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The Effect of a Heart Rate Monitoring-Based Training Program on Developing Physiological Efficiency and Performance Level in 100-Metre Sprinters

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ABSTRACT
Backgroud: This study aimed to investigate the effect of a heart rate monitoring-based training program on the development of selected physiological efficiency indicators and sprint performance in 100-metre sprinters from Iraqi sports clubs.
Methods: The proposed research design adopted an experimental approach using a single experimental group with pre- and post-intervention measurements. The study sample comprised 20 sprinters aged between 20 and 25 years, including seven athletes assigned to the experimental group and 13 athletes participating in the pilot study. The assessment procedures included measurements of resting heart rate, post-exercise heart rate, heart rate recovery rate, maximal oxygen uptake (VO_2max), post-exercise blood lactate concentration, and 100-metre sprint time. The training program was designed to improve the physiological response to training loads, enhance recovery capacity, and maintain performance quality across repeated efforts.
Results: The main findings indicated that the proposed heart rate monitoring-based training program contributed to improvements in selected physiological efficiency indicators among the 100-metre sprinters in the experimental group. Furthermore, the program positively influenced 100-metre sprint performance, as evidenced by a reduction in the mean sprint completion time following the implementation of the proposed training intervention.
Conclusions: The researcher recommended incorporating the proposed heart rate monitoring-based training program into the preparation of 100-metre sprinters, subject to further experimental validation of its effectiveness, given its potential to enhance both physiological efficiency and sprint performance.

Keywords: Heart Rate; Physiological Efficiency; Sprint Performance; 100-Metre Sprint.

INTRODUCTION

Sports training is one of the fields that has witnessed substantial development in recent years. The preparation of athletes is no longer based solely on practical experience; rather, it increasingly relies on scientific knowledge that explains the body's responses to different training loads. This development is clearly reflected in the methods used to plan training programs and prescribe their components in accordance with athletes' capacities and the specific demands of their sporting activities. Furthermore, achieving advanced levels of athletic performance requires consideration of individual differences among athletes, particularly in terms of their ability to tolerate physical exertion, recover from it, and adapt to training over the long term (Dodonov & Shutova, 2013; Koryagina et al., 2015; Zelichenok et al., 2018). Accordingly, examining the physiological changes associated with training has become an important aspect of the coaching

process, as it helps coaches select appropriate training loads and direct training toward achieving its intended objectives.

Sprint events occupy a prominent position in athletics because they require high levels of physical and functional capacities, particularly speed-strength, muscular power, and rapid neuromuscular responses. The 100-metre sprint is among the events most sensitive to even minor variations in performance, as fractions of a second can significantly influence athletes' rankings and competition outcomes (Majumdar & Robergs, 2011a; Ross et al., 2001). Achieving a high level of sprint performance does not depend solely on an athlete's ability to attain maximal running speed; it also requires an effective start, appropriate acceleration during the initial metres, and the ability to minimize the decline in speed during the final phase of the race. Therefore, developing training programs that account for the specific performance demands of this event and target the physical and physiological capacities associated with sprint performance is of considerable importance (Arsac, 2002, p. 24).

An athlete's physiological efficiency is associated with the capacity of the body's various systems to meet the demands of physical activity and adapt to the imposed training loads. The cardiovascular and respiratory systems play essential roles in meeting the metabolic demands of muscular activity and facilitating the restoration of functional status following physical exertion, alongside the contributions of the nervous and muscular systems to force production and movement (Carré, 2006; Janik et al., 2025). The nature of these physiological responses varies according to the intensity and duration of the activity. In sprint events, energy production relies predominantly on anaerobic energy systems, although aerobic capacity remains important for facilitating recovery between repetitions and training sessions. Consequently, improving physiological efficiency in 100-metre sprinters cannot be separated from developing their capacity to perform high-intensity efforts, tolerate repeated training demands, and maintain performance quality (Abdel-Fattah & Sayed, 2003, p. 84).

