EFFECTS OF HIGH INTENSITY INTERVAL TRAINING ON BODYCOMPOSITION, MUSCLE STRENGTH, AND CARDIOVASCULAR ENDURANCE IN JUNIOR SOCCER REFEREES

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BY

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Author	WANG ERFU
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This study investigates the effects of high-intensity interval training (HIIT) on the body composition, muscle strength, and cardiovascular endurance of youth soccer referees. The research aimed to examine how an 8-week HIIT program impacts these physical attributes in referees aged 18 to 20, registered with the Jieyang City Football Association, China. A true experimental design was used, with participants randomly assigned to an experimental group (HIIT) and a control group. The experimental group underwent three HIIT sessions per week, while the control group maintained their normal daily routines. Results showed that the HIIT group experienced significant improvements in all measured parameters. Following the intervention, the experimental group demonstrated significant improvements in body composition, as evidenced by reductions in body fat percentage and body mass index. Significant within-group improvements were also observed in muscle strength, particularly in lower-limb strength assessed by the leg extension and leg curl tests. In addition, cardiovascular endurance showed significant enhancement, as indicated by improved performance in the YOYO test. When compared with the control group, the experimental group exhibited significantly greater improvements in body composition, muscle strength, and cardiovascular endurance after the intervention. The findings suggest that HIIT is a highly effective training method for improving the physical fitness of young soccer referees, particularly in reducing body fat, enhancing muscle strength, and boosting cardiovascular endurance. These improvements are critical for referees who must maintain peak physical condition during matches. Future research could explore the long-term effects of HIIT on different age groups of referees and combine it with other training methods for further enhancement of refereeing performance.

Keyword : High Intensity Interval Training, Body Composition, Muscle Strength, Soccer Referee, Cardiovascular Endurance

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TABLE OF CONTENTS

Page

ABSTRACT ..... D

ACKNOWLEDGEMENTS ..... E

TABLE OF CONTENTS ..... F

LIST OF TABLES I

LIST OF FIGURES ..... J

CHAPTER 1 INTRODUCTION 1

1.1 Research background 1

1.2 The importance of this research 3

1.3 Research purpose 3

1.4 Research scope 3

1.5 Study the population 3

1.6 Factors affecting the study 4

1.7 Explanation of terms 4

1.8 Research framework 6

1.9 Research hypotheses 6

CHAPTER 2 LITERATURE REVIEW 7

2.1 Soccer 7

2.2 Soccer Refereeing 10

2.3 Referee Grading System in China 22

2.4 Physical Demands According to Competition Level 23

2.5 Physical Fitness of Soccer Referees 27

2.6 High-Intensity Interval Training: HIIT 32
2.7 Related Research 40
2.8 Chapter Summary and Research Gap 44
CHAPTER 3 RESEARCH METHOD 46
Research Design 46
Sample Selection: 47
Random Sampling: 47
Group ID: 47
Inclusion Criteria 47
Exclusion Criteria 48
Athletic training programs 48
Participants of the study 51
Research Instrument. 51
Data collection 52
Ethical considerations 53
Data analysis 53
CHAPTER 4 FINDINGS 54
4.1 Basic information of the research object 54
4.2 Comparison of body composition between the 8-week intervention groups 54
4.4 Comparison of cardiovascular endurance between 8-week intervention groups 59
CHAPTER 5 CONCLUSION AND DISCUSSION 61
5.1 The Influence of cyclic strength Training on the Body composition of youth Soccer referees 61

5.2 The Influence of cyclic strength Training on the muscle strength of junior Soccer referees 65

5.3 The Influence of cyclic strength Training on the cardiovascular endurance of junior Soccer referees 69

Conclusion 74

Recommendations of Future Studies 75

REFERENCES 77

APPENDIX 84

VITA 94

LIST OF TABLES

Page

Table 1 Basic information of the research object (X±S) 54

Table 2 Intra-group Comparison of Body Composition (Mean ± SD) 54

Table 3 Inter-group Comparison of Body Composition After 8 Weeks (Mean ± SD)..... 55

Table 4 Intra-group Comparison of Muscle Strength (Mean ± SD)..... 57

Table 5 Inter-group Comparison of Muscle Strength After 8 Weeks (Mean ± SD) 57

Table 6 Intra-group Comparison of Cardiovascular Endurance (Mean ± SD)..... 59

Table 7 Inter-group Comparison of Cardiovascular Endurance After 8 Weeks (Mean ± SD) 59

