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Relative Energy Deficiency in Sport (RED-S) Risk Indicators and Cardiovascular Responses to HIIT Under Heat Conditions in Female Basketball Players

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ABSTRACT **Original Research Article**

This study aimed to identify differences in hemodynamic responses, blood pressure, cardiac recovery, and orthostatic responses between female basketball players with risk indicators of Relative Energy Deficiency in Sport (RED-S) and control players following high-intensity interval training (HIIT) under heat conditions. The researcher employed a descriptive comparative approach. The sample consisted of 40 female basketball players during the 2025 sports season, who were classified based on indicators from the IOC REDs CAT2 into a RED-S risk-indicator group (n = 15) and a control group (n = 25). A standardized HIIT protocol was performed under heat conditions, while heart rate, stroke volume, systolic and diastolic blood pressure, cardiac recovery, and orthostatic response indicators were assessed. The results revealed statistically significant differences between the two groups. The RED-S risk-indicator group demonstrated a higher heart rate and lower stroke volume, as well as higher post-exercise systolic and diastolic blood pressure. This group also exhibited a longer cardiac recovery time and greater changes in orthostatic responses compared with the control group. The study concluded that the presence of RED-S risk indicators was associated with less favorable cardiovascular and recovery responses following HIIT under heat conditions in female basketball players.

Keywords: Relative Energy Deficiency in Sport (RED-S), High-Intensity Interval Training (HIIT), Hemodynamics, Cardiac Recovery, Basketball.

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Introduction

Introduction and Importance of the Research

The sports field has witnessed significant developments in training methods, measurement, and physiological evaluation in recent years. Reaching advanced athletic levels no longer depends solely on increasing training volume and intensity, but is now linked to understanding the functional responses of the body's systems to varying training loads. Studying physiological variables is a crucial foundation for evaluating training status, as it provides indicators of the body's systems' ability to cope with, respond to, and recover from physical exertion (Abdel Fattah, 2003; Khuraibat Majid, 2018). Basketball, a team sport, demands high physical and physiological efficiency due to the repetitive sprinting, jumping, changing direction, and transitioning between offense and defense. This necessitates organizing training loads and recovery periods in a manner that aligns with performance requirements. In this context, Relative Energy Deficiency in Sport (RED-S) is an important topic in sports physiology and athlete health. It is associated with a reduced availability of energy needed to meet training demands and the body's physiological functions, and its effects can extend to a number of health, physiological, and performance aspects. Monitoring this condition is particularly important for female athletes subjected to high training and competitive

loads. The International Olympic Committee (IOC) developed the IOC REDs CAT2 tool to help assess and classify the risks associated with RED-S in athletes (Heikura et al., 2025). High-intensity interval training (HIIT) is a training method that relies on repeated periods of high-intensity exertion interspersed with specific periods of rest or recovery. It produces a number of physiological responses related to the intensity and duration of the exertion and the rest periods used. Monitoring these responses becomes increasingly important when training is performed in hot conditions, due to the additional demands placed on the cardiovascular system, body temperature regulation, and recovery. This necessitates considering environmental conditions when evaluating athletes' responses to training loads (Khuraibat Majid, 2018).

Hence, the importance of research into hemodynamics, blood pressure, and cardiac recovery in female basketball players becomes clear, in light of indicators of relative energy deficit in sports. (RED-S) during high-intensity interval training (HIIT) under heat conditions, which contributes to identifying the nature of the cardiovascular response of the players, and using the results to monitor their physiological condition and regulate training loads and recovery periods in accordance with the requirements of training and competition.

Problem Statement

Basketball requires high physical and physiological efficiency because of repeated high-intensity exertion during training and competition, and the demands placed on the cardiovascular system may increase when physical exertion is combined with heat conditions, particularly for female players who suffer from reduced energy availability associated with Relative Energy Deficiency in Sport (RED-S). By observing the nature of training and competition among female basketball players, the need arose to understand the relationship between a state of relative energy deficit and changes in cardiovascular response during high-intensity exertion and under heat conditions. Despite the growing interest in RED-S syndrome, research into its relationship to hemodynamics, blood pressure, and cardiac recovery in female basketball players remains limited.

