

ISSN: 2392-5442 ESSN : 2602-540X		<i>Sport system journal</i>
V/13 N/01 Year/2026		<i>International scientific journal published by: Ziane Achour –Djelfa- Algeria</i>
P 467 - 489		<i>Received: 2025-12-08 Accepted: 2026-02-23</i>

The Effect of Physical Preparation Using Interval Training on Some Physiological Variables in U19 Youth Football Players

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Abstract:

This study aimed to examine the effect of physical preparation using interval training on certain physiological variables in U19 youth football players. The researcher employed an experimental method on a sample from Najm Beni Oualban Club, divided into a control group and an experimental group, each consisting of 12 players randomly selected using simple random sampling. The proposed training program was applied to the experimental group over a period of six weeks, with 2 to 3 training sessions per week. Pre- and post-tests were conducted for both groups using a Polar 300 heart rate monitor to measure resting heart rate and heart rate recovery, as well as the field test Yo-Yo IR1 to determine maximal aerobic speed. The results indicated that the proposed interval training program had a positive effect on physiological variables, namely resting heart rate, heart rate recovery, and maximal oxygen consumption.

Keywords : Interval training; physical preparation; physiological variables; U19 youth

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1. INTRODUCTION

Football is characterized by intermittent and varied activity involving alternating periods of effort and rest. For this reason, most coaches have turned to interval training as a training method that simulates the player's actual activity during a match. Interval training is a training method based on repeating high-intensity exercise bouts interspersed with passive or active rest periods. The main goal of interval training is to maintain a high exercise intensity for the longest possible duration compared to continuous training (Chiha, 2022, p. 54).

The development of the football player's physical abilities during physical preparation is undoubtedly accompanied by a development in physiological capacities. Since match time in football is long, it requires the player to possess high aerobic capacities in addition to anaerobic capacities. Therefore, "interval training with its various methods aims to develop cardiorespiratory endurance through improving the vital capacity of the lungs and the capacity of the heart, as well as increasing the blood's ability to carry more oxygen. It also enhances the individual's ability to adapt to the exerted effort, which leads to delaying the appearance of fatigue" (Al-Fateh & El-Sayed, 2002, p. 326)

Improvement in the player's ability to repeat high-intensity interval efforts also leads to an enhancement in maximal aerobic speed, in addition to improving the value of maximal oxygen consumption, lowering the resting heart rate, and improving the ability to recover quickly. All these physiological variables are considered indicators for assessing and monitoring the extent to which the body systems respond to the interval loads that players undergo either during pre-season physical preparation or during the competition phase. These indicators are also relied upon in planning and programming interval training loads, whether in training units or training cycles.

From here emerges the research problem: due to the randomness in applying interval training among some teams and clubs, and the lack of attention to physiological measurements and tests and to adjusting training loads accordingly, the researcher found it necessary to develop a proposed training program based on interval training specifically for the pre-season physical preparation stage, using controlled interval loads. The aim is to determine its effect on certain physiological variables among football players. This inquiry gives rise to the following main



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research question: **Does physical preparation using interval training have a positive effect on some physiological variables among U-19 football players?**

From this central question emerge the following sub-questions:

- Are there statistically significant differences between the control and experimental groups in the pre-tests of physiological variables?
- Are there statistically significant differences between the pre- and post-tests of the control group in physiological variables?
- Are there statistically significant differences between the pre- and post-tests of the experimental group in favor of the post-tests in physiological variables?
- Are there statistically significant differences between the control and experimental groups in the post-tests in favor of the experimental group in physiological variables?

1.2 Objectives of the Study

- Designing a training program specific to the pre-season physical preparation stage based on controlled interval loads, in accordance with the characteristics of this phase and the target category.
- Identifying the players' level of physical abilities through physical tests, and thus providing recommendations, including the preparation of a training program.
- Identifying the effect of the proposed program on resting heart rate, maximal oxygen consumption, and heart-rate recovery.

1.3 Hypotheses of the Study

- There are no statistically significant differences between the control and experimental groups in the pre-tests of physiological variables.
- There are no statistically significant differences between the pre- and post-tests of the control group in physiological variables.
- There are statistically significant differences between the pre- and post-tests of the experimental group in favor of the post-tests in physiological variables.
- There are statistically significant differences between the control and experimental groups in the post-tests in favor of the experimental group in physiological variables.

