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The Impact of High-Intensity Interval Training (HIIT) on Improving Aerobic and Anaerobic Capacity in Team Sport Athletes

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Abstract:

In recent years, team sports have witnessed significant advances in training methods, making the adoption of scientific programs essential to enhance athletes' physical and functional performance. This study aims to investigate the effects of High-Intensity Interval Training (HIIT) on aerobic capacity, anaerobic power, and explosive strength in team sport athletes.

A practical experimental study was conducted with team sport athletes divided into two groups: the experimental group, which followed a HIIT program, and the control group, which continued conventional training. Physical variables were measured before and after the training program, including VO2max, short sprint speed, anaerobic power (RAST), and vertical jump height.

Results showed that the experimental group achieved significantly greater improvements in all variables compared to the control group, with a 15.9% increase in VO2max, 6.9% in short sprint speed, 15.5% in anaerobic power, and 14.6% in vertical jump. Post-intervention differences between the two groups were statistically significant ($p < 0.01$), confirming the effectiveness of HIIT in enhancing physical performance in team sport athletes.

Keywords: High-Intensity Interval Training ;HIIT ; aerobic capacity; anaerobic power ; explosive strength

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1-Introduction:

In recent decades, team sports have witnessed significant advancements in training methodologies. The focus has shifted from traditional approaches based on repetition and high training volume to modern methods grounded in scientific evidence and precise physiological techniques. The adoption of such approaches has become essential for enhancing athletic performance, particularly in light of the continuously increasing demands of competition and game intensity. This necessitates that athletes possess well-rounded physical capacities, including endurance, speed, strength, and rapid recovery ability.

In this context, High-Intensity Interval Training (HIIT) has emerged as one of the most effective and widely utilized training methods in contemporary sports. Its popularity is largely attributed to its ability to produce substantial physiological gains within a relatively short period compared to traditional low-intensity continuous training. This training modality is based on alternating periods of high-intensity physical effort with intervals of rest or low-intensity activity, thereby simultaneously stimulating both aerobic and anaerobic energy systems within the body ***(Gibala et al., 2012).***

The significance of HIIT lies in its close resemblance to the nature of performance in team sports such as football, basketball, and handball. These sports are characterized by continuous fluctuations in performance intensity, involving sprinting, stopping, changing direction, and executing various technical skills. Such variability requires high efficiency in both aerobic and anaerobic systems, which HIIT effectively develops ***(Yuan et al., 2024).***

Moreover, recent studies indicate that HIIT induces important physiological adaptations, including increased maximal oxygen uptake (VO_2max), improved cardiorespiratory efficiency, enhanced mitochondrial density within muscle cells, and greater tolerance to lactate accumulation. These adaptations are directly reflected in improved physical and technical performance among athletes ***(Helgerud et al., 2001; Gibala et al., 2012).***

In addition, this type of training is characterized by its time efficiency, as it can yield results comparable to—or even better than—traditional training methods in less time. This makes it an ideal option for coaches facing the constraints of intensive training schedules and competitive demands. Numerous studies have confirmed that HIIT not only enhances physical capacities but also improves in-game performance by increasing the ability to repeatedly perform high-intensity efforts and reducing fatigue rates ***(Yamen et al., 2023).***

Based on the foregoing, it can be argued that High-Intensity Interval Training represents a qualitative advancement in the field of sports training, particularly in team sports. It combines effectiveness with efficiency and responds precisely to the demands of modern performance, making it a fundamental component in the design of contemporary training programs.

2-Research Problem:

Despite the significant advancements in modern sports training methodologies, many training programs in team sports still rely primarily on traditional approaches that emphasize training volume over intensity. Such approaches may not align with the demands of modern performance, which is characterized by high speed and continuous fluctuations in effort

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intensity. In this context, High-Intensity Interval Training (HIIT) has emerged as an effective training method that has demonstrated its ability to improve physical efficiency within a relatively short period. However, its effectiveness in developing various physical capacities—particularly aerobic and anaerobic capacity, remains a subject of scientific debate ***(Gibala et al., 2012)***.