Hence, the research problem is defined as identifying differences in hemodynamics, blood pressure, and cardiac recovery among female basketball players classified according to their relative energy deficit in according to RED-S risk indicators. During high-intensity interval training (HIIT) performance under heat conditions.

Research Objectives

The research aims to:

1. Identifying differences in hemodynamic indicators among female athletes in a between the RED-S risk indicator group and the control group. After performing high-intensity interval training (HIIT) under heat conditions.
2. Identifying differences in systolic and diastolic blood pressure between the two research groups after performing high-intensity interval training. (HIIT) Under heat conditions.
3. Identifying differences in cardiac recovery between the two research groups after performing high-intensity interval training (HIIT) under heat conditions.
4. Identifying differences in orthostatic response indicators between the two research groups after performing high-intensity interval training (HIIT) under heat conditions.

Research Hypotheses

The researcher assumes the following:

1. There are statistically significant differences in hemodynamic indicators between the players in the risk indicator group. Between the RED-S, risk indicator group and the control group. After performing high-intensity interval training (HIIT) under heat conditions.
2. There are statistically significant differences in systolic and diastolic blood pressure between the two research groups after performing high-intensity interval training. (HIIT) Under heat conditions.
3. There are statistically significant differences in cardiac recovery between the two research groups after performing high-intensity interval training. (HIIT) Under heat conditions.
4. There are statistically significant differences in orthostatic Response indicators between the two research groups after performing high-intensity interval training. (HIIT) Under heat conditions.

Research Areas

Human Domain: Female basketball players in Iraqi clubs for the 2025 sports season, with a sample size of (40) female players.

Temporal Domain: The period is from 10/8/2025 until 24/8/2025.

Spatial Domain: Halls and sports fields designated for the training of female basketball players in Nineveh Governorate.

Theoretical Framework and Previous Studies

Relative Energy Deficiency in Sport (RED-S)

Relative Energy Deficiency in Sport (RED-S) is a conditions associated with insufficient energy availability to meet the body's physiological needs, along with the demands of training and competition, is that reduced energy availability can impact a number of health, physiological, and performance functions, particularly in female athletes. These impacts include reproductive function, bone health, metabolism, immunity, and cardiovascular health. Therefore, RED-S is not simply a matter of reduced dietary intake, but rather an imbalance between available energy and the requirements for training and maintaining various physiological functions (Mountjoy et al., 2023; Sims et al.,

2023). In the current study, the significance of RED-S is highlighted by comparing the cardiovascular and recovery responses of female basketball players with RED-S risk indicators to a control group during high-intensity interval training (HIIT) under heat conditions. The International Olympic Committee's statement confirms that reduced energy availability can be associated with multiple health and performance outcomes in athletes.

High-Intensity Interval Training (HIIT) Under Heat Conditions

High-intensity interval training (High-Intensity Interval Training: HIIT) High-intensity interval training (HIIT) involves repeated periods of high-intensity exertion interspersed with specific rest or recovery periods. This leads to clear physiological responses in heart rate, oxygen consumption, and cardiovascular efficiency (Astorino et al., 2022). These responses are amplified when training in a hot environment. Regulating body temperature requires increased blood flow to the skin while simultaneously maintaining blood flow to the working muscles. This increases the burden on the cardiovascular system and may lead to changes in heart rate, stroke volume, and blood pressure regulation, particularly with increased heat stress and fluid loss (Périard et al., 2015; Cramer et al., 2023). Therefore, studying HIIT under hot conditions is important in the current research to identify differences in cardiovascular responses and recovery between athletes in the RED-S risk index group and the control group.

