The effect of high-intensity interval training on malondialdehyde (MDA) concentration in blood, circulatory respiratory endurance, and 1500-meter runner performance in young men

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Abstract

The circulatory and respiratory systems play a significant role in increasing the 1500m runner's endurance, who must be able to withstand the demands of competition and distribute their physical abilities over the race distance, depending on the circumstances they face during the race. As well as increasing the body's functional systems' ability to eliminate waste products of energy production reactions, particularly those reactions that result in increasing production of free radicals, which in turn leads to increased malondialdehyde (MDA), which affects functioning cells and limits their effectiveness, and occasionally leads to their damage. The research aimed to identify the effect of high-intensity interval training on the concentration of malondialdehyde (MDA), circulatory system endurance, and the achievement of 1500-meter runners. The research sample consisted of 7 young runners representing the Anbar Governorate team in this sports event. The researcher supposed that this training method leads to differences in the level of MDA in blood and improves the ability of the circulatory and respiratory systems, as well as improves the 1500-meter achievement for the research sample. The researcher chose the experimental method that is compatible with solving the research problem. The researcher chose the experimental curriculum which fits with solving the research problem. The most important conclusions reached by the study results are that the high-intensity interval training method increases MDA levels in the blood that result from lipid oxidation, develops of the ability of the circulatory and respiratory systems, in addition to improves 1500 meters performance for the research sample. The researcher recommended using this training method in the development of the ability of the circulatory and respiratory systems to endure competition at an ideal level. As well, He emphasises that the trainers should monitor MDA concentrations in the blood, as it plays a key role in determining the number of free radicals produced during fat metabolism to produce energy.

1- Introducing Research:

1-1 Introduction and the Importance of Research:

The 1500-meter sports event is one of the races that receives attention from most of the audience during Athletics because of its special feature in exchanging positions between the runners throughout the race. This special feature depends on the level of physical fitness and the endurance of the circulatory and respiratory systems for each runner. The exercises of this sports event are characterized by overlapping aerobic and anaerobic training, by both the phosphagen and the lactic systems, because a 1500m runner requires all of the energy production systems, as each system is needed for a specific distance of the race. High-intensity interval training is perfect for this sport event because its exercises are characterised by near-maximal intensity, permeated by rest periods that are suitable for the intensity and density of the exercises, which leads to the development of physical abilities essential for the runner to achieve the race optimally, such as speed, endurance, and strength. Moreover, it

helps improve both special and general endurance for each of these physical traits. The importance of the research lies in the requirement of accurately monitoring the physiological and physical changes that occur in the runner's body during these exercises, particularly focusing on malondialdehyde (MDA), which plays a key role in detecting the amount of free radicals involved in lipid oxidation to release the energy desired. Furthermore, it aims to enhance the runner's respiratory endurance, which is important for finishing the race with a remarkable performance, mainly in the final lap.

1-2 Research Problem:

Some coaches lack the culture of studying physiological changes, such as biochemical variables that influence the oxidation of food substances, especially fats. They also neglect monitoring the developments in athletes' functional systems during special sports training. As the researcher is a former runner and former coach who follows global scientific advancements in training and sports physiology, it has been observed these shortcomings. Also it has been noted the difficulties faced by the research sample in finishing the race in a perfect manner, mainly in the final lap. Therefore, the researcher proposed studying this issue by developing a training program based on high-intensity training methods and monitoring blood levels of malondialdehyde (MDA), which reflects free radical levels resulting from lipid metabolism for energy production, which lead to understand the changes caused by this training load, helping to improve the athletes' respiratory endurance. The goal is for them to distribute their physical capabilities appropriately across the race distance, thereby enhancing their performance and completing the race at the best possible level.

1-3 Research Aims:

- Developing exercises based on high-intensity training methods for the research sample.
- Investigating the effect of high-intensity training on blood levels of MDA, the capacity of the cardiovascular and respiratory endurance systems, and performance in the 1500-meter race among the research sample.

1-4 Research Assumptions:

There are statistically significant differences between the pre-test and post-test in the 1500-meter performance, the endurance capacity of the cardiovascular and respiratory systems, and the blood levels of MDA among the research samples.