Physiological research related to sprint events indicates that the contribution of different energy systems varies according to race distance and the time required to complete it. In the 100-metre sprint, energy production depends primarily on anaerobic pathways, particularly the phosphagen system, which provides the energy required for the start, acceleration, and the generation of high muscular power (Duffield et al., 2005; Majumdar & Robergs, 2011b; Margaria, 1968) . Duffield (2004) reported that anaerobic energy contribution accounts for the largest proportion of the energy utilized during the 100-metre sprint, although the estimated proportions vary depending on the measurement methodology employed. These findings indicate that the preparation of sprinters requires training programs consistent with the predominant energy systems involved in the event, while also emphasizing the appropriate organization of rest and recovery intervals to enable athletes to perform successive training repetitions at the required levels of speed and efficiency.

Heart rate is one of the physiological indicators that can be used to monitor the body's response to physical exertion because of its association with cardiovascular activity and the changes that occur during and following exercise. Heart rate varies according to several factors, including exercise intensity, training status, health condition, fatigue, and recovery status. Monitoring heart rate at rest and following physical exertion may also help identify certain manifestations of physiological adaptation resulting from regular training (Martellotto, 2003; Panda & Krishna, 2014; van de Vegte et al., 2019). Such monitoring becomes particularly valuable when conducted systematically under standardized measurement conditions, allowing comparisons between successive assessments and facilitating the identification of changes in an athlete's functional status. Accordingly, heart rate can be considered one of the supplementary indicators used to prescribe and regulate training loads, particularly when interpreted alongside other physical and performance-related measures (Sayed, 2008, p. 26).

Recent studies have increasingly utilized heart rate recovery following physical exertion as an indicator associated with training status and physiological responses to exercise loads. The rate at which heart rate declines during the recovery period is related, among other factors, to the

mechanisms underlying autonomic regulation of cardiac function and may reflect certain changes associated with training adaptation (Daanen et al., 2012; Suzic Lazic et al., 2017) . In this regard, Daanen (2012) examined several studies that employed heart rate recovery to monitor athletes' training status and highlighted the importance of this indicator, while emphasizing the need to standardize measurement procedures and account for the factors that may influence it. Accordingly, monitoring post-exercise heart rate can provide useful information about individual responses among sprinters. However, it should be recognized that the return of heart rate to a particular level does not necessarily indicate complete recovery of the muscular and nervous systems following maximal-speed training.

In light of the foregoing, improving 100-metre sprint performance requires training programs that combine the development of event-specific physical capacities with consideration of individual physiological responses to training loads. Furthermore, monitoring heart rate may provide coaches with valuable information for assessing athletes' functional status and regulating recovery processes, thereby creating more favorable conditions for the implementation of high-intensity training. This consideration forms the basis of the present study, which investigates the effect of a heart rate monitoring-based training program on developing selected physiological efficiency indicators and sprint performance in 100-metre sprinters. The study utilizes cardiac measurements to monitor training loads and recovery while adhering to the established scientific principles of sprint training. The researcher hopes that the findings will provide a practical contribution to helping coaches incorporate physiological monitoring methods into the development of training programs for short-distance sprinters (Salama, 2009, p. 69).

Research Problem

The 100-metre sprint is an event characterized by highly specific and demanding performance requirements, in which final performance outcomes depend on several physical, physiological, and neuromuscular factors that interact in an integrated manner over an extremely short period. Achieving improvements in this event requires the implementation of scientifically structured training programs designed to enhance acceleration, maximal speed, and the ability to maintain speed throughout the race, in addition to developing the capacity of the body's functional systems to respond to training loads and recover from their effects. Despite the considerable advances in sports training theories and methods of load prescription, reliance on external training-load components, such as exercise intensity, distance covered, number of repetitions, and predetermined rest intervals, may not be sufficient on its own to reflect the individual physiological responses of sprinters. This highlights the need for additional indicators that can facilitate more objective monitoring of these responses.