1.4 Fields of the Research

- Human field: 24 U-19 football players (12 control and 12 experimental).
- Temporal field: From 26/08/2024 to 20/10/2024 (pilot and main experiment).
- Spatial field: Ben Hammou Municipal Stadium in Beni Walban, Skikda.

1.5 Research Terminology

1.5.1 Physical Preparation

Physical preparation in football aims to prepare the player physically, functionally, and psychologically, and to work on developing the various components of physical fitness so that the player can move across large areas of the field and perform defensive and offensive duties (Abu Abda, 2001, p. 35).

The physical preparation stage is divided into general physical preparation and specific physical preparation. This stage is defined as a set of planned, integrated, and interactive elements directed toward a number of physiological body systems and organs to achieve certain objectives within a specified period of time (Al-Nahas, 2001, p. 257).

1.5.2 Interval Training

Interval training is one of the training methods characterized by the alternating succession of exertion and rest. Most scholars believe that the term “interval training” originates from the inter-rest (interval) between each exercise and the one that follows it (Rbidi, 2004, p. 216).

1.5.3 Physiological Variables

A. Resting Heart Rate (HR in rest)

It is considered one of the most important physiological variables used to infer the level of the athlete's training status, since the circulatory system is one of the most adaptive bodily systems to exertion and rest. It is expressed as the number of beats per minute at rest (beats/min) (Amir, 1999, p. 78).

B. Heart Rate Recovery (HRR1stmin)

It provides insight into the intensity of the effort exerted by the player, his recovery capacities, and his physical condition. It is measured one minute (60 seconds) after maximal effort, and is expressed by the number of beats lost after



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stopping maximal exertion (Dellal, 2017, p. 83).

C. Maximal Oxygen Consumption (VO₂ max)

It is the maximum volume of oxygen consumed in liters or milliliters per minute, and this is referred to as absolute consumption. The more widely used measurement in the field of exercise physiology is relative maximal oxygen consumption, meaning the volume of oxygen consumption extracted for each kilogram of body weight by dividing absolute consumption by body weight. It is measured in (ml/min/kg) (El-Sayed, 2003, p. 217).

D. U-19 Category

This refers to players whose ages range between 18 and 19 years, according to the classification adopted by the Algerian Football Federation (WWW.FAF.DZ).

2. Previous and Similar Studies

With an aim of situating the present research within its scientific context, next is a simple review of previous studies that have examined interval training and its influence on physiological and physical performance indicators among football players.

2.1 Study of Dellal Alexander (2008)

It is a doctoral dissertation from the University of Strasbourg entitled: *“Analysis of the Physical Activity of the Football Player and the Factors Guiding Training: A Scientific Experiment through High-Intensity Interval Exercises and Small-Sided Games.”*

This study included 10 players from the French First Division, all in good health, whose last injury occurred at least one year earlier. The researcher used the experimental method due to its suitability for the study, applying training programs over seven weeks at a rate of two sessions per week.

The results confirmed that small-sided games raise heart-rate responses equivalent to those found in short-interval exercises. That is, small-sided games such as 2 vs 2 and 8 vs 8 lead to cardiac responses parallel to interval exercises 20–5 at 120%, 10–10 at 110%, 15–15 at 110%, and 30–30 at 100%, with either passive or active recovery.

On the other hand, small-sided games 1 vs 1, 4 vs 4, and 10 vs 10 produce the

same cardiac responses as interval exercises 15–15 and 30–30 at 110% with passive recovery. This means that small-sided games allow the performance of integrated aerobic physical work equivalent to high-intensity interval training, highlighting the importance of multifactor physical work that engages the player's fitness (anaerobic and aerobic factors) as well as technical and tactical aspects.

2.2 Study of Markovic, G., & Mikulic, P. (2011)

It is an article published in the Journal of Strength and Conditioning Research, entitled: *“A Descriptive Study of Youth Football Players' Abilities in Performing the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1).”*

The researcher relied on the descriptive method as it suits the nature of the study. The sample consisted of 106 youth football players grouped according to chronological age and playing positions. The participating players underwent the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1).