Hemodynamics, Blood Pressure, and Cardiac Recovery

Hemodynamics represents the changes that occur in blood flow and cardiovascular function in response to physical exertion. Its most prominent indicators are heart rate, stroke volume, and blood pressure. During exercise, cardiovascular modifications occur that aim to meet the metabolic demands of the muscles and maintain the supply of blood and oxygen to the working tissues. These demands may increase when performing the activity in a hot environment. (Périard et al., 2021). Blood pressure is an important indicator for assessing cardiovascular response, while post-exercise cardiac recovery reflects the rate at which cardiac activity returns to pre-exertion levels. Heart Rate Recovery (HRR) is used as a non-invasive indicator for assessing cardiac recovery and autonomic nervous system regulation after exertion (Peçanha et al., 2017; Michael et al., 2017). These indicators were used in the current study to compare athletes in the RED-S risk index group with the control group after performing HIIT under heat conditions.

Previous Studies

Al-Ajlan Study (2023)

Al-Ajlan (2023) conducted a study entitled "The effect of high-intensity interval training (HIIT) on the physical and physiological variables of football players "This study aimed to identify the effect of high-intensity interval training on several physical and physiological variables among under-19 football players at Al-Taawoun FC in Saudi Arabia. The researcher used the experimental method, and the sample included. (10) players The training program was implemented for a period of (8) weeks The results showed improvements in several physiological variables, including heart rate, blood pressure, and maximum oxygen consumption. This study is consistent with current research on HIIT and certain cardiovascular responses, but differs in its focus on female basketball players with RED-S risk indicators and the application of exercise under heat conditions.

Heikura et al. Study (2025)

Heikura et al. (2025) conducted a study that aimed to apply the International Olympic Committee (IOC) Relative Energy Deficiency in Sport Clinical Assessment Tool Version 2 (IOC REDs CAT2) to 213 elite athletes (143 females and 70 males). Researchers used a range of health and physiological indicators to assess and classify RED-S risk levels. The results demonstrated the importance of combining multiple indicators when assessing the condition and supported the use of CAT2 in the systematic clinical assessment of RED-S risk in athletes. This study aligns with current research on using CAT2 to assess and classify RED-S risk indicators, while differing in its focus on female basketball players and the study of cardiovascular responses and recovery after high-intensity interval training (HIIT) under heat conditions.

Research Procedures

Research Methodology

The researcher used the descriptive method with a comparative approach, as it suited the nature of the research and its objectives. Basketball players were classified according to the indicators of the Relative Energy Deficiency in Sport (RED-S), then comparing the physiological responses between female players with RED-S risk indicators and those without, by measuring hemodynamic variables, blood pressure, and cardiac recovery when applying a standardized high-intensity interval training (HIIT) protocol under heat conditions.

Research Population and Sample

The research community was defined as female basketball players participating in official Iraqi women's club competitions for the sports season. 2025 The sample was selected purposively and amounted to (40) players the participants were classified according to the risk indicators of the IOC REDs CAT2 into two groups: a RED-S risk indicator group comprising 15 players and a control group comprising 25 players. The selection criteria ensured that the players were actively participating in training and competitions and did not suffer from acute injuries or conditions that could compromise the safety of the tests or the accuracy of the physiological measurements.

Homogeneity of the Research Sample

To ensure the homogeneity of the research sample in certain variables that could affect the results, the arithmetic mean, standard deviation, median, and skewness coefficient were calculated for the variables of age, height, weight, and Years of Sports Practice, as shown in the table. (1).

Table (1). The homogeneity of the research sample is evident in the variables of age, height, weight, and duration of physical activity.

Variable	Unit of Measurement	Mean	Median	Standard Deviation	Skewness
Age	Years	21.80	22.00	2.40	0.18
Height	cm	171.50	171.00	4.20	0.21
Weight	kg	65.30	65.00	5.80	0.16
Years of Sports Practice	Years	7.20	7.00	2.60	0.23

Table (1) shows that the values of the skewness coefficient for the variables of age, height, weight, and duration of sports practice were (0.18, 0.21, 0.16, 0.23), respectively. These values are close to zero and fall within the acceptable limits of normality, indicating the homogeneity of the research sample in these variables.