One of the challenges associated with training short-distance sprinters is achieving an appropriate balance between training-load intensity and recovery requirements. Maximal-speed and acceleration training demand high levels of neuromuscular effort, while simultaneously requiring adequate recovery periods to maintain performance quality across successive repetitions. Inadequate regulation of this balance may reduce the quality of training performance or lead to accumulated fatigue, thereby compromising the benefits derived from training sessions. In this context, heart rate monitoring may provide useful information regarding the cardiovascular response to exercise and the rate of recovery following exertion. Nevertheless, the specific nature of 100-metre sprint performance necessitates interpreting such information as supplementary indicators within a broader set of physiological and performance measures, rather than treating heart rate as an independent criterion for determining exercise intensity or confirming complete recovery.

Furthermore, advances in wearable physiological monitoring devices have created increasing opportunities to utilize cardiac data in training-load planning and monitoring their effects. However, incorporating these technological capabilities into training programs for 100-metre sprinters requires experimental investigation that accounts for the physiological and biomechanical characteristics of this event. The research problem therefore arises from the need to determine the extent to which heart rate monitoring can be used to guide selected training

decisions related to recovery and load modification, and whether this approach translates into improvements in physiological efficiency indicators and sprint performance. The importance of investigating this relationship is further emphasized by the distinction between endurance events, in which heart rate is widely used to monitor internal exercise intensity, and maximal-speed events, which primarily require reliance on indicators of speed, power, and performance quality, alongside complementary physiological measures.

In light of the above, the present research problem is defined by the need to investigate the effectiveness of a heart rate monitoring-based training program in developing selected physiological efficiency indicators and improving 100-metre sprint performance. This will be achieved through the design of a training program incorporating exercises appropriate to the physical and physiological demands of the event, while utilizing heart rate measurements to monitor individual responses among sprinters and regulate recovery processes accordingly. The study seeks to identify the magnitude of changes that may occur in the selected physiological indicators and 100-metre sprint time following the implementation of the proposed program. This will provide an opportunity to evaluate the potential value of this training approach and generate findings that may inform the development of training practices in sprint events.

Research Objectives

The present study aims to investigate the effect of a heart rate monitoring-based training program on developing physiological efficiency and sprint performance in 100-metre sprinters, through the following objectives:

1. To design a heart rate monitoring-based training program that is appropriate to the physical and physiological characteristics of 100-metre sprinters.
2. To identify the effect of the proposed training program on improving selected physiological efficiency indicators in 100-metre sprinters.
3. To determine the effect of the proposed training program on improving 100-metre sprint performance, as measured by the time required to complete the event, expressed in seconds.

Research Hypotheses

1. There are statistically significant differences between the pre- and post-test mean scores of the experimental group in selected physiological efficiency indicators among 100-metre sprinters, in favor of the post-test measurements.
2. There is a statistically significant difference between the pre- and post-test mean scores of the experimental group in 100-metre sprint performance, in favor of the post-test measurement.

METHODS

Research Methodology

The researcher employed the experimental method, as it was considered appropriate to the nature of the study. A one-group experimental design was adopted, incorporating pre- and post-test measurements.

Research Domains

Human Domain:

The study was conducted on a sample of 20 male 100-metre sprinters from sports clubs in Wasit Governorate.

Geographical Domain:

The pre- and post-test assessments and measurements were conducted at the Sub-Federation of Athletics in Wasit Governorate.

Time Domain:

1. The pilot study was conducted from 12 July 2026 to 19 July 2026.
2. The pre-test measurements were conducted on 22 July 2026.
3. The proposed training program was implemented from 25 July 2026 to 24 September 2026.
4. The post-test measurements were conducted on 26 September 2026.

Research Population and Sample

Research Population

The research population comprised 100-metre sprinters registered with the Iraqi Athletics Federation.

Research Sample

The researcher randomly selected a sample of 20 100-metre sprinters. The sample was divided into two groups: 13 athletes participated in the pilot study to establish the scientific properties of the tests (validity and reliability), while seven athletes constituted the experimental group. The distribution is presented in Table 1.

Table 1. Numerical Distribution of the Research Sample

Classification	Total Sample	Pilot Study	Percentage	Experimental Group	Percentage
100-metre sprinters	20	13	65%	7	35%

Statistical Description of the Research Sample

The researcher measured the sample's basic characteristics, including age, height, body mass, and training age, to control for variables that might influence the research procedures. Table 2 presents the descriptive statistics for these variables.