The researcher concluded that there were significant differences between age categories as well as between playing positions in performing the Yo-Yo IR1 test. The study also found that center-backs were weaker than midfielders and forwards in performing the same test.

2.3 Study of Bardi Taha Elias et al. (2023)

It is an article published in Al-Manzuma Sports Journal entitled: *“Proposing a Medium Training Cycle Using High-Intensity Interval Training (HIIT) to Develop Explosive Leg Power and Its Effect on Improving Running Speed Among U17 Football Players.”*

The researcher used the experimental method (one group) due to its suitability for the study. The study sample consisted of 10 players from the U17 category. After statistical processing, the results showed differences between the pre- and post-tests of explosive power and maximal speed for the experimental group. It was found that developing explosive power positively affected running speed.

2.4 Study of Yi-Wen Chiu et al. (2024)

It is an article published in the Journal of Human Kinetics entitled: *“Relationships Among Physical Fitness, External Loads, and Heart Rate Recovery: A Study on Futsal Players During Competition.”*

The researcher used the descriptive method based on observation. The sample included 11 elite futsal players from the U20 category. The study was conducted



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during a ten-day training camp prior to participation in the World Cup in Portugal. Five matches were played in five days, interspersed with four training days, while only one day was allocated for rest. Internal and external loads were measured through movement rates and heart-rate values, and goalkeepers were excluded from the statistical analysis.

The results concluded that the overall correlations observed between fitness measures and heart-rate recovery (HRR) were affected by factors not controlled during all phases of play, as well as by cardiac responses during match substitutions. Heart-rate measures may also be affected by fatigue resulting from accumulated accelerations during congested match schedules in a futsal training camp. Although heart-rate measures provide insight into physical fitness and acceleration activities, the researcher suggests that coaches should take fatigue into account, as it may be an important factor influencing heart-rate values, at least during congested match periods.

2.5 Synthesis of Previous Research

The review of previous and similar studies reveals a consistent emphasis on the value of interval training, as well as related training methods such as small-sided games, in enhancing various physiological and physical capacities in young football players. Indeed, most studies confirm improvements in indicators such as cardiorespiratory responses, explosive power, recovery ability, and maximal oxygen consumption. However, the literature also accentuates differences related to age categories, playing positions, training loads, and contextual conditions such as match congestion or training-camp environments.

Despite the richness of prior findings, a noticeable gap persists regarding controlled interval-training programs specifically designed for the pre-season preparation stage of U-19 football players, particularly with respect to key physiological variables such as resting heart rate, maximal oxygen consumption, and heart-rate recovery. This gap reinforces the importance of the present study, which aims to contribute to the field by proposing and testing a structured interval-training program tailored to this developmental stage.

3. Field Study Procedures

3.1 The Pilot Experiment

The pilot experiment was conducted on 26/08/2024 at the Ben Hammou Municipal Stadium in Skikda, and the same test was repeated one week later at the same time as the first test on 31/08/2024, on a sample of six (06) U19 players from Najm Beni Welbane in Skikda.

3.1.1. Scientific Foundations of the Tests Used

Table 1. Results of the internal validity (IV) and reliability coefficient (RC) of the tests for the pilot-experiment sample

Units	Tests	Test			Re-test			R C	I V
		Mean	SD	Shapiro Proba.	Mean	SD	Shapiro Proba.		
HR in rest	(bpm)	71	4.05	0.99	70.67	3.39	0.70	0.86	0.93
HRR_{1st min}	(bpm)	39.16	1.72	0.83	39.66	1.36	0.55	0.96	0.98
YoYoIR1	(km/h)	17.08	0.58	0.42	16.97	0.57	0.10	0.94	0.97

Based on Table (01), we observe that the reliability coefficient and internal validity of the tests used in the study are high, as the values of the former range between (0.86 and 0.96), while the values of the latter range between (0.93 and 0.98). This indicates the validity and reliability of the measurements and tests employed in the research.

3.2 Research Method

The researcher used the experimental method due to its suitability to the nature of the study, in order to identify the effect of the proposed training program (implemented through interval training) as an independent variable on the physiological variables as dependent variables.