LIST OF FIGURES

Page

Figure 1 Study Design Flowchart 6

Figure 2 RPE scale 48

Figure 3 HIIT Intervention Flowchart for Youth Soccer Referees RPE scale 49

CHAPTER 1
INTRODUCTION

1.1 Research background

Since the professionalization of the Chinese Soccer league in 1994, soccer has become increasingly popular among Chinese fans. With the continuous improvement of the professional league's overall quality, the scale of competitions has expanded, and the intensity of match play has steadily increased. Concurrently, the standards of refereeing have risen accordingly, thereby placing heightened and more rigorous demands on the physical fitness of soccer referees.

Through the progress of the level of the professional league, the development of Chinese soccer is changing day by day, gradually connecting with the international standard and improving the game system. We not only need to study the relevant rules of soccer matches to ensure the standardization of the game, but also need to pay attention to whether the soccer referee can make more professional judgment in the game. Soccer referees play an increasingly important role as professional supervisory talents controlling the process of the game and regulating the competition in soccer matches. In the context of the new era, the demand for referees is high, the degree of youthfulness is high, and the psychological and physical requirements are also increasing year by year. Therefore, in the training of national-level referees, according to the relevant training regulations of the CFA, the age limit of soccer referees is below 30 years old, and the training of soccer referees is also an indispensable and important force for the healthy development of the sport of soccer.

The development of soccer referees in China has been a research topic in recent years due to the increasing demand for referees in professional leagues and matches at all levels, and the fact that soccer referees need to accumulate their level of law enforcement and competence day by day, and that more soccer referees need to begin to get in touch with and learn refereeing knowledge when they are students in the general trend of rejuvenation. One study focused on the need to develop students' soccer refereeing ability in a university sport soccer elective course. (Guo miao 2023)

Cultivating and selecting college students as soccer referees during their college years is a must for Chinese soccer associations at all levels to reserve refereeing talent. The physical fitness test is a mandatory test in the referee grade and pre-match enforcement, and in China, young referees have been found to perform better in the physical fitness test and receive higher ratings as qualified referees in the annual pre-match referee training for all levels of league matches.(Antonella Muscella 2020)

In terms of the current status of research on soccer referees in China, although a more complete system has been developed in the management of soccer referees, a more systematic training method is still lacking in the systematic training for young soccer referees. High-intensity interval training (HIIT) has been shown to be an effective training method to improve endurance and anaerobic capacity in young athletes (Daniel Castillo Alvira 2020) and in the context of young referees, a high-intensity interval training program improved the repetitive sprinting ability (RSA) of top soccer referees and (Takuma Yanaoka 2017), aerobic and anaerobic performance was improved by a specific training program based on high-intensity interval running and repetitive sprinting. The effects of high-intensity interval training training on body composition, muscle strength and VO2 power of youth soccer referees have implications for training methods for youth referees.

However, within the field of Soccer refereeing, there currently exists no portable training methodology for high-intensity interval training, nor its specific effects. Soccer referees, particularly youth referees, are not professional athletes and consequently lack adequate training facilities. Whilst some studies indicate that targeted high-intensity interval training yields positive outcomes for youth Soccer players, no in-depth research has been conducted on its application for youth referees. Consequently, there is a pressing need for in-depth research to explore training methods suitable for youth referees and to evaluate their impact on performance outcomes. The significance of this study lies primarily in addressing a research gap: current investigations into the daily training of youth Soccer referees are relatively scarce, lacking both systematic rigour

and depth. This research will fill this void, providing more reliable scientific data and theoretical underpinnings for this field.

1.2 The importance of this research

The significance of this research is primarily reflected in the following aspects:

1.2.1 By assessing the YOYO test, 1RM, and body composition using the HHIT training method, it enriches training approaches, enabling the provision of more effective and personalised training programmes for young referees, thereby enhancing their overall officiating standards.

1.2.2. The findings of this study can be applied to develop high-efficiency methods for improving adolescent referees' performance in daily training within confined spaces, offering valuable reference for various associations in designing routine training programmes for referees.

1.3 Research purpose

1.3.1 The purpose of this research examine the effect of High-intensity interval training on body composition.

1.3.2 The purpose of this research examine the effect of High-intensity interval training on muscular strength.

1.3.3 The purpose of this research examine the effect of High-intensity interval training on cardiovascular endurance.

1.4 Research scope

Jieyang City, Guangdong Province, Jieyang City Soccer Association.