Table 2. Descriptive Statistics of the Research Sample's Baseline Characteristics. n = 20

Variable	Unit of Measurement	Mean	Standard Deviation	Skewness	Kurtosis
Age	Years	22.45	1.54	0.18	-0.82
Height	cm	176.85	5.62	0.24	-0.46
Body mass	kg	72.35	6.14	0.31	-0.38
Training age	Years	5.65	1.42	0.27	-0.64

As shown in Table 2, the baseline measurements of the overall research sample indicate relatively homogeneous data with an approximately normal distribution. Skewness coefficients ranged from 0.18 to 0.31, indicating values close to zero. Kurtosis coefficients ranged from -0.82 to -0.38, suggesting an acceptable degree of deviation from the normal distribution. These findings indicate a reasonable degree of similarity among the research participants in their baseline characteristics prior to the experiment.

Data Collection Tools and Equipment

Equipment and Instruments Used in the Study

Following a review of relevant references and previous studies, the researcher identified the equipment and instruments required to complete the research procedures and achieve the study objectives, as follows:

1. A stadiometer (restameter) for measuring standing height in centimetres.
2. A calibrated electronic medical scale for measuring body mass in kilograms.
3. A heart rate monitoring device equipped with a chest strap sensor to measure heart rate during training and following physical exertion.
4. A compatible electronic sports watch for recording heart rate readings and monitoring recovery intervals.
5. A metabolic gas analyser for measuring maximal oxygen uptake (VO_2max).
6. A portable blood lactate analyser, equipped with measurement strips and blood-sampling materials, in accordance with safety procedures.
7. Electronic timing gates for measuring 100-metre sprint performance in seconds.
8. Electronic stopwatches for controlling repetition times and rest intervals during training sessions.
9. A metric measuring tape for determining different training distances.
10. Cones and ground markers for identifying sprint distances and start and finish zones.
11. Starting blocks for start-training exercises and performance assessment.
12. A standard athletics track for conducting 100-metre sprint training sessions and tests.

13. Low training hurdles and cones for implementing selected coordination and acceleration exercises.
14. A computer equipped with software for recording physiological measurement data and conducting statistical analyses.
15. Data recording forms for documenting participants' pre- and post-test measurements.
16. Training-load monitoring forms for recording training loads, heart rate responses, and recovery intervals throughout the implementation of the proposed program.

Measurements and Tests Used in the Study

The researcher conducted a review of scientific references, research papers, and previous studies addressing the physiological variables of track and field athletes. The following variables were initially identified:

1. Resting heart rate.
2. Post-exercise heart rate.
3. Resting diastolic blood pressure.
4. Resting systolic blood pressure.
5. Heart rate recovery rate.
6. Maximal oxygen uptake (VO_2max).
7. Respiratory rate per minute.
8. Post-exercise blood lactate concentration.

These physiological variables were presented to a panel of seven experts (Appendix 1), specializing in sports training and sports health sciences, to obtain their opinions regarding the suitability of the proposed measurements for the present study. Table 3 presents the percentage of agreement among the experts concerning the selected physiological efficiency indicators.

Table 3. Expert Opinions Regarding Physiological Efficiency Indicators. n = 7 experts

No.	Physiological Efficiency Indicators	Agree (n)	Agreement (%)	Disagree (n)	Disagreement (%)
1	Resting heart rate	7	100%	0	0%
2	Post-exercise heart rate	7	100%	0	0%
3	Resting diastolic blood pressure	3	42.86%	4	57.14%
4	Resting systolic blood pressure	3	42.86%	4	57.14%
5	Heart rate recovery rate	7	100%	0	0%
6	Maximal oxygen uptake (VO_2max)	7	100%	0	0%
7	Respiratory rate per minute	2	28.57%	5	71.43%
8	Post-exercise blood lactate concentration	6	85.71%	0	14.29%

Based on the experts' opinions, the researcher excluded physiological variables with an agreement percentage below 50%. Accordingly, the physiological efficiency indicators adopted in the present study were:

Physiological Indicators:

1. Resting heart rate.
2. Post-exercise heart rate.
3. Heart rate recovery rate.
4. Maximal oxygen uptake (VO_2max).
5. Post-exercise blood lactate concentration.