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3.3 Research Population

The research population consisted of 16 teams of under-19 youth football players competing in the Inter-Regions Championship (East) of the Constantine League (Ligue Inter Régions – Est – Constantine).

3.4 Research Sample

The research sample consisted of 24 under-19 youth football players selected using the simple random method. The sample was also divided randomly into two groups: an experimental group and a control group, with 12 players in each.

3.5 Homogeneity of the Research Groups

Table 2. The homogeneity of the two research groups (control and experimental).

Variables	Experimental Group			Control Group			Fisher Proba.
	Mean	SD	Shapiro Proba.	Mean	SD	Shapiro Proba.	
Age	18.58	0.51	0.000	18.50	0.52	0.000	0.31
Training Age	3.92	0.29	0.000	3.83	0.39	0.000	0.23
Height	173.58	1.24	0.11	173.92	1.24	0.11	0.57
Weight	66	2.34	0.11	65.58	2.43	0.18	0.98

From Table (02), we observe that the Fisher probability values fall within the range [0.23, 0.98], which are greater than the 0.05 margin of error. This indicates that the control and experimental groups are homogeneous in variance for the variables: age, training age, height, and weight.

4. Instruments, Equipment, and Data Collection Tools

4.1 Instruments and Equipment Used

A medical scale for measuring weight – pens and pencils – a football field for conducting the tests and implementing the training program – a computer equipped with a maximal aerobic speed test program – two (Cardio-Fréquencemètre) of the type (Polar A300) – a loudspeaker – a stopwatch – a whistle – bibs – cones, poles, and plastic markers – data recording forms – a decameter.

The researcher consulted various scientific research works and similar studies and used all the devices and tools available at the club .

4.2 Tests Used

4.2.1 Resting Heart Rate Test

- Purpose of the test: Measuring heart rate at rest.
- Equipment used: A room, two heart rate monitors (Cardio-Fréquencemètre) of the type (Polar A300) consisting of a wristwatch and a chest strap, and a recording form.
- Procedure: Players lie down on the mat with eyes closed in a quiet place for 10 minutes.
- Recording: The lowest reading is taken, and it represents the resting heart rate (Dellal, 2008, p.149).

4.2.2 Heart Rate Recovery Test

- Purpose of the test: Measuring the number of heartbeats recovered after one minute of maximal effort.
- Equipment used: A field, two heart rate monitors (Cardio-Fréquencemètre) of the type (Polar A300) consisting of a wristwatch and a chest strap, and a recording form.
- Procedure: Immediately after stopping the effort following the Yo-Yo intermittent test, the maximal heart rate value is recorded, then exactly one minute later, heart rate is measured again.
- Recording: Maximum heart rate – heart rate after one minute = heart rate recovery rate (Dellal, 2008, p.149).

4.2.3 Maximal Oxygen Consumption Test (VO₂MAX)

- Purpose of the test: Measuring maximal oxygen consumption.
- VO₂MAX values were obtained from the equation of the maximal aerobic



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speed test known as the Yo-Yo Endurance Intermittent Recovery Test – Level 1 (10 km/h):

- $\text{Max VO}_2 \text{ (ml/min/kg)} = \text{total distance covered in meters} \times 0.0084 + 36.4$

The test table is consulted to determine the distance covered (Bangsbo, 2008, p 37–51).

5. Characteristics of the Proposed Program

The program consists of two phases:

- **Phase One:** A micro-training cycle aimed at improving the aerobic base or aerobic capacity of the players through continuous running exercises. (This phase was programmed to avoid injuries before conducting the pre-tests and is unrelated to the study results.)
- **Phase Two:** This phase lasts six (6) training weeks, with (3 to 4) training sessions per week. The duration of each session ranges from 18 to 33 minutes, not including the warm-up period (15–20 minutes) and the cool-down period (5–7 minutes).

The program includes long-interval training exercises to enhance players' aerobic capacity such as (3'/3'), and medium intervals such as (1' / 2'30").

It also includes short-interval training such as: (30"/60") – (30"/30") – (15"/30") – (20"/20") – (10"/20") – (15"/15") – (10"/10") – (5"/25") – (5"/15").