The core issue lies in the fact that team sport athletes require an integrated combination of aerobic and anaerobic capacities due to the nature of performance, which involves alternating between high-intensity efforts and short recovery periods. Although numerous studies have examined the effects of HIIT, their findings vary depending on the type of sport, training intensity, duration, and athletes' level. This variability raises questions about the generalizability of these results and whether HIIT can be adopted as an effective alternative to traditional training methods ***(Yuan et al., 2024)***.

Furthermore, some coaches remain hesitant to implement this type of training due to a limited understanding of its physiological effects or concerns about potential negative consequences, such as overtraining or increased risk of injury, particularly when training load is not properly regulated (Yamen et al., 2023). This highlights the need for a precise scientific investigation that clarifies the effects of HIIT on both aerobic and anaerobic aspects in an integrated manner and determines its suitability for team sport athletes.

Accordingly, the research problem is centered on addressing the following main question:

To what extent is High-Intensity Interval Training (HIIT) effective in improving aerobic and anaerobic capacity among team sport athletes compared to traditional training methods?

This main question gives rise to several sub-questions:

*Does HIIT contribute to improving VO_2max in team sport athletes?

*What is its effect on anaerobic capacity (strength, speed, and lactate tolerance)?

*Is HIIT superior to traditional continuous training in terms of efficiency and outcomes?

*What are the optimal methods for implementing HIIT to maximize benefits while minimizing fatigue and injury risk?

Thus, this study seeks to bridge a knowledge gap regarding the effectiveness of this training method and to provide a scientific framework that may assist coaches and researchers in designing more efficient training programs tailored to the demands of performance in team sports.

3-Terms and Concepts

-Defining key terms and concepts is an essential step in any scientific research, as it contributes to clarifying the theoretical framework and avoiding ambiguity in the interpretation of results. The following are the main terms adopted in this study:

-High-Intensity Interval Training (HIIT)

It is a training method based on alternating short periods of high-intensity physical effort (ranging from 80% to 95% of maximum heart rate) with periods of rest or low-intensity

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activity. It aims to improve physical fitness efficiently within a relatively short time frame ***(Gibala et al., 2012).***

-Operationally, in this study, it is defined as: A structured training program based on repeated bouts of high-intensity effort interspersed with specific recovery periods, with the aim of improving aerobic and anaerobic capacities in team sport athletes.

-Aerobic Capacity: It refers to the ability of the cardiorespiratory system to supply muscles with oxygen during sustained physical activity, and it is commonly measured by maximal oxygen uptake (VO_2max) ***(Helgerud et al., 2001).***

-Operationally, it is defined as:The athlete's ability to sustain moderate to high-intensity physical effort for an extended period with efficient oxygen utilization.

-Maximal Oxygen Uptake (VO_2max): It is the maximum amount of oxygen that the body can utilize during intense physical exertion and is considered one of the most important physiological indicators of cardiorespiratory fitness ***(Yuan et al., 2024).***

-Anaerobic Capacity :It is the body's ability to produce energy without the use of oxygen, particularly during short, high-intensity activities such as sprinting or jumping (Chanlaya & ***Kaithongsuk, 2024).***

-Operationally, it is defined as:The athlete's ability to perform high-intensity physical efforts over a short duration while tolerating fatigue.