1.5 Study the population

Youths aged 18-20 years old were selected as the study population, and referees registered in the system by the Jieyang City Soccer Association of China were selected as the study subjects.

1.6 Factors affecting the study

1.6.1 Independent variables: High-intensity interval training program.

1.6.2 Dependent variables: body composition, muscular strength , cardiovascular endurance

1.7 Explanation of terms

1.7.1 Soccer Referee

Soccer Referee is a professional personnel responsible for supervising a Soccer match in accordance with the International Laws of the Game to uphold fairness, safety, and sporting standards. A referee must possess expertise in the knowledge of competition laws, decision-making skills under pressure, a stable mental state, and appropriate physical fitness for performing their duties. Furthermore, in matches adhering to FIFA standards, the referee works with two assistant referees and a fourth official to support the overall management of the competition.

1.7.2 Elementary Soccer Referee

Refers to a Soccer referee who is in the initial phase of their officiating career, typically a junior referee certified at the basic level after completing training provided by the Soccer association. This group of personnel is still in the process of developing their knowledge of the Laws of the Game, situational decision-making skills on the field, and the physical fitness required for performing their duties. In the context of this research, elementary soccer referees are a crucial target group due to their specific needs regarding appropriate physical conditioning, particularly cardiorespiratory endurance, muscular strength, and body composition, which are necessary for advancing to higher refereeing levels in the future. Therefore, studying the effects of High-Intensity Interval Training (HIIT) is vital for systematically and effectively enhancing the potential of referees at this level.

1.7.3 High-intensity Interval Training (HIIT)

High-intensity Interval Training (HIIT) refers to a training format consisting of short periods of high-intensity exercise alternating with periods of rest or low-intensity exercise. The primary goal is to develop both aerobic and anaerobic fitness within a

relatively short timeframe, leading to increased cardiorespiratory endurance, repeated sprint ability, and improved recovery efficiency. HIIT is an appropriate training program for elementary or junior soccer referees as it enhances the essential physical fitness components required for effective performance, such as cardiorespiratory endurance, repeated sprint ability, muscular strength, and appropriate body composition. Therefore, studying the effects of HIIT is crucial for systematically improving the physical potential of junior referees, enabling them to perform duties effectively and progress to higher levels in the future.

1.7.4 Body Composition

Body Composition refers to the proportions of various components within the human body, typically categorized into Fat Mass and Fat-free Mass (such as muscle, bone, and body water). Assessing body composition is crucial as it accurately reflects an individual's physical condition and level of fitness, rather than relying solely on body weight measurement. In the context of this research, tracking body composition is a significant indicator for evaluating the effectiveness of the HIIT program on elementary or junior soccer referees. This is because an optimal body composition (e.g., adequate muscle mass and appropriate fat levels) directly correlates with cardiorespiratory endurance, movement agility, running efficiency to match game pace, and physical recovery. Therefore, monitoring changes in body composition serves as a concrete measure for assessing the progress of physical fitness in junior referees.

1.7.5 Cardiovascular Endurance

Cardiovascular Endurance refers to the maximum capacity of the heart, lungs, and blood vessels to continuously deliver oxygen to working muscles over an extended period, as well as the body's ability to efficiently utilize energy during high-endurance activities such as running, sprinting, or movement throughout a Soccer match. In the context of this research, Cardiovascular Endurance is a key variable reflecting the physical fitness of junior soccer referees, particularly those at the elementary level, who require continuous running and decision-making during the

competition. Therefore, High-Intensity Interval Training (HIIT) is utilized to improve the endurance of this system to meet the demands required for officiating on the field.