The researcher also used mixed interval exercises alternating between strength exercises, running, supports, and speed, and incorporated the ball into most of the interval exercises used (Dellal, 2013, pp. 97–98, 171; Dellal, 2017, pp. 11, 32–33, 60; www.preparationphysique.com; Dellal, 2008, p.34).

The experimental group was divided into two subgroups based on their maximal aerobic speed (VMA). Rest intervals between repetitions and sets were adjusted during all weeks of the training program according to the interval training.

6. Statistical Study

The researcher used the following statistical procedures: arithmetic mean, standard deviation, Shapiro–Wilk test, Fisher test, Pearson's simple correlation coefficient, paired-samples t-test, Wilcoxon test, independent-samples t-test, and Mann–Whitney test. The SPSS V26 statistical package was used and Excel 2016.

7. Presentation and Analysis of Results

7.1 Verification of the First Hypothesis

Table 3. Results of the Differences Between the Control Group and the Experimental Group in the Pre-Test of the Physiological Variable

Variables	Control Group			Experimental Group			Fisher Proba.	t-test / Mann-Whitney p
	Mean	SD	Shapiro Proba.	Mean	SD	Shapiro Proba.		
HR in rest (bpm)	71.25	1.36	0.27	70.58	1.24	0.17	0.81	*0.22
HRR₁stmin (bpm)	38.41	1.78	0.64	38.66	1.67	0.26	0.42	*0.73
VO₂MAX (ml/kg/min)	49.46	4.71	0.16	50.16	5.41	0.54	0.66	*0.74

* Difference test used: t-test** When marked: Mann-Whitney test

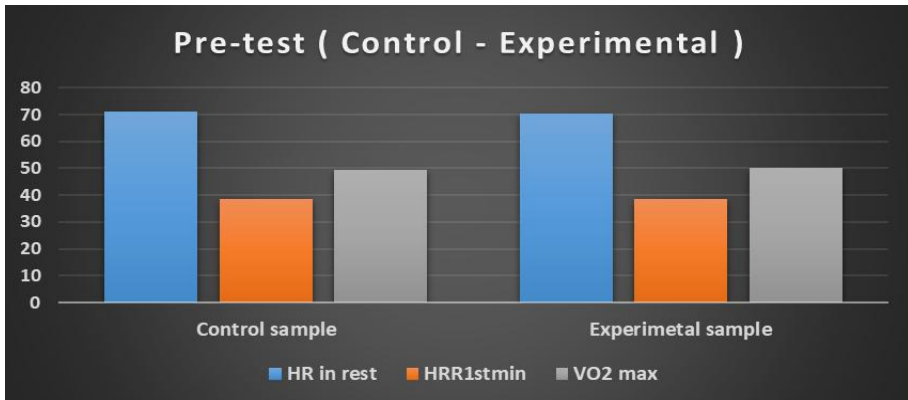


Figure 1. Bar chart illustrating the difference between the control group and the experimental group in the pre-tests

From Table (03), it is evident that the probability values of t-test and Mann-Whitney range between [0.22 and 0.74], which are all greater than the error threshold 0.05. This indicates the absence of statistically significant differences between the control group and the experimental group in resting heart rate, heart rate recovery, and maximum oxygen consumption.

Accordingly, the two groups were equivalent before the implementation of



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the training program.

7.2 Verification of the Second Hypothesis:

Table 4. Results of the Differences Between the Pre-test and Post-test for the Control Group in Physiological Variables

Variables	Pre-test			Post-test			t-test / Wilcoxon p
	Mean	SD	Shapiro proba.	Mean	SD	Shapiro proba.	
HR at rest (bpm)	71.25	1.36	0.27	70.25	1.60	0.11	0.12*
HRR 1 st min (bpm)	38.41	1.78	0.64	38.83	1.40	0.19	0.18*
VO ₂ MAX (ml/kg/min)	49.46	4.71	0.16	49.63	4.80	0.25	0.17*