Athletic Performance:

100-metre sprint performance, expressed as the time required to complete the event.

Pilot Study

The pilot study was conducted from 12 July 2025 to 19 July 2025 using the same 13 participants assigned to the pilot-study sample, who were excluded from the main experimental sample. The primary purpose was to establish the scientific properties of the tests in terms of validity and reliability.

The second pilot study aimed to:

Verify the scientific properties (validity and reliability) of the tests used in the present study, as presented in Tables 4 and 5.

Results of the Second Pilot Study

Test validity was established using the extreme-groups method (known-groups comparison), as presented in Tables 4 and 5.

Scientific Properties of the Physiological Tests Used in the Study

Validity

To establish the validity of the physiological tests under investigation, the researcher employed discriminant validity using the extreme-groups method. This involved comparing the mean scores of the upper and lower quartiles of the pilot-study sample, which comprised 13 athletes drawn from the research population and excluded from the main research sample. Table 4 presents the results.

Table 4. Differences Between the Upper and Lower Quartiles to Establish the Discriminant Validity of the Physiological Efficiency Indicators. n = 13

Physiological Variable	Unit of Measurement	Upper Quartile		Lower Quartile		t-value	p-value
		Mean	SD	Mean	SD		
Resting heart rate	Beats/min	62.33	1.53	69.67	2.08	4.924	0.0079
Post-exercise heart rate	Beats/min	177.67	2.52	185.33	2.52	3.723	0.0204
Heart rate recovery rate	Beats/min	34.33	2.52	25.67	2.52	4.209	0.0136
Maximal oxygen uptake (VO_2max)	ml/kg/min	55.33	1.53	48.67	1.53	5.331	0.0060
Post-exercise blood lactate concentration	mmol/L	10.20	0.60	12.50	0.70	4.321	0.0124

Critical t-value at the 0.05 significance level = 2.571. Statistical significance: $p < 0.05$.

As shown in Table 4, statistically significant differences were identified between the upper and lower quartiles across all the physiological variables. The calculated t-values ranged from 3.723 to 5.331, exceeding the critical t-value at the 0.05 significance level. These findings provide evidence supporting the discriminant validity of the physiological efficiency indicators.

Reliability

To establish the reliability of the physiological tests, the researcher employed the test–retest method using the same pilot-study sample of 13 athletes. The tests were administered again seven days after the initial assessment to calculate the correlation coefficients between the first and second administrations. Table 5 presents the results.

Table 5. Test–Retest Reliability Coefficients for the Physiological Efficiency Indicators

Physiological Variable	Unit of Measurement	First Test		Retest Mean		Pearson's r
		Mean	SD	Mean	SD	
Resting heart rate	Beats/min	66.25	3.42	66.08	3.35	0.92
Post-exercise heart rate	Beats/min	181.83	4.56	181.42	4.38	0.89
Heart rate recovery rate	Beats/min	29.75	3.64	30.08	3.51	0.91
Maximal oxygen uptake (VO_2max)	ml/kg/min	52.35	3.72	52.48	3.65	0.94
Post-exercise blood lactate concentration	mmol/L	11.42	1.28	11.35	1.24	0.87

Critical Pearson correlation coefficient at the 0.05 significance level = 0.532. Statistical significance: $p < 0.05$.

As indicated in Table 5, statistically significant correlations were found between the first and second test administrations across all physiological efficiency indicators. The calculated correlation coefficients ranged from 0.87 to 0.94, exceeding the critical value of 0.532 at the 0.05

significance level. These results indicate a high level of test–retest reliability for the physiological efficiency indicators investigated in the present study.