1- 5 Research Fields:

1-5-1 Human field: Anbar Province national team in the 1500-meter run event for youth.

1-5-2 Time Field: From April 6, 2024, to August 11, 2024.

1-5-3 Place Field: Ramadi Sports Club stadium.

2- Theoretical studies:

2-1 High-Intensity Interval Training:

High-intensity interval training involves alternating periods of intense effort with recovery stages during the workout period. The intensity reaches up to approximately 90% of the athlete's maximum capacity. Rest periods are properly timed to allow the heart rate to fall between 90 and 120 beats per minute between repetitions. This method effectively enhances cardiovascular fitness and overall performance in a short amount of time. This training method is characterized by increasing the intensity of the workload while reducing its volume. It purposes to develop physical efficiency and body adaptation based on incomplete effort and

recovery periods. As a result, it is widely used by coaches to improve special fitness capabilities such as endurance, strength endurance, and speed endurance. These abilities are essential and fundamental for a 1500-meter runner to complete the race optimally, "as they improve the athlete's capacity to exert effort under oxygen debt conditions, which will be experienced during the race when intensity approaches the athlete's maximum capacity. However, this endurance will improve oxygen exchange between muscles as well as increase the capacity of the body's systems to achieve physical effort in the presence of oxygen debt"**(1).** Furthermore, it enhances their ability to delay fatigue because of adaptation to such training load. Progression in training load using this method can be achieved by increasing running speed, increasing the number of repetitions while keeping the distance fixed, or by maintaining the number of repetitions and reducing the rest intervals between them.

2-2 Malondialdehyde (MDA):

The body's functional systems of an athlete require a significant amount of energy to perform their duties normally during physical exercises, especially those close to maximum intensity for a relatively long time, such as a 1500-meter race. This energy is resulting from metabolic processes, supplemented by chemical reactions within the working cells and tissues, particularly during the oxidation of unsaturated fats. "These chemical reactions produce numerous free radicals, which increase the level of Malondialdehyde (MDA) in the blood. Raised levels of these oxidized by-products can damage cells and impair their functions" **(2).** Malondialdehyde (MDA) is a key biomarker used to detect changes caused by free radicals during the oxidation of fats within cells or tissues as a result of physical effort. Its significance lies in being a major indicator for assessing oxidative stress intensities. Specialally, "measuring MDA levels in blood serum, which typically range from 1.0 to 3.0 micromoles per liter, provides valuable insights into the health of an athlete's functional systems, especially the muscular, circulatory, and respiratory systems"**(3)(4)**. "Oxidative stress affects the body's functional systems, which leads to muscle weakness. Therefore, an increase in MDA levels helps in stimulating body's antioxidant defences, which reduce the effects of oxidative stress resulting from energy production processes (5). The most important antioxidant enzymes whose activity increases with increasing of the concentration of MDA are superoxide dismutase (SOD) and glutathione peroxidase (GPX), these enzymes reduce fat oxidation and decrease the level of MDA, thus preserving the functioning cells when physical effort is performed (6). Therefore, MDA has two effects: firstly, the positive effect, which stimulates and increases the activity of antioxidants; secondly, the negative effect, which weakens and damages cell function Its concentration level in blood depends on the imbalance between antioxidant defence mechanisms and the amount of free radical production. The high-intensity interval training method, which is characterised by high intensity, requires a continuous supply of oxygen, especially when performing relatively long-period exercises as "High-intensity exercises increase oxygen consumption, with continued physical effort leading to the production of active oxygen. This oxygen oxidizes unsaturated fats, which increases the production of MDA" (7). A significant increase in fat oxidation leads to an imbalance in the amount of fats required by the cells, which affects the proper performance of the cells' functions, and here comes the important role of MDA in maintaining the functions of the body's systems, rationing training, and identifying the body's organs' ability to withstand the load of training, according to a compatible intensity with the runner's physiological and physical ability, as "MDA has the major role by identifying the reactions of nutrients metabolism which produce energy, especially when fats are metabolized and oxidized, which is accompanied by a significant increase of free radicals; this abnormal increase leads to damage to the cell structurally and functionally" (8). This leads to the preservation of muscle strength and the ability of the circulatory and respiratory systems to