*: t-test used **: Wilcoxon test used

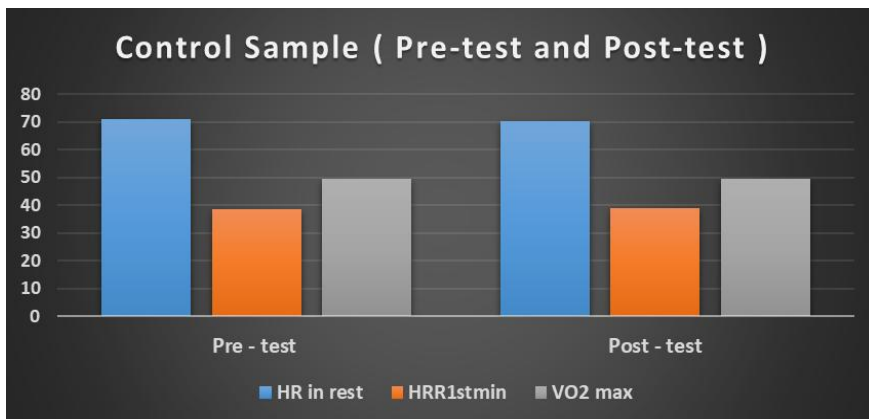


Figure (02): Bar chart illustrating the difference between the pre-test and post-test of the control group

From Table (04), it appears that the probability values of the t-test and Wilcoxon test range between [0.12 and 0.18], which are greater than the error threshold 0.05. This indicates the absence of statistically significant differences between the pre- and post-tests of the control group in resting heart rate, heart rate

recovery, and maximum oxygen consumption. Accordingly, the control group did not improve, and the researcher attributes the lack of significance to the absence of the necessary physical tests, which led to the random use of running exercises, circuit training, and interval training without proper regulation of training load (intensity, distance, volume, duration, repetitions, sets, etc.), in addition to frequent absences from training sessions.

7.3 Verification of the Third Hypothesis

Table 5. Differences Between Pre-test and Post-test for the Experimental Group

Variables	Pre-test			Post-test			t-test / Wilcoxon p
	Mean	SD	Shapiro proba.	Mean	SD	Shapiro proba.	
HR in rest (bpm)	70.58	1.24	0.17	66.00	2.34	0.14	0.00*
HRR 1st min (bpm)	38.66	1.67	0.26	47.16	2.04	0.29	0.000*
VO₂MAX (ml/kg/min)	50.16	5.41	0.54	55.13	4.53	0.37	0.000*

*: t-test used , **: Wilcoxon test used

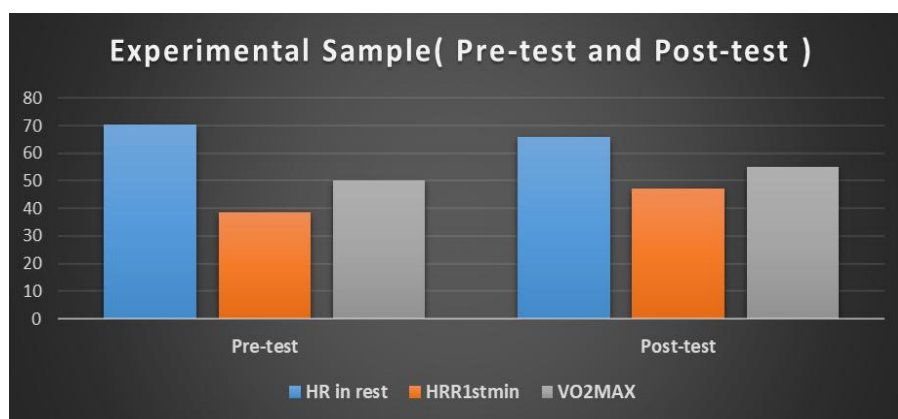


Figure 3. Bar chart illustrating the difference between the pre-test and post-test of the experimental group



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From Table (05), we observe that the probability values of the t-test and Wilcoxon test range between [0.000 and 0.000], which are smaller than the error threshold 0.05. This indicates the presence of statistically significant differences between the pre- and post-tests in resting heart rate, heart rate recovery, and maximum oxygen consumption.

Accordingly, the experimental group showed improvement thanks to the application of the proposed interval training program.