-Endurance :It is the athlete's ability to resist fatigue and sustain physical performance over prolonged periods. It is divided into aerobic and anaerobic endurance ***(Helgerud et al., 2001).***

-Anaerobic Endurance :It is the athlete's ability to continue performing high-intensity activity for a short duration while resisting fatigue caused by lactate accumulation **(Yamen et al., 2023).**

-Lactate: A chemical compound produced during anaerobic metabolism when oxygen availability is limited. Its accumulation leads to muscular fatigue ***(Gibala et al., 2012).***

-Recovery: It is the process through which the body returns to its normal state after physical exertion, including the restoration of energy and the removal of metabolic byproducts ***(Yamen et al., 2023).***

-Team Sports: These are sports practiced collectively between two or more teams, such as football, basketball, and handball. They are characterized by complex physical and physiological demands, including alternating between high- and low-intensity efforts ***(Yuan et al., 2024).***

4-Applied Study

Research Methodology :This study adopted the experimental method using a two-group design (experimental and control) in order to measure the effect of High-Intensity Interval Training (HIIT) on aerobic and anaerobic capacity among team sport athletes. This method is considered appropriate for such studies aiming to identify causal relationships between variables ***(Gibala et al., 2012***).

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2 .Population and Sample

-Research Population : The research population consists of team sport athletes (football players) aged between 18 and 25 years.

-Research Sample :A purposive sample of 20 players was selected and divided into two groups:

Experimental group: 10 players (subjected to the HIIT program)

Control group: 10 players (following traditional training)

The two groups were homogenized in terms of:

-Age

-Weight

-Height

-Physical fitness level

Tools and Measurement Instruments: A set of scientifically validated tests was used to measure the study variables:

-Aerobic Capacity Measurement

-Yo-Yo Intermittent Recovery Test

-Estimation of VO_2max

This test is widely used in team sports ***(Helgerud et al., 2001)***.

-Anaerobic Capacity Measurement

-Running-based Anaerobic Sprint Test (RAST)

-30-meter sprint test

-Vertical jump test (Sargent Test)

These tests assess explosive power and tolerance to high-intensity effort ***(Chanlaya & Kaithongsuk, 2024***).

4 .Training Program (HIIT)

-Program Duration

-8 weeks

-3 training sessions per week

-Sample Training Session

-Warm-up: 10 minutes

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-Main exercise (HIIT):

-30 seconds of high-intensity running(%95–85)

-30 60–seconds of active recovery

-Repetition: 10–15 times

-Cool-down: 10 minutes

The program was designed according to scientific training principles ***(Gibala et al., 2012).***

5 .Field Procedures

-Conducting pre-tests for both groups

-Implementing the training program for 8 weeks

-Conducting post-tests under the same conditions

-All variables (time, location, and equipment) were controlled to ensure the accuracy of the results.

6 .Statistical Methods

The following statistical methods were used:

Mean

Standard deviation

T-test for paired and independent samples (Kaithongsuk, 2024).

1 .Presentation of the Research Sample Characteristics

Table (1): Characteristics of the Research Sample (Mean ± Standard Deviation)

Variable	Experimental Group (n=10)	Control Group (n=10)	T-value	Significance
Age (years)	21.3 ± 1.2	21.6 ± 1.1	0.52	Not significant
Height (cm)	178.4 ± 5.3	177.9 ± 4.8	0.31	Not significant
Weight (kg)	72.6 ± 6.2	73.1 ± 5.9	0.28	Not significant
VO_2max	45.2 ± 2.1	46.0 ± 2.3	0.67	Not significant

Prepared by the Researcher

Analysis:

The homogeneity of the two groups in the basic variables (age, height, weight, and VO_2max) strengthens the validity of the experimental design, as it allows for isolating the effect of the training program (HIIT) as an independent variable. This equivalence is a fundamental requirement in experimental studies to ensure that any changes observed in post-test measurements are attributable to the experimental intervention rather than pre-existing individual differences.

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From a physiological perspective, the similarity in pre-test VO_2max values indicates comparable cardiorespiratory efficiency between the groups, which enhances the accuracy and objectivity of post-intervention comparisons. Additionally, the homogeneity in weight and height minimizes the influence of biomechanical factors on performance, thereby supporting a more precise scientific interpretation of the results.