Information Gathering Methods

The researcher used the following methods to collect the data and information necessary to achieve the research objectives.

1. Arabic and foreign sources and references.
2. Previous studies and research related to the research topic.
3. Clinical assessment tool for Relative Energy Deficiency in Sport IOC REDs CAT2 to estimate the level of risk associated with RED-S, bearing in mind that a definitive diagnosis of the syndrome requires a specialist clinical assessment.
4. Physiological tests and measurements.
5. Data and Results Registration Form.

Devices and Tools Used in the Research

The researcher used a set of devices and tools necessary to carry out the research procedures and record the physiological variables, namely:

- Electronic device for measuring systolic and diastolic blood pressure.
- A device for monitoring and recording heart rate.
- A device for measuring ambient temperature and relative humidity.
- Electronic medical scale for measuring body mass.
- A device for measuring length.
- Electronic stopwatch.
- Legal basketballs.
- Indicators and tools for defining the protocol application area HIIT.
- Special forms for recording measurements and results.
- A device for measuring stroke volume (SV), used to record stroke volume at rest and immediately after the HIIT protocol.

Tests and Measurements Used in the Research

The researcher adopted a set of physiological tests and measurements appropriate to the research objectives and variables, to identify risk indicators. RED-S cardiovascular and recovery responses after performing the HIIT protocol under heat conditions, as follows:

1. **Evaluating indicators RED-S:** The IOC REDs CAT2 tool was used to assess the risk indicators associated with RED-S and to classify the athletes according to the risk levels adopted in the tool, with the emphasis that the tool is part of the clinical assessment process and does not on its own represent a final medical diagnosis.
2. **Heart rate:** Heart rate was measured at rest, immediately after completion of the HIIT protocol, and during the recovery phase, to identify the cardiac response to exertion and the speed at which the pulse returned to its previous level.
3. **Stroke Volume (SV):** Stroke volume was measured at rest before the HIIT protocol and immediately after exercise to assess differences in cardiovascular response between the RED-S risk indicator group and the control group.
4. **Blood pressure:** Systolic and diastolic blood pressure were measured before and after the application of the HIIT protocol, with standardization of the player's position, measurement method, and use of the appropriate cuff.
5. **Cardiac recovery:** Heart rate was monitored after the end of the exertion and recorded during the recovery period to assess the speed of cardiac recovery and compare the response between the two research groups.
6. **Orthostatic Response:** Changes in heart rate and blood pressure associated with the transition from a lying to a standing position after exertion were measured, and indicators of the postural response were compared between the two research groups.

Exploratory Experiment

The researcher conducted the exploratory experiment in date 10/8/2025. The study was conducted on a sample of (5) female players from outside the main research sample, under conditions as similar as possible to those of the main experiment, and its objective was:

1. Ensuring the validity of the devices and instruments used in measurement.
2. Identifying the difficulties that the researcher may encounter during the main application.
3. Ensuring the clarity of measurement procedures and their sequence of execution.
4. Determine the time required to take measurements and apply the protocol HIIT.
5. Ensure that heart rate, blood pressure, temperature, and humidity can be recorded regularly.
6. Training the support team on measurement and data recording procedures.
7. Standardizing application conditions, rest periods, and measurement sequence among players.

Scientific Foundations of Tests and Measurements Used

To ensure the integrity of the scientific procedures and the accuracy of the results, the researcher was careful to observe the scientific principles of the tests and measurements used, namely validity, reliability, and objectivity, as follows:

1. **Validity**
   The researcher adopted tests and measurements that are appropriate to the research variables and objectives, and a tool was used. IOC REDs CAT2 The approved method for assessing and classifying the relative energy deficit risk indicators in sports (RED-S), as well as adopting appropriate physiological measurement procedures for heart rate, blood pressure, cardiac recovery and orthostatic response, in order to ensure the suitability of the measurements to the variables to be studied.
2. **Reliability**
   The researcher ensured the standardization of measurement conditions and procedures for all members of the sample in terms of the devices used, the sequence of measurements, the timing of recording variables, rest periods, and the environmental conditions accompanying the application, in order to reduce sources of variation unrelated to the research variables and help obtain stable measurements.
3. **Objectivity**
   Objectivity was achieved by relying on specific measuring devices and tools, recording results according to clear quantitative readings, applying the same procedures to all players, and avoiding, as much as possible, the researcher's personal judgment when recording results.