1.8 Research framework

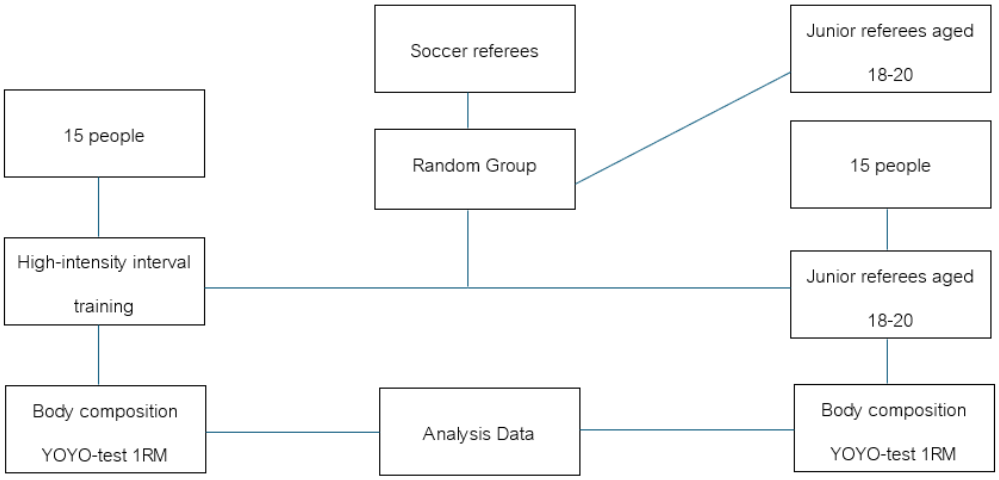

Figure 1 Study Design Flowchart

1.9 Research hypotheses

1.9.1 High-intensity interval training helps reduce body fat percentage.

1.9.2 High-intensity interval training improves muscle strength.

1.9.3 High-intensity interval training improves cardiovascular endurance.

CHAPTER 2
LITERATURE REVIEW

2.1 Soccer

2.1.1 History of Soccer

Soccer, also known as association football, is the most popular sport in the world in terms of both participants and spectators. Its origins can be traced back thousands of years, with early forms of ball-kicking games documented in various cultures. Notably, the Chinese ball game cuju—often written as ts'u-chü, meaning "kick-ball"—dates back over 2,000 years. Cuju included multiple versions of a game in which a ball was kicked, many of which coexisted. Although cuju is now largely played only as a minor tourist attraction or during ceremonial events, its historical significance remains, particularly in connection with the founding myths of the Chinese nation and people (Murray, 1994; Goldblatt, 2006).

Similarly, In medieval Europe, similar ball games were played, including the French Soule and the Italian Gioco del Calcio, which shared certain characteristics with modern football. However, the development of standardized rules began in England in the 19th century, culminating in the establishment of The Football Association (FA) in 1863 and the publication of the Laws of the Game. These regulations formalized the structure, team sizes, and procedures, laying the foundation for modern association football.

Furthermore, Soccer is a complex and dynamic sport involving 22 players competing for a single ball. The game is structured around the concepts of "own possession," "out of possession," and "transitions," meaning that a single ball can influence all players on the field. Modern coaching strategies therefore focus on the ball's impact on the team as a whole, rather than on individual players (Islam, 2020). The global appeal of soccer stems from countless intuitive movements that generate rapidly changing situations during matches (Dolci et al., 2018; Islam et al., 2019; Islam, 2018). Studying the evolution of soccer in the modern era is essential, alongside preserving its historical context.

In addition, Soccer's simple rules and minimal equipment requirements allow it to be played in diverse environments, including standard pitches, gymnasiums, streets, schoolyards, parks, and beaches.

Currently, soccer is the sport with the highest number of participants and spectators worldwide. Competitions take place at both club and national levels, such as the FIFA World Cup, the UEFA Champions League, and England's Premier League (FIFA, 2024). Modern matches also incorporate Video Assistant Referee (VAR) technology to assist in accurate decision-making. Additionally, both players and referees are required to possess high physical fitness, including endurance, speed, agility, and the ability to make rapid decisions, to meet the demands of the modern game.

2.1.2 History of football in China

The history of soccer in China is a narrative of profound complexity, characterized by a cyclical pattern of ancient invention, modern adoption, state-driven organization, tumultuous commercialization, and ambitious strategic planning. It serves as a unique lens through which to examine the broader socio-political and economic transformations of the nation over the past century.

Ancient Precursor: Cuju and Its Disconnect

Any discussion of soccer's lineage in China must begin with Cuju (蹴鞠), an organized ball-kicking game with military and recreational purposes dating to the Warring States period (475–221 BCE). Historical records, such as those in the Zhan Guo Ce, and Han Dynasty (206 BCE – 220 CE) physical treatises detail its rules and cultural significance. While often celebrated as soccer's earliest ancestor, academic consensus emphasizes a historical discontinuity. As Hong and Mangan (2002, p. 325) argue, the revival of Cuju in modern discourse is largely a "constructed tradition" for nationalistic purposes, with "no evidence of a direct, continuous link between it and modern soccer." Its legacy is cultural rather than practical, symbolizing indigenous physical culture but not contributing to the modern game's technical or organizational development.