withstand performance, as well as their increased adaptation in the rapid delivery of necessary oxygen and the removal of metabolic waste products generated during energy production. It also ensures that all active tissues respond to physical exercises in a manner proportionate to their intensity and duration, whether during training or competition. Conversely, training loads of low or moderate intensity, or high-intensity training with extended rest periods between sessions, do not increase Malondialdehyde (MDA) levels; instead, they reduce its concentration. This is because "exposing the athlete's body to high effort, then low effort, followed by high effort with rest breaks, means that this type of high-intensity interval training does not require continuous energy, which lowers metabolic activity and reduces free radical production" **(9)**. Consequently, this situation helps balance free radicals with antioxidants, resulting in a decrease MDA levels in blood.

2-3 Cardiopulmonary endurance:

Cardiopulmonary endurance is a key component that a 1500-meter runner must possess. This ability is essential during most stages of the race, especially after crossing roughly half the distance. At this point, the body's functional systems alteration to relying on different energy sources compared to the start of the race. Because "when the working cells exhaust their stored energy compounds such as ATP and phosphocreatine (CP) the athlete's body changes from the phosphagen system to the anaerobic glycolytic system. This system metabolizes carbohydrates without oxygen, converting them into glucose to produce ATP directly that sustaining the effort desired during the race"**(10)**. As for "excess glucose is stored in the blood and used continuously as the body demands energy for optimal performance. However, these oxygen-independent energy production reactions cause accumulation of pyruvic acid and lactic acid in the muscles and blood, which lead to muscle fatigue"**(11)**. Here, the importance of the cardiovascular and respiratory systems adapting becomes greater in handling the demands of the race especially when the body enters the aerobic energy production system. At this stage, the runner needs more energy compounds to support the working muscle groups in performing continuous and powerful contractions. Furthermore, the athlete must endure fatigue that lasts until the end of the race, which places a significant load on the cardiovascular and respiratory systems to deliver oxygen efficiently to the working tissues and quickly remove metabolic waste produced during energy reactions and the ability to resist ongoing fatigue throughout physical performance until the finish line reflects the efficiency of these two systems. Their effectiveness represents "the body's vital capacity to supply energy and support the working muscles in maintaining contractions that match the demands and duration of the athletic activity"**(12)**.

2-4 The 1500-meter race event:

The 1500-meter race is one of the most popular events among spectators because it is marked by strong competition between runners throughout the race. This athletic event requires a runner with strong willpower, determination, and the ability to distribute physical effort evenly across all stages of the race, depending on their fitness level and the functional efficiency of their body systems in handling the demands of the race. The runner must have a high physical capacity to endure the stresses of training or competition, as well as tolerate oxygen debt and muscle fatigue that occur during the race. Therefore, the runner's body systems must be adapted to all physical qualities and abilities, especially those that combine endurance with speed and strength. This type of special endurance must match the capabilities of all body systems, especially the heart, circulatory system, and respiratory system, which are responsible for delivering the main requirements to the working muscles to produce the energy needed for strong and continuous contractions. Due to the special nature of the 1500-meter race, which requires continuous running over this distance at a relatively high speed,

the runner must improve the efficiency of both the circulatory and respiratory systems. That's why they need to develop general endurance, special endurance, and speed endurance to reduce the appearance of oxygen debt and muscle fatigue during the competition. Training programs for 1500-meter runners should include exercises that develop all energy systems, including the aerobic system and both types of anaerobic systems; the phosphagen system and the lactic acid system.

3- Research Methodology and Field Procedures:

3-1 Research Methodology:

The researcher used the experimental method with a one-group pre-test and post-test design, as it is suitable for the nature of the research problem.

3-2 Research Sample:

The research sample was selected intentionally and consisted of (7) runners representing the Al-Anbar province team in the 1500-meter running event for youth. Table (1) shows the homogeneity of age and the variables under study.

Table (1) shows the homogeneity of the research sample.