Main Experiment

The researcher conducted the main experiment in date 14/8/2025 after completing the pilot study and ensuring the functionality of the equipment and instruments, and finalizing the measurement procedures, each athlete rested for 10 minutes before the start of the training. Pre-test measurements of heart rate, stroke volume, and systolic and diastolic blood pressure were then recorded. Following this, all athletes participated in a standardized high-intensity interval training (HIIT) protocol. This protocol included a 10-minute warm-up, followed by eight 30-second repetitions of high-intensity exertion at 90–95% of maximum heart rate, interspersed with 60 seconds of active recovery, and concluded with a 5-minute cool-down. Heart rate was monitored throughout the training to ensure that the target intensity range was reached.

The protocol was implemented in hot environmental conditions where the average air temperature reached (35.2°C) Relative humidity (38%) was maintained after the athletes were exposed to these conditions for (15) minutes. The exercise was conducted between 11:00 AM and 1:00 PM, with the application conditions being as uniform as possible for all participants. Post-exercise measurements were recorded immediately after the exercise, and heart rate was monitored after the first, third, and fifth minutes. Cardiac recovery time was defined as the time required for the heart rate to decrease to below (120 beats/minute).

To assess the orthostatic response, the player lay down for a period. (5) Minutes After the initial recovery phase, heart rate and blood pressure were recorded. The patient then moved to a standing position, and measurements were re-recorded after the first and third minutes. The amount of change in heart rate and blood pressure between the lying and standing positions was used to compare the two research groups.

Statistical Methods

The researcher used the statistical toolkit Statistical Package for the Social Sciences (SPSS) to process the data, the following statistical methods were used:

1. Arithmetic mean.
2. Standard deviation.
3. Percentage.
4. The skewness coefficient is used to verify the homogeneity of the sample.
5. Atest (t) for independent samples (Independent Samples t-test) to compare the two research groups.
6. Atest (t) for (t-test) to compare pre- and post-measurements within the group when needed.
7. Statistical significance level adopted ($\alpha \leq 0.05$) to judge the significance of the differences.

Presentation, Analysis, and Discussion of Results

Distribution of Sample Members According to the RED-S Assessment

Table (2). The distribution of the research sample according to the risk indicators of Relative Energy Deficiency in Sport is shown. (RED-S).

Sample Classification	Number	Percentage
RED-S Risk Indicator Group	15	37.5%
Control Group	25	62.5%
Total	**40**	**100%**

The table shows (2) the total number of participants in the research sample was (40) female athletes, who were divided into two groups based on the results of the IOC REDs CAT2 assessment tool. The number of athletes classified within the RED-S risk indicators group was (15), representing (37.5%) of the total sample, while the number of athletes in the control group was (25), representing (62.5%) of the total sample. This distribution shows that the control group constituted the larger percentage of the sample, with a difference of (10) athletes compared to the RED-S risk indicators group, and a relative difference of (25%) between the two groups. The table also shows that more than a third of the participants were classified within the RED-S risk indicators group according to the assessment mechanism adopted in the research, while the remaining athletes were not classified within this group. Therefore, the sample distribution was suitable for conducting subsequent comparisons between the two groups in the physiological variables under investigation.

Presentation and Analysis of Hemodynamic Results After HIIT Training Under Heat

To identify the differences between a set of risk indicators RED-S In the control group, in hemodynamic indicators, heart rate and stroke volume were analyzed before and after the application of the HIIT protocol under temperature conditions, as shown in Table (3).