7.4 Verification of the Fourth Hypothesis

Table 6. Differences Between the Control and Experimental Groups in Post-test Physiological Variables

Variables	Control Group			Experimental Group			Fisher p	t-test / Mann–Whitney p
	Mean	SD	Shapiro proba.	Mean	SD	Shapiro proba.		
HR in rest (bpm)	70.25	1.60	0.11	66.00	2.34	0.14	0.77	0.000*
HRR1st min (bpm)	38.83	1.40	1.19	47.16	2.04	0.29	0.11	0.00*
VO₂MAX (ml/kg/min)	49.63	4.80	0.25	55.13	4.53	0.37	0.66	0.009*

*** test used: t-test , **: Mann–Whitney test**

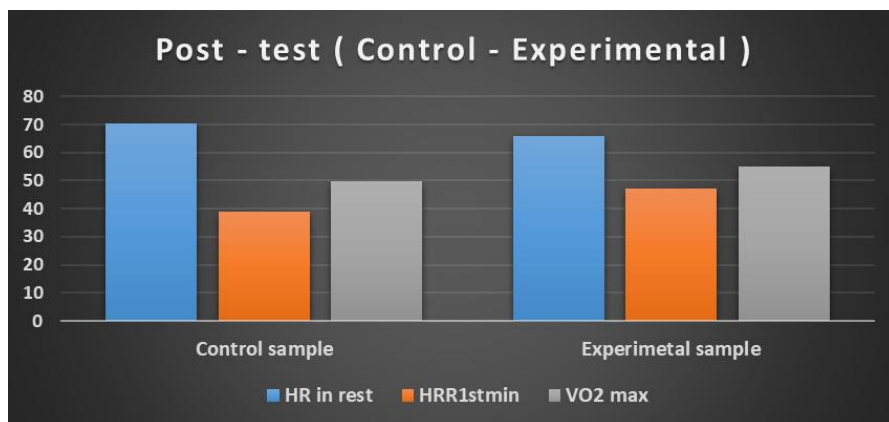


Figure 4. Bar chart illustrating the difference between the control and experimental groups in the post-test results

From Table (06), we observe that the probability values of the t-test and Mann–Whitney test range between [0.000 and 0.009], which are smaller than the error threshold 0.05. This indicates the presence of statistically significant differences between the control and experimental groups in the post-test results, in favor of the experimental group regarding resting heart rate, heart rate recovery, and maximum oxygen consumption.

This confirms the improvement of the experimental group, which applied the interval training program.

8. Discussion of Results

8.1 Resting Heart Rate

The mean resting heart rate of the experimental group in our study reached **66 bpm** after six weeks of interval training. Thus, our findings exceed those reported in the study of **Alouis (2015)**, which subjected a group of young players to a low-intensity interval training program for three months and succeeded in developing their resting heart rate, as it decreased from **80 bpm** to **73 bpm**.



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Meanwhile, our results are quite close to those of **Magliaro (2001)**, who examined heart rate among youth aged 15 to 20, where the rate decreased from **66.9 to 65.1 bpm**.

Similarly, the findings of **Songsorn (2022)** (who studied the effect of high-intensity interval training (HIIT) on resting heart rate among adults) showed a development in resting heart rate from **73.94 bpm to 66.1 bpm**, which aligns closely with our results, particularly in terms of training method (interval training), training duration, and post-training outcomes.

However, our findings were slightly lower than those of **Sarbout (2013)**, who implemented an eight-week interval training program for U19 football players, where resting heart rate declined from **63.37 bpm to 61.43 bpm**.

Despite the notable improvement in resting heart rate in our study, it did not reach the level reported by **Metaxas (2009)**, who studied physiological parameters of fourth-division Greek football players. Their resting heart rate was **59.8 bpm**, and although this measurement took place before the competitive season, the results of our study did not reach the fitness level observed in Greek fourth-division players.

8.2 Heart Rate Recovery

The mean heart rate recovery (HRR) of the experimental group in our study reached **47.16 bpm** after six weeks of interval training. This result is entirely consistent with **Yi-Wen Chiu (2024)**, who investigated the relationship between fitness components, external load, and heart recovery; HRR improved from **33 bpm** in the first match to **47 bpm** in the fifth match.

