in Heart Rate Variability Index (RMSSD)

Daily RMSSD Status Compared to Moving Average	Quantitative Training Decision
5% or more above average	Increase planned intensity by 2.5–5% of 1RM or add one training set to the main exercise
Within ±5% of average	Perform the planned training load as is without any modification
5–10% below average	Reduces total training volume by 10% by decreasing one set per exercise or one repetition per set.
More than 10% below average	Reduces planned intensity by 5–10% of 1RM and reduces the number of sets to three per exercise, or replaces the training session with a recovery session that includes exercises at 50–60% of 1RM intensity.

Since training load is not described by intensity alone but consists of several key components including intensity, volume, density, repetitions and rest the researcher calculated the Total Training Volume (TCF) as the quantitative indicator reflecting the actual amount of mechanical work performed by the athlete. This was done using the following equation: Total Training **Volume for the Exercise (kg) = Weight Used (kg) × Number of Repetitions × Number of Sets.**

The values for all exercises in a single training session were then summed to acquire the total volume for the session and the volumes of the three sessions were summed to attain the total volume for the training week. This indicator allowed for the determination of the amount of mechanical work performed, comparison of loads between weeks, monitoring of load progression and confirmation of its connection with program objectives. It also facilitated the documentation of load adjustments resulting from the use of HRV data. Table (3) showes the planned total training volume for each week based on the average 1RM weights of the experimental group. It should be observed that the actual volume varied among the athletes according to their weights and the daily adjustments based on RMSSD readings.

Table 4. Total planned weekly training volume for the experimental group

Week	Training Phase	Number of Exercises	Total Repetitions	Average Intensity (%1RM)	Total Planned Volume (kg)*
1	Functional Setup and Adaptation	8	208	70.7	13,920

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2	Functional Setup and Adaptation	6	150	75.7	11,760
3	Maximum Strength Development	4	120	80.7	8,820
4	Maximum Strength Development	3	75	85.7	6,150
5	Maximum Strength Development	4	70	88.7	6,230
6	Maximum Strength Development	3	40	90.7	3,960
7	Consolidation and Recovery	4	60	83.3	5,100
8	Consolidation and Recovery	3	30	76.7	2,610
	Total	**35**	**753**	—	**58,550**

The program weeks included a gradual approach to shaping the training load. Weeks (1-2) were dedicated to the preparation and functional adaptation phase with a high training volume and moderate intensity while weeks (3-6) included the phase of developing maximum strength and raising the efficiency of the nervous and muscular systems with high intensity and a decrease in the overall training volume. As for weeks (7-8) they were dedicated to the phase of consolidating training adaptations, improving recovery and maintaining the level of physical achievement.

As for the members of the control group they continued to employ the traditional training program approved by the team's coach which includes the same exercises, the same order the same intensity and quantities shown in Table (2) without any daily modification, during the same period and with the documentation of the total training volume according to the same equation, while giving attention to unify the number of training units their time and training conditions between the two groups as much as possible.

The researcher took into account the control of all factors that have the impact to the course of the experiment consist of the training location and times the tools and equipment used, the nature of the warm-up, and the performance instructions to ensure that any differences that may appear in the post-test results are due to the effect of the independent variable which is the standardization of the training load according to the readings of the variation in heart rate and not due to other external factors.

Post-test

After the completion of the training program for both the experimental and control groups the researcher conducted post-tests on the research sample on May 4, 2026, in the indoor weightlifting hall of the Police Club. These tests assessed heart rate variability (HRV) and maximum oxygen consumption (VO_2max) to establish the extent of change findings from the main experiment. The researcher ensured that the post-tests were conducted under the same conditions as the pre-tests including location, time, equipment, support staff and testing procedures. This was done to guarantee the objectivity of the results the accuracy of the

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comparison between the pre- and post-test measurements and to accurately specify the true impact of the training program.

Statistical methods

The research data were statistically processed using the Statistical Package for the Social Sciences (SPSS) and the following statistical methods were used:

- Arithmetic mean
- Standard deviation
- Independent Samples T-Test.
- T-test for correlated samples.
- Percentage

Results:

Table 4. Results of the Pre- and Post-Tests for the Experimental Group on the Research

Variables	Unit of Measurement	Pre-Test M	Pre-Test SD	Post-Test M	Post-Test SD	T-value	Significance Value	Significance Level
Heart Rate Variability (HRV)	milliseconds	34.80	3.11	48.60	3.43	8.954	0.001	Significant
Maximum Oxygen Consumption (VO_2max)	ml/kg/min	45.72	2.41	52.18	2.56	7.826	0.001	Significant

Significant at a significance level of less than 0.05 and 4 DF*

Table 5.Results of the Pre- and Post-Tests for the Control Group In the research variables:

Variables	Unit of Measurement	Pre-Test M	Pre-Test SD	Post-Test M	Post-Test SD	T-value	Significance Value	Significance Level
Heart Rate Variability (HRV)	milliseconds	35.20	2.94	38.10	3.02	2.167	0.096	Not Significant
Maximum Oxygen Consumption (VO_2max)	ml/kg/min	46.10	2.28	47.80	2.31	2.014	0.114	Not Significant

Significant at a significance level of less than 0.05 and 4 DF*

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Table 6. Results of the post-tests between the experimental and control groups in the variables Research

Variables	Unit of Measurement	experimental groups M	experimental groups SD	control groups M	control groups SD	T-value	Significance Value	Significance Level
Heart Rate Variability (HRV)	milliseconds	48.60	3.43	38.10	3.02	5.156	0.001	Significant
Maximum Oxygen Consumption (VO_2max)	ml/kg/min	52.18	2.56	47.80	2.31	2.840	0.022	Significant

Significant at a significance level of less than 0.05 and 8 DF*

Discussion:

The current discussion focuses on trying to explain the physiological mechanisms underlying the superiority shown by the experimental group in the two study variables surpassing simply describing the apparent results by constructing an analytical framework that links the experimental intervention (regulating the training load) with the noticed adaptive responses.