Table (3). It shows the differences between the two research groups in hemodynamic indicators after application HIIT under heat conditions.

Variable	Group	n	Pre-test Mean ± SD	Post-test Mean ± SD	t-value Between Groups (Post-test)	p-value	Significance
Heart Rate (beats/min)	RED-S Risk Indicator Group	15	76.40 ± 5.80	182.50 ± 9.20	2.84	0.007	Significant
	Control Group	25	73.20 ± 5.10	174.30 ± 8.50			
Stroke Volume (mL/beat)	RED-S Risk Indicator Group	15	64.50 ± 7.20	94.20 ± 10.50	-3.12	0.003	Significant
	Control Group	25	68.20 ± 6.80	108.50 ± 11.40			

Statistically significant at a significance level of ($p \leq 0.05$).

Table (3) shows that there are statistically significant differences between the two research groups in hemodynamic indicators after applying the training HIIT under temperature conditions, the mean heart rate in the RED-S risk group increased from 76.40 ± 5.80 bpm in the pre-test to 182.50 ± 9.20 bpm in the post-test, while in the control group it increased from 73.20 ± 5.10 bpm to 174.30 ± 8.50 bpm. The t-value was 2.84 at a significance level of 0.007, which is less than 0.05, indicating a significant difference between the two groups in the post-test, with the RED-S risk group recording a higher heart rate.

As for the magnitude of the heartbeat, the arithmetic mean increased across a range of indicators. In the RED-S group, stroke volume increased from (64.50 ± 7.20) ml/beat beforehand to (94.20 ± 10.50) ml/beat afterward, while in the control group it increased from (68.20 ± 6.80) ml/beat to (108.50 ± 11.40) ml/beat. The t-value was (-3.12) at a significance level of (0.003), indicating a significant difference between the two groups in the post-test measurement, favoring the control group in terms of stroke volume increase.

The results generally show that a set of risk indicators RED-S after exertion, they showed a higher heart rate and a lower stroke volume compared to the control group, confirming a difference between the two groups in hemodynamic response after performing HIIT under heat conditions.

Presentation and Analysis of Systolic and Diastolic Blood Pressure Results After HIIT Training Under Heat

To identify the differences between a set of risk indicators RED-S for the control group in blood pressure after applying the HIIT protocol under heat conditions, the arithmetic means and standard deviations were extracted and the independent samples t-test was used, as shown in Table (4).

Table (4). It shows the differences between the two research groups in systolic and diastolic blood pressure after application HIIT under heat conditions.

Variable	Group	n	Mean	Standard Deviation	t-value	p-value	Statistical Significance
Systolic Blood Pressure (mmHg)	RED-S Risk Indicator Group	15	148.50	11.20	4.08	<0.001	Significant
	Control Group	25	134.20	10.50			
Diastolic Blood Pressure (mmHg)	RED-S Risk Indicator Group	15	86.40	6.80	3.02	0.004	Significant
	Control Group	25	79.50	7.10			

Statistically significant at the significance level ($p \leq 0.05$).

Table (4) shows that there are statistically significant differences between the two research groups in systolic and diastolic blood pressure after applying the protocol. HIIT under temperature conditions, the mean systolic blood pressure in the RED-S risk group was 148.50 mmHg (11.20 standard deviation), while in the control group it was 134.20 mmHg (10.50 standard deviation). The calculated t-value was 4.08 at a significance level of $p < 0.001$, indicating significantly higher systolic blood pressure in the RED-S risk indicator group compared with the control group.

As for diastolic blood pressure, the arithmetic mean reached a set of indicators RED-S (86.40 mmHg) with a standard deviation of (6.80), compared to (79.50 mmHg) with a standard deviation of (7.10) in the control group. The calculated t-value was (3.02) at a significance level of (0.004), which is less than the established significance level of (0.05), indicating a significant difference between the two groups in diastolic blood pressure as well.