Variables	Measuring Unit	Mean	Standard deviation	Median	Kurtosis*
Biological age	Year	18.14	1.069	18	0.393
training age	Month	21.285	2.288	22	- 0.937
Malondialdehyde (MDA)	µmol/L	2.30	0.983	2.40	- 0.305
Cardiorespiratory Endurance	Second	77.57	2.572	78.00	- 0.502
1500m achievement	Second	240.42	3.552	239	1.199

The distribution is considered normal if the skewness coefficient values are less than (±3).

3-3 Pre-Tests:

The pre-measurement of MDA was conducted at Al-Shifa Laboratory, while the respiratory endurance and performance tests were performed at Al-Ramadi Sports Club on (6/4/2024) as follows:

3-3-1 Measurement of MDA Concentration in Blood Serum (13):

Aim of measurement: Determine MDA concentration in blood serum.
Measurement process: (0.1) ml of blood serum is taken from each one of research sample and putted in test tubes, (0.1) ml is added to Thio-barbituric acid tube and acetic trichloride acid tube, then (0.6) ml of distilled water is add to the solution, the tubes are placed in a hot water bath at a temperature of (95 C) for (60) minutes, then the quickly cooled in an ice bath. Impurities or sediments are then removed by placing the tubes in a centrifuge, then the spectral absorption is measured by a spectrophotometer at a wavelength of (532) nanometres.

: The result is read and processed statistically according to the following equation: **Recording**

(MDA) concentration (mol/L) = Spectral Absorption × Total volume of the solution (L) / molar extinction coefficient × Optical Path length (cm) × Sample volume (L).

- **Spectral Absorption**: measured by using a spectrophotometer at a wavelength of **(532) nanometers**.
- **Total volume of the solution**: by measuring the final volume of the mixture, in liters.
- **molar extinction coefficient**: A constant for the MDA-thiobarbituric acid (TBA) complex. Its typical value is: $\mathbf{1.56 \times 10^5\ mol^{-1} \cdot cm^{-1}}$.
- **Optical Path length**: Usually **1 cm**, which is the width of the glass cuvette used for the measurement.
- **Sample volume**: The amount of the sample used in the reaction, in **liters**.

3-3-2 Cardiorespiratory Endurance Test: 5 × 55 m Shuttle Run(14):

Two cones are set up with a distance of (55) meters between them, using a stopwatch. The player starts in a high starting position in front of the first cone, behind the starting line (point A). When the start signal is given, the player runs towards the second cone, turns around it, and returns to the starting line. The player continues to run back and forth between the two lines five times, with the last return ending at the finish line (point B). The time taken by the player to cover the distance between the two lines back and forth five times is recorded in seconds to the nearest tenth of a second.

3-3-3 1500-Meter Performance Test:

The test starts from the legal starting position for middle-distance races. The runners take their positions behind the starting line, and when the start signal is heard, the timer is started. The runners then race their individual 1500-meter distances. The stopwatch is stopped when a runner crosses the finish line. The recorder notes each runner's time in the registration form, rounded to the nearest tenth of a second.

3-4 Main Experiment:

The researcher relied on a high-intensity interval training method for the sample of study, with the intensity of the speed exercises ranging between (80-90%) of the athlete's maximum capacity. This was based on researcher's review of modern practical sources, particularly in the fields of physiology and sports training. With positive rest periods and suitable for the physical and functional level of the sample, whether between repetitions or between sets that make up the training unit. The training program included (24) training units, with exercises applied in the main part for (60) minutes to each training unit. The program was applied over a period of (8) weeks, consisting of (3) training units on Sundays, Tuesdays, and Thursdays each week. The goal of the training program was to increase physical capacities related to endurance, especially special endurance and speed endurance, using both aerobic and anaerobic lactate training. This was achieved through continuous running exercises over distances ranging from (400 to 2000) meters, with attention given to increasing the intensity of the exercises in the final weeks to reach (90%) of the athletes' physical and physiological capacity. This was done either by fixing the distance and increasing the speed or by fixing the speed and increasing the distance. Such an approach leads to improved efficiency of both the circulatory and respiratory systems and helps develop the athlete’s adaptation to endure race distances and meet competition requirements at the best possible level. The training program included exercises that fall within the aerobic energy production system as well as those within the anaerobic lactate energy production system, both of which are essential for a 1500-meter runner to perform at a level that allows them to distribute their energy throughout the race according to their ability and the adaptation of their functional systems, especially the circulatory and respiratory systems. This enables them to control the race better than their competitors and finish in a way that helps them achieve the best performance.