The Heart Rate Monitoring-Based Training Program for Developing Physiological Efficiency and 100-Metre Sprint Performance

First: Aim of the Training Program

The proposed training program aimed to develop selected physiological efficiency indicators and improve 100-metre sprint performance among sprinters from Iraqi sports clubs. This was achieved through the implementation of specialized physical training exercises based on the systematic prescription of training loads and heart rate monitoring, with the aim of regulating exercise intensity and recovery intervals and improving sprinters' ability to perform high-intensity training effectively.

Second: Specific Objectives of the Training Program

The proposed program was designed to achieve the following objectives:

1. Improve cardiovascular efficiency by monitoring changes in heart rate during training and following physical exertion.
2. Enhance the rate of heart rate recovery following high-intensity physical efforts.
3. Develop anaerobic capacity associated with 100-metre sprint performance.
4. Improve selected physiological efficiency indicators, including maximal oxygen uptake and post-exercise blood lactate concentration.
5. Develop acceleration ability, the capacity to attain maximal speed, and the ability to maintain it throughout the different phases of the race.
6. Improve 100-metre sprint performance by reducing the time required to complete the distance.
7. Utilize heart rate monitoring to assess individual responses to training loads and regulate recovery intervals.

Third: Principles Underlying the Design of the Training Program

In developing the proposed training program, the researcher considered the following scientific principles:

1. Ensuring that the program content was appropriate to the age group and training level of the participants.
2. Taking into account the physiological and physical characteristics of the 100-metre sprint.
3. Applying progressive increases in training loads in terms of intensity, volume, and density.
4. Accounting for individual differences in responses to training loads.
5. Using heart rate monitoring devices throughout the training sessions.
6. Providing appropriate recovery intervals between repetitions and training sets.
7. Emphasizing acceleration, maximal-speed, and speed-endurance training.
8. Incorporating a variety of physical and physiological training exercises consistent with the objectives of the program.
9. Observing safety requirements and injury-prevention principles.
10. Conducting pre- and post-test measurements under comparable conditions.

Fourth: Time Distribution of the Proposed Training Program

Table 6. Time Distribution of the Proposed Training Program

No.	Program Component	Time Allocation
1	Program duration	8 weeks
2	Training sessions per week	3 sessions
3	Total number of training sessions	24 sessions
4	Duration of each training session	90 minutes

Fifth: Example of a Heart Rate Monitoring-Based Training Session

Table 7. Example of a Heart Rate Monitoring-Based Training Session

Session Component	Training Exercise	Volume	Intensity	Rest Interval
Preparatory	General and specific warm-up and sprint technique drills	20 minutes	Progressive	As required
Main	20-metre sprints from various starting positions	4 repetitions	90–95%	2–3 minutes
Main	30-metre sprints from starting blocks	4 repetitions	95–100%	3–4 minutes
Main	Flying 20-metre sprints following an acceleration run-up	3 repetitions	95–100%	4–6 minutes
Main	Low-volume explosive strength exercises	2 sets × 4 repetitions	According to individual capacity	2–3 minutes
Cool-down	Cool-down exercises and monitoring of heart rate recovery	10 minutes	Low	—

Main Study Procedures

The main study was conducted from 22 July 2025 to 26 September 2025. The procedures were implemented as follows:

Pre-test Measurements

The pre-test measurements of the study variables were conducted on 22 July 2025 among the seven participants constituting the research sample. The tests were carried out at the sports clubs.

Implementation of the Training Program

The proposed training program was implemented with the experimental group, comprising seven athletes. The program lasted eight weeks, from 25 July 2025 to 24 September 2025, and was administered to the main research sample (experimental group).

Post-test Measurements

The post-test measurements of the study variables were conducted on 26 September 2025 among the research participants. The assessments were carried out at the sports clubs following the completion of the eight-week training program.

Statistical Analyses

The researcher used the Statistical Package for the Social Sciences (SPSS) to process the collected data and perform the following statistical analyses:

1. Arithmetic mean.
2. Standard deviation.
3. Median.
4. Skewness coefficient.
5. Kurtosis coefficient.
6. Student's t-test.
7. Pearson's correlation coefficient.
8. Frequencies and percentages.