2-Aerobic Capacity (VO_2max) Results

Table (2): Pre- and Post-Test Differences within the Experimental Group

Measurement	Mean	Standard Deviation	T-value	Significance
Pre-test	45.2	2.1		
Post-test	52.4	2.5	6.87	Significant (0.01)

Prepared by the Researcher

The table shows a clear difference between the pre- and post-test measurements for aerobic capacity (VO_2max) in the experimental group, with the mean increasing from 45.2 (pre-test) to 52.4 (post-test), and standard deviations of 2.1 and 2.5, respectively. The T-value of 6.87 is statistically significant at the 0.01 level.

The T-value (6.87) indicates a highly significant statistical difference between pre- and post-tests, meaning the observed change in VO_2max is not random but a direct result of the HIIT program.

- The significance level (0.01) reflects a high confidence in the results, with less than a 1% probability of statistical error, reinforcing the credibility of the conclusions.
- The improvement rate can be calculated as follows:
  [
  \text{Improvement %} = \frac{52.4 - 45.2}{45.2} \times 100 = 15.9%
  ]
  This is a substantial increase in the context of sports training, especially over a short period of 8 weeks, indicating the effectiveness of HIIT in enhancing aerobic capacity.

Physiological mechanisms explaining the VO_2max improvement include:

1. **Cardiac efficiency**
   - Increased stroke volume
   - Improved blood delivery to working muscles
2. **Respiratory system development**
   - Enhanced gas exchange efficiency
   - Improved cellular oxygen utilization
3. **Muscular adaptations**
   - Increased mitochondrial density
   - Enhanced aerobic enzyme activity
4. **Oxygen transport improvements**
   - Increased capillary density in muscles
   - Improved muscular oxygen extraction and utilization

These combined adaptations lead to higher performance capacity over longer durations with greater efficiency.

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These findings align with Helgerud et al. (2001), who reported that HIIT leads to substantial increases in VO_2max among football players. Gibala et al. (2012) also confirmed that HIIT induces rapid physiological adaptations that surpass traditional training, particularly in terms of cardiorespiratory efficiency.

Table (3): Pre- and Post-Test Differences within the Control Group

Measurement	Mean	Standard Deviation	T-value	Significance
Pre-test	46.0	2.3		
Post-test	48.1	2.4	2.11	Significant (0.05)

The table shows that the mean aerobic capacity (VO_2max) in the control group increased from 46.0 in the pre-test to 48.1 in the post-test, with standard deviations of 2.3 and 2.4, respectively. The T-value of 2.11 is statistically significant at the 0.05 level.

The T-value (2.11) indicates that there is a statistically significant difference between pre- and post-test measurements, but with a lower confidence level compared to the experimental group.

The significance level of 0.05 means that the probability of error is less than 5%, suggesting that the observed change in VO_2max is due to traditional training; however, the improvement is less pronounced than that achieved through the HIIT program.

Analysis of Improvement Rate

$$\textbf{Improvement Rate} = \frac{48.1 - 46.0}{46.0} \times 100 = 4.57\%$$

- The improvement rate in the control group is relatively low compared to the experimental group (+15.9%), indicating that traditional training leads to only a modest increase in aerobic capacity and is less effective than HIIT.

This limited improvement in VO_2max can be explained as follows:

- **Partial improvement in the cardiorespiratory system:**Traditional training induces a slight increase in stroke volume and gas exchange efficiency, but it is less intense compared to HIIT.
- **Limited muscular mitochondrial stimulation:**Low-intensity continuous training does not stimulate mitochondrial development as strongly as HIIT, restricting physiological adaptations.
- **Effect of moderate training load:**Traditional programs are less variable in intensity, allowing only limited improvements in aerobic capacity.