3-5 Post-Tests:

The post-tests were conducted using the same method as the pre-tests. The researcher took the measurements and tests under study on (27/5/2024).

3-6 Statistical Means(15):

Mean, Standard Deviation, Median, Skewness Coefficient, T-Test

4- Presentation, analysis, and discussions of results

4-1 Presentation, and analysis of results

Table (2): Statistical Treatments for the Pre-test and Post-test of the Research Variables

Variables	Pre-test		Post-test		X Variance	S Variance	T-test Cal.	Results
	X	S	X	S				
Malondialdehyde	2.30	0.983	5.26	0.873	2.957	0.220	13.440	Significant
Cardiorespiratory Endurance	77.57	2.572	69.14	1.345	8.428	0.369	22.840	Significant
1500m achievement	240.42	3.552	233.14	3.484	7.286	0.522	13.958	Significant

The results of Table (2) regarding the pre- and post-measurements of the research variables (MDA, respiratory endurance, and 1500-meter performance) showed various differences between the pre-test and post-test measurements, which were (2.957, 8.428, 7.286) respectively. The standard deviations of these differences were (0.220, 0.369, 0.522) respectively. Thus, the calculated T-test values for the research variables were (13.440, 22.840, 13.958) respectively. When comparing these values to the table value of (3.143) at a significance level of (0.01) and degrees of freedom (7 - 1 = 6), it was found that the calculated T values were greater than the table value. This indicates that the differences are statistically significant for the post-test for all research variables

4-2 Discussions of results

The researcher attributes the increased level of MDA concentration in the blood serum, as confirmed by the significant differences between the pre- and post-measurements in the sample according to Table (2) to high-intensity interval training, where the intensity of the exercises reaches (90%) of the athlete's maximum capacity. This type of physical training exposes the athlete’s body to high effort due to continuous movement during running. This persistence in physical performance requires significant energy, leading to the use of fat as an energy source, especially within the skeletal muscles. The continuous stress on the athlete's body results in increased fat oxidation, which increases glucose levels in the blood and muscles. The increment in fat oxidation leads to a higher concentration of MDA. As "skeletal muscles' demand for oxygen and energy increases, there is a corresponding rise in nutrient metabolism to enhance energy production along with higher oxygen consumption. Additionally, fat oxidation contributes to increased oxidative stress in cell membranes, resulting in a higher number of free radicals and, consequently, an elevated concentration of MDA"**(16)**. Therefore, the researcher believes it is important to monitor MDA levels in the blood and to find and improve suitable mechanisms that reduce the levels of free radicals and MDA resulting from fat oxidation, due to their negative effects on the function of working cells and tissues during physical exertion. Studies show that "near-maximal intensity physical training stimulates antioxidants that help lower the levels of free radicals and the