Interval training has also been shown to positively affect heart rate recovery in the study of **Khoshnaw (2006)**, who applied an interval training program to football players and examined its effect on respiratory rate and heart rate recovery

after 1, 2, and 3 minutes of exertion. Heart rate after one minute of exertion decreased from **168.8 bpm** to **160.7 bpm**, a reduction of **8 bpm**.

Moreover, high-intensity interval training (HIIT) also positively influences HRR, as shown by **Buchheit et al. (2008)**, who compared repeated-sprint training (RS) with HIIT in U17 handball players over nine weeks. Results showed significant differences in favor of the HIIT group, which experienced improved parasympathetic function; heart rate 60 seconds post-exercise decreased from an average of **60 bpm** before training to **75.6 bpm** after training. Meanwhile, the RS group improved from **64.4 bpm** before training to **70.1 bpm** after training.

8.3 Maximal Oxygen Consumption (VO₂max)

The mean maximal oxygen consumption (VO₂max) of the experimental group in our study reached **55.13 ml/kg/min** after six weeks of interval training. Comparing these findings with the results of **Roe & Malone (2016)**—who conducted a descriptive study using the YoYoIR1 test among Gaelic football players from youth to senior categories—reveals that VO₂max among players aged 17–19 years was **46.2 ml/kg/min**, which is lower than our results.

VO₂max reached **50.8 ml/kg/min** among players under 16 years old, while senior players recorded a mean of **56.3 ml/kg/min**, which is close to our study results. The maximum value recorded among seniors reached **65 ml/kg/min**.

Our findings also align with **Kharashi et al. (2021)**, who studied the effect of a running program on body mass and VO₂max among U19 football players. After administering the YoYoIR1 test, VO₂max increased from **52.36 ml/kg/min** before training to **56.12 ml/kg/min** after training, slightly better than our results.

Our results were also close to those of **Boufadene et al. (2018)**, who compared aerobic capacity indices after applying interval training on U19 football players. After an eight-week program consisting of three weekly sessions, VO₂max improved from **57.68 ml/kg/min** before training to **58.18 ml/kg/min** after training.



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Thus, the improvement in VO_2max occurs following regular high-intensity training over periods ranging from several weeks to months. Interval training also proved effective in **Khoddari (2024)**, who investigated its effect on VO_2max among long-distance runners under 17 years old, where VO_2max increased from **50.1 ml/kg/min** before training to **56.54 ml/kg/min** after training. This aligns with **Kenney (2017)**, who stated that VO_2max generally increases during the first 8–12 weeks of specific endurance training; however, the increase remains modest, and individuals must continue long-term endurance training to maintain improvements.

9. CONCLUSIONS

- There are **no statistically significant differences** between the control and experimental groups in the pre-test for resting heart rate, heart rate recovery, and maximal oxygen consumption.
- There are **no statistically significant differences** between the pre-test and post-test of the control group in resting heart rate, heart rate recovery, and maximal oxygen consumption.
- There are **statistically significant differences** between the pre-test and post-test in favor of the post-test for the experimental group in resting heart rate, heart rate recovery, and maximal oxygen consumption.
- There are **statistically significant differences** between the control and experimental groups in the post-test, in favor of the experimental group, in resting heart rate, heart rate recovery, and maximal oxygen consumption.

Therefore, we can conclude that all the study hypotheses have been confirmed.

Recommendations

In light of the study's findings and the observed effects of the proposed interval training program on physiological variables, the following recommendations are presented to guide future training practices and related research:

- Resting heart rate is an important indicator of cardiac efficiency, but other indicators should also be assessed, such as heart rate reserve and systolic and diastolic blood pressure.
- The researcher recommends monitoring heart rate recovery after maximal exertion at 30 seconds, 2 minutes, and 3 minutes.
- The researcher suggests examining additional physiological indices such as the respiratory quotient (QR) and aerobic thresholds (SV).
- The use of a sound-stimulus device (**Sportbeeper**) is recommended to facilitate interval training.
- Training load should be monitored using the CR10 perceived exertion scale to avoid the phenomenon of **overtraining (Surentrainement)**.

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