RESEARCH RESULTS

First: Presentation and Discussion of the Results Related to the First Hypothesis

The first hypothesis stated that:

There are statistically significant differences between the pre- and post-test mean scores of the experimental group in selected physiological efficiency indicators among 100-metre sprinters, in favour of the post-test measurements.

Table 8. Statistical Significance of Pre- and Post-Test Differences in Physiological Efficiency Indicators in the Experimental Group. n = 7

Physiological Variable	Unit of Measurement	Pre-test		Post-test		t-value	p-value
		Mean	SD	Mean	SD		
Resting heart rate	Beats/min	66.14	3.18	62.43	2.76	4.12	0.0062
Post-exercise heart rate	Beats/min	181.57	4.35	178.29	4.11	2.68	0.0365
Heart rate recovery rate	Beats/min	29.43	3.21	36.14	3.58	5.24	0.0019
Maximal oxygen uptake (VO_2max)	ml/kg/min	52.14	3.42	54.71	3.16	3.17	0.0193
Post-exercise blood lactate concentration	mmol/L	11.36	1.24	10.42	1.18	2.79	0.0316

Critical t-value at the 0.05 significance level = 2.447.

The results presented in Table 8 reveal statistically significant differences at the 0.05 significance level between the pre- and post-test mean scores of the experimental group, in favour of the post-test measurements, across all physiological efficiency indicators: resting heart rate, post-exercise heart rate, heart rate recovery rate, maximal oxygen uptake, and post-exercise blood lactate concentration. The calculated t-values ranged from 2.68 to 5.24.

Second: Presentation and Discussion of the Results Related to the Second Hypothesis

The second hypothesis stated that:

There are statistically significant differences between the pre- and post-test mean scores of the experimental group in 100-metre sprint performance, in favour of the post-test measurement.

Table 9. Statistical Significance of Pre- and Post-Test Differences in 100-Metre Sprint Performance in the Experimental Group. n = 7

Performance Variable	Unit of Measurement	Pre-test		Post-test		t-value	p-value
		Mean	SD	Mean	SD		
100-metre sprint performance	Seconds	12.18	0.36	11.82	0.32	4.28	0.0052

Critical t-value at the 0.05 significance level = 2.447.

The results presented in Table 9 indicate statistically significant differences at the 0.05 significance level between the pre- and post-test mean scores of the experimental group in 100-metre sprint performance, in favour of the post-test measurement, with a calculated t-value of 4.28.

DISCUSSION

These findings are consistent with those reported by Reem Salam Ibrahim (2022), who indicated that the use of maximal-intensity training prescribed according to target heart rate contributed to the development of selected specific physical abilities and improved performance levels among young 100-metre sprinters. The observed improvements may be explained by the use of heart rate monitoring to regulate training loads and recovery intervals according to the individual capacities of the sprinters. Such regulation may help maintain performance quality across successive training repetitions and minimize the accumulation of fatigue resulting from high-intensity efforts.

Similarly, the findings of Fatima Sayed Abdel-Aleem Mohamed (2022) demonstrated statistically significant differences in heart rate measured immediately after a 100-metre sprint between the pre- and post-test assessments. The study also recommended the use of interval training to promote the development of recovery processes.

Furthermore, Litleskare et al. (2020) reported that implementing an eight-week sprint interval training program resulted in a considerable improvement in maximal oxygen uptake, alongside improvements in the ability to perform repeated sprint efforts. These changes may be

attributed to the physiological adaptations associated with regular training, which may include improved muscular oxygen utilization and enhanced efficiency of certain metabolic processes involved in energy production. Although the 100-metre sprint relies predominantly on anaerobic energy systems, improvements in aerobic capacity may contribute to supporting recovery between training repetitions and sets. This, in turn, may help sprinters tolerate the demands of the training program and maintain performance levels across successive training sessions.

The researcher considers that the observed trends in physiological efficiency indicators may be associated with the characteristics of the proposed training program, which combined sprint, acceleration, and speed-endurance exercises with systematic monitoring of heart rate during training and recovery. This approach may have contributed to improving the sprinters' ability to tolerate repeated training loads and providing recovery intervals more appropriately suited to individual physiological responses, thereby supporting the development of the targeted functional adaptations.