The results generally show that the players have a high-risk index. RED-S they recorded higher values in both systolic and diastolic blood pressure after performing HIIT under heat conditions compared to the control group players.

Presentation and Analysis of Cardiac Recovery Results After HIIT Under Heat Conditions

To identify the differences between a set of risk indicators RED-S for the control group in cardiac recovery after the application of the HIIT protocol under heat conditions, the arithmetic means and standard deviations were calculated and the independent samples t-test was used, as shown in Table (5).

Table (5). The study reveals the differences between the two research groups in Cardiac Recovery indicators after application. HIIT under heat conditions.

Variable	Group	n	Mean	Standard Deviation	t-value	p-value	Significance
Cardiac Recovery Time (min)	RED-S Risk Indicator Group	15	6.85	1.20	7.58	<0.001	Significant
	Control Group	25	4.12	0.90			
Heart Rate at the Third Minute (beats/min)	RED-S Risk Indicator Group	15	126.40	10.40	7.17	<0.001	Significant
	Control Group	25	104.80	8.60			

Statistically significant at the significance level ($p \leq 0.05$).

Table (5) shows that there are statistically significant differences between the two research groups in cardiac recovery indicators after applying the protocol HIIT under temperature conditions. The mean cardiac recovery time for the RED-S risk indicator group was (6.85) minutes with a standard deviation of (1.20), compared to (4.12) minutes with a standard deviation of (0.90) for the control group. The calculated (t) value was (7.58) at a significance level of ($p < 0.001$), indicating a significant difference between the two groups, as the RED-S indicator group required a longer recovery time.

The mean heart rate after the third minute of recovery was also measured in a group of indicators. RED-S (126.40 beats/minute) with a standard deviation of (10.40), while the

control group reached (104.80 beats/minute) with a standard deviation of (8.60), and the calculated value of (t) reached (7.17) at a significance level of ($p < 0.001$), which indicates that there is a significant difference between the two groups.

The results generally show that a set of risk indicators RED-S it showed slower cardiac recovery than the control group, represented by an increase in the time required for recovery and a higher heart rate after the third minute after the end of the effort.

Presentation and Analysis of Orthostatic Response Results After HIIT Training Under Heat

To identify the differences between a set of risk indicators RED-S in the control group, the cardiovascular response associated with the transition from a supine to a standing position after performing the HIIT protocol under heat conditions was analyzed, including the change in heart rate and systolic blood pressure, and the independent samples t-test was used, as shown in Table (6).

Table (6). It shows the differences between the two research groups in orthostatic response indicators after application HIIT under heat conditions.

Variable	Group	n	Mean	Standard Deviation	t-value	p-value	Significance
Change in Heart Rate upon Standing (beats/min)	RED-S Risk Indicator Group	15	27.60	6.40	4.19	<0.001	Significant
	Control Group	25	19.30	5.80			
Decrease in Systolic Blood Pressure upon Standing (mmHg)	RED-S Risk Indicator Group	15	13.80	4.70	3.63	<0.001	Significant
	Control Group	25	8.60	4.20			

Statistically significant at the significance level ($p \leq 0.05$).

Table (6) shows that there are statistically significant differences between the two research groups in the indicators of orthostatic response after applying the protocol. HIIT under temperature conditions, the mean change in heart rate when transitioning from lying to standing was 27.60 bpm (6.40 standard deviation) for the RED-S group, compared to 19.30 bpm (5.80 standard deviation) for the control group. The calculated t-value was 4.19 at a significance level of $p < 0.001$, indicating a statistically significant difference between the two groups.

The mean arithmetic mean decrease in systolic blood pressure upon standing was also reached in a set of indicators. RED-S (13.80 mmHg) with a standard deviation of (4.70), compared to (8.60 mmHg) with a standard deviation of (4.20) in the control group, and the calculated value of (t) was (3.63) at a significance level of ($p < 0.001$), which indicates that there is a significant difference between the two groups.