concentration of MDA resulting from fat oxidation."**(17)**. Furthermore, knowing the levels of MDA allows for the adjustment of training based on the athlete's physical and physiological condition. Thus, sports training can enhance the antioxidant defence system, which reduces levels of MDA and free radicals. This enables the coach to progressively increase training loads smoothly without harming the working cells and tissues. "Training of near-maximal intensity increases the activity of antioxidant enzymes, which helps reduce oxidative damage during physical exercises."**(18)**. As for the development of respiratory endurance in the sample, as evidenced by the results of the pre- and post-tests, the researcher attributes this improvement to the training program, which included mostly near-maximal intensity exercises, which involved continuous running for distances of up to (2000) meters. This difficult physical performance requires continuous metabolic support for energy production, accompanied by an increase in oxygen consumption, leading to muscle fatigue, as "near-maximal intensity exercises increase the rate of oxygen consumption, which accelerates fatigue due to impaired mitochondrial function and inhibition of both lactic and aerobic metabolisms"**(19)**. This was observed in the sample, where the functional systems, particularly the circulatory and respiratory systems, improved their ability to handle physical and functional loads and increased their capacity to endure continuous high-intensity exercises, reaching up to (90%) of the maximum capacity of the runners. The study results revealed an improvement in respiratory endurance among the sample, leading to adaptations in both the circulatory and respiratory systems. This enhanced their cooperation in delivering the necessary oxygen for energy production to the working cells and tissues, as well as increasing their ability to eliminate the byproducts of metabolic reactions resulting from energy production. Furthermore, these systems adapted to endure fatigue and function under conditions of oxygen deficiency when the runner needed it, both during training and competition. The skeletal muscles also adapted by increasing the activity of antioxidant enzymes to reduce the levels of free radicals and MDA resulting from fat oxidation. Although "near-maximal intensity exercises can cause oxidative stress and increase MDA levels, this rise is necessary to stimulate the body's antioxidant defences, which improve the adaptation of the muscular, circulatory, and respiratory systems. Oxidation levels correspond directly to the amount of oxidants produced, which relates to the intensity, volume, and density of the exercise performed"**(20)**. The researcher attributes the improvement in performance levels in the sample to near-maximal intensity exercises that align with the special preparation phase, as these athletes need this level of training intensity to develop the special physical abilities required for the 1500-meter race. This training helps the functional systems of the athlete's body adapt to the physical demands that runners face before entering competition. As "increasing the training intensity according to the athlete's capabilities leads to a high level of adaptation."**(21)**. Thus, the researcher focused on developing the special endurance of the runners, which played a key role in the adaptation of both the circulatory and respiratory systems to meet the demands of high-intensity exercises. The adaptation of these functional systems allowed them to work in harmony to provide oxygen almost continuously and to quickly eliminate metabolic by-products from the muscle cells. The training program also facilitated the adaptation of the skeletal muscles to handle training loads close to the runner's maximum capacities. Additionally, it increased the stimulation of oxidative enzymes to remove free radicals and malondialdehyde (MDA) produced from fat oxidation, which can affect muscle structure and performance efficiency. Therefore, the development of special endurance had a positive impact on increasing the circulatory and respiratory systems' ability to withstand fatigue and operate under conditions of reduced oxygen supply to the working muscles. This enabled the runner to better distribute their physical capabilities throughout the race and maintain their speed from start to finish. The sample ultimately achieved improved performance, as evidenced by shorter times in the post-tests, resulting from an increase in

running speed with precise and continuous technique without a decrease in speed, especially in the final stages of the race.

5- Conclusions and Recommendations:

5-1 Conclusions:

- The high-intensity interval training method led to an increased level of malondialdehyde (MDA) concentration in the blood of the sample.
- The high-intensity interval training method led to the development of respiratory endurance in the sample.
- The high-intensity interval training method led to improved performance in the 1500-meter run among the sample.
- Near-maximal intensity exercises that require relatively long durations increase the number of free radicals due to fat oxidation, leading to an increase in the concentration of MDA in the blood.

5-2 Recommendations

- Developing the ability the circulatory and respiratory systems and the achievement of 1500-meter runners by using the high-intensity interval training method.
- MDA concentration in the blood is considered a vital indicator to identify the athlete's level of physical fitness, especially the abilities related to general and specific endurance, to protect the cells and tissues of the skeletal muscles, maintain their strength and prevent their damage by not making the athlete perform exercises above his physical level
- The necessity to monitor MDA concentration in the athlete's blood, because it is a valid indicator of his physical and functional level, which leads to identify the athlete's ability to work on rationing training according to intensity, volume and density in a suitable manner to his ability to tolerate performance, whether during training or competition.
- Conducting studies to understand the physiological mechanisms of fat oxidation processes combined by increasing in free radicals and (MDA) concentration in the blood when physical stress is performed, particularly when the intensity or volume of the exercise is increased.
- Conducting studies using near-maximal intensity training methods to identify the positive role of antioxidant enzymes and how to stimulate these enzymes for decreasing the levels of free radicals and (MDA) resulting from fat oxidation processes, because of the negative effect of them on skeletal muscle cell functions when physical stress is performed.

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