These findings are consistent with Yamen et al. (2023), who reported that low-intensity continuous training leads to moderate improvements in VO_2max but does not achieve the substantial gains provided by HIIT. Similarly, Helgerud et al. (2001) concluded that

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enhancements in aerobic capacity are directly dependent on training intensity, with high-intensity intermittent stimulation (as in HIIT) producing greater increases in VO_2max.

Table (4): Post-Test Comparison between Groups in VO_2max

Group	Mean	Standard Deviation	T-value	Significance
Experimental	52.4	2.5		
Control	48.1	2.4	3.92	Significant (0.01)

Analysis of Post-Test Differences between Groups in Aerobic Capacity (VO_2max):

The table illustrates the post-intervention differences in VO_2max between the experimental group, which followed the High-Intensity Interval Training (HIIT) program, and the control group, which continued traditional training.

- The mean VO_2max in the experimental group reached **52.4 ± 2.5**, compared to **48.1 ± 2.4** in the control group.
- The T-value of **3.92** is statistically significant at the 0.01 level.

This indicates that the post-intervention differences between the two groups are substantial and highly significant, demonstrating the direct effect of the experimental HIIT program on improving aerobic capacity.

- The high T-value and significance level (0.01) confirm a marked and statistically important difference between the groups after the training program.
- This means that any observed difference in VO_2max post-intervention is not due to chance but is a result of the HIIT program applied to the experimental group.

Analysis of Relative Improvement Rate

$$\text{Improvement Rate} = \frac{52.4 - 48.1}{48.1} \times 100 \approx 8.9\%$$

- This relative improvement highlights the substantial difference between HIIT and traditional training. The improvement in the experimental group (+15.9% compared to pre-test) is much greater than the post-intervention difference between the experimental and control groups (+8.9%).
- This confirms the effectiveness of HIIT in enhancing aerobic capacity more quickly and clearly.

Key mechanisms contributing to HIIT's superior effects include:

1. **Stronger stimulation of the cardiorespiratory system:**
   - HIIT increases stroke volume and cardiac pumping efficiency.
2. **Improved cellular oxygen transport:**

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   - Increased capillary density and mitochondrial activation enhance oxygen delivery and utilization.
3. **Enhanced cardiomuscular endurance:**
   - Greater ability to sustain effort for longer periods with reduced fatigue.

- All these adaptations are less pronounced in traditional training, explaining the large difference between the groups.
- Gibala et al. (2012) confirmed that HIIT produces greater improvements in VO_2max compared to low-intensity continuous training.
- Helgerud et al. (2001) similarly showed that HIIT programs significantly elevate aerobic capacity in football players more than traditional training.

3. Anaerobic Capacity Results

Table (5): 30-Meter Sprint Test (Anaerobic Capacity)

Group	Pre-test (s)	Post-test (s)	Improvement (%)	T-value	Significance
Experimental	4.35	4.05	6.9%	4.12	Significant
Control	4.33	4.22	2.5%	1.98	Not Significant

Analysis of 30-Meter Speed Test Results

The table presents pre- and post-intervention results of the 30-meter sprint test for both groups:

- **Experimental Group (HIIT):** The average time improved from **4.35 s** to **4.05 s**, representing a **6.9% improvement**, with a T-value of **4.12**, which is statistically significant.
- **Control Group (Traditional Training):** The average time improved from **4.33 s** to **4.22 s**, representing a **2.5% improvement**, with a T-value of **1.98**, which is not statistically significant.

1. Experimental Group:

- T-value = 4.12 indicates a significant difference between pre- and post-test measurements.
- Improvement (+6.9%) reflects a notable enhancement in anaerobic and explosive capacity, indicating the effectiveness of HIIT in developing short, explosive speed.

2. Control Group:

- T-value is not significant, and improvement (+2.5%) is limited.
- This suggests that traditional training does not produce substantial changes in short-term explosive performance.