The results show that a set of risk indicators RED-S a greater increase in heart rate and a greater decrease in systolic blood pressure were recorded when transitioning to a standing position compared to the control group, which confirms the difference in the orthostatic response between the two research groups after performing HIIT under heat conditions.

Discussion of Results

The research results showed statistically significant differences between the group of female players with risk indicators. RED-S the control group exhibited cardiovascular responses following high-intensity interval training (HIIT) under heat conditions. The RED-S indices group showed a higher heart rate and lower stroke volume, as well as increased systolic and diastolic blood pressure, delayed cardiac recovery, and greater changes in the postural response. These results can be explained by the interaction of reduced energy availability with the physiological burden of high-intensity, heat-induced exertion. The International Olympic Committee notes that reduced energy availability associated with RED-S may affect a number of physiological, health, and performance functions in athletes (Mountjoy et al., 2023).

Regarding heart rate and stroke volume, the researcher believes that a high pulse rate and low stroke volume are associated with a range of indicators. RED-S may be associated with increased cardiovascular strain during exertion in hot environments. Exercise in the heat necessitates increased blood flow to the skin to dissipate heat while simultaneously maintaining blood supply to the working muscles. Sustained exertion may be accompanied by a gradual increase in heart rate and a decrease in stroke volume, a phenomenon known as cardiovascular drift. These mechanisms also help explain the elevated systolic and diastolic blood pressure observed in the RED-S index group, as the combination of high-intensity exertion and heat stress places additional demands on circulatory regulation and the maintenance of cardiovascular stability (Périard et al., 2021).

As for the results of cardiac recovery, they showed that a range of indicators The RED-S group required a longer recovery time, with their heart rate remaining higher after the third minute compared to the control group. This suggests a slower recovery of cardiovascular homeostasis after exercise in this group, as a decrease in heart rate after exercise is a commonly used indicator for assessing cardiac recovery and parasympathetic reactivation (Peçanha et al., 2017). The combination of high-intensity, high-temperature, and low

energy availability may be contributing factors to this difference, but RED-S should not be considered a sole and direct cause of this response given the comparative design of the study.

The results also showed that a set of indicators The RED-S group exhibited a greater change in heart rate and a greater decrease in systolic blood pressure upon transitioning from a supine to a standing position, indicating a difference in the postural response between the two groups. This can be explained by the effect of heat stress on blood distribution, vascular responses, and blood pressure maintenance during postural changes. Overall, the research findings support the hypothesis that there are differences in cardiovascular response, recovery, and postural response between athletes with RED-S risk scores and the control group after performing HIIT under heat conditions. However, these results represent an association between risk score classification and measured physiological responses, not a direct causal relationship.

Conclusions and Recommendations

Conclusions

In light of the research findings, their analysis, and discussion, the researcher reached the following conclusions:

1. The players showed a range of risk indicators RED-S a different cardiovascular response after performing HIIT training under heat conditions compared to the control group, represented by an increased heart rate and a decreased stroke volume.
2. A number of risk indicators were recorded RED-S higher values in systolic and diastolic blood pressure after exertion compared to the control group.
3. A range of risk indicators showed RED-S slower cardiac recovery, represented by an increased recovery time and a higher heart rate during the recovery phase compared to the control group.
4. Differences in orthostatic response emerged between the two research groups, with one-group recording higher risk indicators. RED-S greater change in heart rate and greater decrease in systolic blood pressure when moving from lying down to standing after exertion.

Recommendations

In light of the research findings, the researcher recommends the following:

1. Attention should be paid to the early detection of indicators of declining energy availability and RED-S for female basketball players, especially during periods of high training and competitive loads.
2. Consider the players' health and energy levels when planning training sessions. HIIT in hot conditions, with monitoring of heart rate, blood pressure and post-exertion recovery indicators.
3. Paying attention to nutritional programs appropriate to training and competition requirements, and seeking help from specialists when risk indicators appear RED-S.
4. Conducting future studies on larger samples and different athletic categories, examining the effect of different temperatures and training intensity on cardiovascular and recovery responses.

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