Regarding the development in heart rate variability (with RMSSD values increasing from 34.80 to 48.60 milliseconds), this improvement cannot be explained as a direct result of the wearable devices, but rather as a consequence of training decisions based on data from these devices. The rise in RMSSD values physiologically reflects an enhancement of parasympathetic nervous system control (vagal tone) and a relative inhibition of sympathetic activity at rest. This autonomic nervous system shift translates into a significant improvement in recovery efficiency, giving the athlete the physiological capacity to absorb and execute larger and higher-intensity training loads without falling into the trap of cumulative fatigue which ultimately leads to improved physiological performance and neuromuscular adaptation. Kiviniemi et al. (2007) indicated that training programs that modify the load according to daily fluctuations in the autonomic nervous system allow the body to respond to the load without disrupting homeostasis, creating an ideal internal environment for improved neuro cardio graphic indicators. Schmitt et al. also demonstrated this. (2015) Relying on HRV indicators allows for determining the optimal training dose that achieves maximum adaptive advantage without exceeding the recovery threshold which is verified by the study of Olmos et al. (2024) which showed that daily monitoring represents the optimal method for improving the efficiency of the autonomic nervous system in athletes.

Regarding the statistically significant increase in the estimated maximum oxygen consumption (VO2max) of the four athletes in the experimental group this can be understood from an integrative standpoint connecting neurological recovery and training capacity. Thanks to the aforementioned improvement in neurological recovery the athletes in the experimental group were able to tolerate a greater overall training volume and higher performance quality in training sets throughout the weeks of the experiment. This higher mechanical load constitutes a maximal training stimulus that leads to central adaptations (such as increased cardiac output) and peripheral adaptations (such as increased capillary density in working muscles) which manifest as an increase in the estimated

VO2max. These interpretations are consistent with Bourdon et al. (2017) suggesting that modern load management systems increase the ceiling for functional adaptations. This approach also connect with the findings of Singh et al. (2018) It is shown that athletes with high levels of HRV have a better ability to withstand intense training loads which positively impacts the development of their overall functional abilities including aerobic efficiency.

In contrast the researcher attributes the lack of statistically significant improvement in both variables in the control group to the rigidity of the traditional training method. Applying a fixed-load training schedule ignores the fact that physiological readiness fluctuates daily depending on the body's ability to restore balance. When a high load is applied on a day when parasympathetic activity is low (low RMSSD) a mismatch occurs, transforming the load from a "training stimulus" to a "stress stimulus." This increases the dominance of the sympathetic nervous system and limits cellular repair processes hindering adaptations at both the autonomic nervous and cardiorespiratory levels. These result support Halson's (2014) assertion that the absence of precise physiological monitoring leads to a mismatch between the training dose and the adaptive response thus limiting training effectiveness. Furthermore the role of technique in promoting objectivity is highlighted as noted by Migliaccio et al. (2024) The integration of wearable technology moves training from personal guesswork to decisions according to the objective data, ensuring optimal adaptation.

In conclusion the results of this study demonstrate that regulating the training load based on heart rate variability readings represents an integrated physiological mechanism, starting with improving parasympathetic recovery which in turn gives the athlete a greater margin to tolerate the training volume which stimulates circulatory and respiratory adaptations represented by a higher estimated value of maximum oxygen consumption thus confirming that improving aerobic efficiency in weightlifting is essentially a reflection of improved neurological recovery efficiency.

Conclusions:

1. Heart rate variability (HRV) measurements suggest a potential improvement in parasympathetic nervous system activity and recovery condition.
2. The training program facilitated to an improvement in the estimated value of maximum oxygen consumption (VO2 max).
3. Using HRV data to regulate training load proved effective contrasted to traditional regulation.
4. The experimental group that used wearable device-guided training to reached better results than the control group that trained using the traditional method.
5. Employing wearable device data to guide and regulate training load demonstrated effectiveness in enhancing the studied variables.

Recommendations:

1. This approach can be considered for training weightlifters provided that further studies are conducted on larger samples to confirm its effectiveness.
2. Heart rate variability (HRV) measurements should be used regularly to regulate training loads and monitor athletes' recovery and training readiness.
3. Weightlifting coaches should be provided with wearable devices and modern physiological data examination software to use in training planning.

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4. Conduct similar studies across different age groups and training levels, and in other sports, to verify the effectiveness of this type of training.
5. Carry out future studies investigating the effects of targeted training using HRV on other physiological and biochemical variables such as blood lactate concentration, creatine kinase (CK) levels, cortisol levels, C-reactive protein and markers of inflammation and muscle fatigue.

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