Mechanisms explaining speed improvement in the experimental group:

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1. **Stimulation of anaerobic systems:**
    - HIIT enhances the muscles' ability to produce high energy in short periods, improving short-distance speed.
2. **Improved explosive strength:**
    - Short, high-intensity efforts stimulate fast-twitch muscle fibers, which are responsible for muscular explosion.
3. **Increased lactate tolerance:**

-Repeated high-intensity efforts with short recovery periods enable muscles to cope with lactate accumulation, allowing sustained high performance during the test.

- Chanlaya & Kaithongsuk (2024) reported that HIIT improves short and explosive speed in football players compared to traditional training.
- Gibala et al. (2012) confirmed that high-intensity interval training enhances repeated sprint ability, demonstrating its effectiveness in improving anaerobic performance and explosive speed, which are critical capacities for players during matches.

Recommendation:

- Incorporating HIIT into physical training programs for team sport athletes is advised to achieve significant improvements in short-distance speed.

Table (6): RAST Test (Anaerobic Capacity)

Group	Pre-test (W)	Post-test (W)	Improvement (%)	T-value	Significance
Experimental	450	520	15.5%	5.21	Significant
Control	455	480	5.4%	2.02	Significant

Analysis of Anaerobic Capacity (RAST) Results:

The RAST test reflects the players' anaerobic capacity by measuring muscular power and explosive performance over short repeated efforts. The table shows pre- and post-intervention differences for each group:

- **Experimental Group (HIIT):**
    - Mean power increased from **450 W** to **520 W**, with a **15.5% improvement** and T-value = 5.21, statistically significant.
    - The large and clear difference between pre- and post-tests demonstrates the effectiveness of HIIT in enhancing anaerobic capacity.
- **Control Group (Traditional Training):**
    - Mean power increased from **455 W** to **480 W**, with a **5.4% improvement** and T-value = 2.02, also statistically significant.
    - The improvement is modest but meaningful, indicating that traditional training can enhance anaerobic capacity to a limited extent.

Mechanisms explaining the improvement in the experimental group:

1. **Stimulation of anaerobic energy production:**
    - HIIT increases muscles' ability to rapidly generate ATP without relying on oxygen.
2. **Improved lactate tolerance:**

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- Repeated high-intensity efforts with short recovery enhance muscles' capacity to handle lactic acid accumulation, reducing fatigue and sustaining explosive performance.

3. **Activation of fast-twitch muscle fibers:**
   - These fibers, responsible for muscular explosion, develop more effectively with HIIT compared to traditional training.

Supporting Evidence:

- Chanlaya & Kaithongsuk (2024) reported that HIIT improves anaerobic capacity more than continuous low-intensity training.
- Gibala et al. (2012) confirmed that repeated short, high-intensity efforts increase explosive power and anaerobic endurance.

Practical Implications:

- HIIT is highly effective for improving anaerobic capacity and explosive strength.
- It can be incorporated into team sport training programs to enhance performance in situations requiring short, high-intensity efforts.
- Traditional training yields limited improvements and should be supplemented with high-intensity exercises for optimal results.

Summary:

- The experimental group achieved a **15.5% improvement**, significantly higher than the **5.4% improvement** in the control group.
- Both improvements are statistically significant, but HIIT produces faster, more pronounced, and more effective gains in anaerobic capacity and explosive power.

Table (7): Vertical Jump Test (Sargent Test)

Group	Pre-test (cm)	Post-test (cm)	Improvement (%)	T-value	Significance
Experimental	48	55	14.6%	4.88	Significant
Control	47	50	6.3%	2.11	Significant

Analysis of Vertical Jump Test Results:

The vertical jump test assesses the explosive power of the lower limbs, a crucial skill in most team sports. The table shows pre- and post-intervention differences for each group:

- **Experimental Group (HIIT):**
  - Average jump height increased from **48 cm** to **55 cm**, a **14.6% improvement**, with T-value = 4.88, statistically significant.
  - The large difference between pre- and post-tests indicates the effectiveness of HIIT in enhancing lower-limb explosive power.
- **Control Group (Traditional Training):**
  - Average jump height increased from **47 cm** to **50 cm**, a **6.3% improvement**, with T-value = 2.11, statistically significant.
  - The improvement is smaller than that of the experimental group, reflecting the limited impact of traditional training on explosive strength.