These findings are consistent with those reported by Reem Salam Ibrahim (2022), who demonstrated that implementing maximal-intensity training based on target heart rate over an eight-week period contributed to the development of selected specific physical abilities and improved performance levels among young 100-metre sprinters.

The findings are also consistent with those of Mohamed Sadiq Ahmed et al. (2025), who concluded that these training exercises contributed to the development of selected aspects of lower-limb muscular strength, which positively influenced sprinters' performance levels.

These findings may be explained by the fact that improving the ability of the lower-limb muscles to generate force over a short period contributes to more effective forward propulsion during sprinting. This is also associated with stride length and stride frequency, both of which are important determinants of running speed. Accordingly, the potential improvement in sprint performance may be associated with the specific components of specialized training programs, particularly explosive strength, acceleration, and maximal-speed exercises, which target the muscular and biomechanical requirements of 100-metre sprint performance.

CONCLUSIONS AND RECOMMENDATIONS

In light of the research objectives and hypotheses, and within the limits of the research sample, the procedures employed, and the results obtained through statistical analyses, the researcher reached the following conclusions:

1. The proposed heart rate monitoring-based training program contributed to improvements in selected physiological efficiency indicators among the 100-metre sprinters in the experimental group.
2. The implementation of the heart rate monitoring-based training program resulted in a reduction in resting heart rate among the experimental group participants, suggesting a potential improvement in cardiovascular efficiency.
3. The proposed training program contributed to reducing post-exercise heart rate among 100-metre sprinters, reflecting a potentially positive change in the cardiac response to physical exertion under standardized measurement conditions.
4. The heart rate monitoring-based training program improved the rate of heart rate recovery following physical exertion, indicating a potential enhancement in the cardiovascular system's recovery capacity after exercise.
5. The proposed training program increased maximal oxygen uptake, suggesting a potential improvement in aerobic capacity among the experimental group participants.
6. The proposed training program contributed to reducing post-exercise blood lactate concentration, which may reflect changes in the metabolic response to training loads, although its interpretation depends on the nature of the exercise protocol used during measurement.
7. The heart rate monitoring-based training program improved 100-metre sprint performance, as demonstrated by the reduction in mean sprint completion time following the implementation of the proposed training program.

8. The proposed training program demonstrated the potential value of heart rate monitoring in regulating training loads and recovery intervals, which may contribute to improving physiological efficiency and sprint performance among 100-metre sprinters.

Based on the findings of the study and the conclusions drawn, the researcher recommends the following:

1. Utilizing the proposed heart rate monitoring-based training program in the preparation of 100-metre sprinters, subject to further experimental validation of its effectiveness, given its potential to improve physiological efficiency and sprint performance.
2. Emphasizing the use of heart rate monitoring devices during training sessions as supplementary scientific tools for prescribing training loads and monitoring sprinters' physiological responses.
3. Taking individual differences among 100-metre sprinters into account when determining training intensity, volume, and recovery intervals, in accordance with each athlete's functional status and physical fitness level.
4. Conducting periodic measurements of resting and post-exercise heart rate to monitor changes associated with training status and cardiovascular efficiency.
5. Utilizing heart rate recovery indicators to monitor recovery processes between successive repetitions and training sets, while considering performance times and movement quality and avoiding exclusive reliance on heart rate as a recovery criterion.
6. Emphasizing the development of physical capacities specific to 100-metre sprinters, particularly acceleration, maximal speed, speed endurance, and explosive strength, given their importance in improving sprint performance.
7. Conducting periodic physiological assessments, particularly of maximal oxygen uptake and blood lactate concentration, using standardized measurement protocols to identify physiological adaptations resulting from training programs.
8. Encouraging athletics coaches in Iraqi sports clubs to utilize modern technologies for monitoring physiological responses and evaluating training loads.
9. Organizing training courses and workshops for coaches on heart rate monitoring methods, interpretation of heart rate indicators, and their application in designing training programs for sprint events.

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