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Mechanisms explaining improvement in the experimental group:

1. **Development of fast-twitch muscle fibers:**
   - HIIT strongly stimulates fibers responsible for explosive muscle contraction and short-duration power.
2. **Increased muscular strength and explosive capacity:**
   - Repeated high-intensity efforts with short rest improve the muscles' ability to generate force quickly.
3. **Enhanced neuromuscular coordination:**
   - High-intensity interval work improves synchronization of muscles during explosive movements, increasing jump height.

Supporting Evidence:

- Chanlaya & Kaithongsuk (2024) reported that HIIT increases vertical jump height in football players compared to continuous training.
- Gibala et al. (2012) confirmed that HIIT improves explosive performance and anaerobic capacity more rapidly and clearly than traditional training.

Practical Implications:

- HIIT is effective in enhancing lower-limb explosive power, a key element for team sport performance.
- It can be combined with traditional training for integrated improvements in aerobic capacity, anaerobic capacity, and explosive strength.
- Traditional training alone provides limited improvements, making HIIT an essential tool for boosting performance.

Summary:

- The experimental group showed a **14.6% improvement**, significantly higher than the **6.3% improvement** of the control group.
- Both improvements are statistically significant, but HIIT is more effective in enhancing lower-limb explosive power.
- The results confirm that high-intensity interval training is an effective method for developing strength and explosive capacity in team sports athletes.

Interpretation and Conclusions Based on the Applied Study Results

Based on the analysis of pre- and post-test differences for both the experimental and control groups, the following conclusions can be drawn:

1. **Effectiveness of HIIT on Aerobic Capacity:**
   - The experimental group showed a significant increase in **VO2max** by **15.9%** compared to the pre-test, while the control group improved by only **4.57%**.
   - Post-intervention differences between the groups were statistically significant (**T = 3.92, p < 0.01**), indicating that HIIT outperformed traditional training in enhancing aerobic capacity for team sports players.
2. **Improvement in Anaerobic Capacity and Explosive Speed:**

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- The experimental group improved **30-meter sprint performance** by **6.9%**, whereas the control group showed no statistically significant improvement (**2.5%**).
- In the **RAST test**, anaerobic power increased by **15.5%** in the experimental group compared to **5.4%** in the control group, with statistically significant differences.

3. **Increase in Explosive Strength (Vertical Jump):**
   - Average vertical jump height increased by **14.6%** in the experimental group versus **6.3%** in the control group, demonstrating the ability of HIIT to enhance lower-limb explosive power.
4. **HIIT Outperforms Traditional Training:**
   - All results indicate that HIIT is more effective than continuous low-intensity training in improving aerobic and anaerobic performance as well as explosive strength.
   - This can be explained by physiological mechanisms such as:
     - Activation of **fast-twitch muscle fibers**
     - Increased **stroke volume** and cardiac output
     - Enhanced **oxygen transport and utilization**
     - Improved **lactate tolerance**
5. **Practical Implications:**
   - HIIT is an effective and time-efficient method for enhancing physical performance in team sports, especially in matches requiring repeated high-intensity efforts with short recovery periods.
   - Integrating HIIT with skill-based and tactical training is recommended for comprehensive improvements in fitness and game performance.

Conclusion:

High-Intensity Interval Training (HIIT) demonstrates clear superiority and high efficacy over traditional training in developing **aerobic capacity, anaerobic power, speed, and explosive strength** among team sports athletes.

- Therefore, HIIT can be considered the **optimal training program** for improving functional physical performance in modern team sports, while also minimizing fatigue and enhancing efficiency during competitions.

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