Modern Introduction and Early Institutionalization (1840s–1949)

The modern game was introduced in the 19th century through Western imperial presence, primarily by British colonial agents in port cities like Shanghai, Hong Kong, and Tianjin. The first clubs, such as the Shanghai Football Club (1867), were exclusive to foreigners. The critical transmission channel into Chinese society was the missionary school system (e.g., St. John's University, Tianjin's Nankai School), which embedded the sport in modern educational curricula (Morris, 2004). By the early Republic era, soccer had become intertwined with projects of national strengthening and anti-imperialism. The national team's dominance in the Far Eastern Championship Games (1910s-1930s) was leveraged to assert a modern Chinese identity on the international stage (Xu, 2008). This nascent development was, however, catastrophically halted by war and social upheaval from 1937 onward.

The Socialist Period: Sport under the "Whole Nation System" (1949–1992)

Following the establishment of the People's Republic, soccer was subsumed into the state's tǐyù tǐzhì" (sports system). This model prioritized elite training for international prestige within a framework of amateurism and central planning. Provincial and institutional teams (e.g., the PLA's "August First" team) became the sole pathway for athletes. While providing basic infrastructure and stability, this system isolated Chinese soccer from global professional trends. The focus on Olympic sports also meant soccer received relatively fewer resources compared to individual disciplines. Sullivan (2013) notes that this period created a "bureaucratic, coach-centered" culture that emphasized physical conditioning over tactical creativity and player autonomy, a legacy that would later hinder adaptation to professional norms.

Professionalization and Its Discontents: The Jia A League (1994–2004)

The 1992 "Red Beach" talks ushered in market reforms, leading to the launch of the fully professional Jia A League in 1994. This represented a radical departure, transforming clubs into commercial entities. The league initially enjoyed explosive popularity, embodying the dynamism of 1990s China. The zenith was the national team's qualification for the 2002 FIFA World Cup. Yet, this rapid commercialization occurred without robust legal or regulatory frameworks. The league

quickly became synonymous with systemic corruption, including match-fixing (known as “hei shao” or "black whistles" for corrupt referees), gambling, and financial fraud. As Gong and Koh (2016) analyze, this was not merely a sporting failure but a manifestation of broader governance issues during a period of rapid economic transition, where the pursuit of profit vastly outstripped institutional oversight.

The Super League Era and the "Football Dream" (2004–Present)

The scandal-ridden Jia A was rebranded as the Chinese Super League (CSL) in 2004. A genuine clean-up only began after a major anti-corruption crackdown in 2009-2012. The 2010s saw a new phase defined by massive capital investment, with clubs signing global stars and coaches. This commercial boom was strategically aligned with a top-down national football revitalization plan issued in 2015. This policy explicitly linked soccer's success to the "Chinese Dream," targeting grassroots development, stadium construction, and long-term goals like hosting a World Cup (Shapiro, 2021). However, this model has proven financially unstable. The recent collapse of several champion clubs (e.g., Jiangsu FC) exposed unsustainable spending. The current era is one of recalibration, with new regulations prioritizing financial sustainability and youth development over marquee signings, reflecting a shift from market exuberance to more managed development (Chen, 2023).

In conclusion, the history of soccer in China is marked by repeated attempts to harness the sport for broader national projects—be it anti-colonial modernism, socialist state-building, commercial modernization, or global soft power. Each phase has left a residue of challenges, from a rigid technical culture to systemic corruption and financial imbalance. The ongoing struggle to build a sustainable soccer ecosystem continues to reflect the fundamental tensions between state planning, market forces, and sporting culture in contemporary China.

2.2 Soccer Refereeing

2.2.1 Definition of a Soccer Referee

Soccer referees are generally characterized by high self-confidence in their decision-making, and they effectively apply their decision-making styles (Gülle, 2017).

Beyond psychological stability, a key role of soccer referees is to act as the ultimate authority enforcing the 17 Laws of the Game on the field (IFAB, 2024). Therefore, referees are essential personnel who must possess complex qualities across multiple dimensions, including psychological attributes (Gülle, 2017), comprehensive knowledge of the laws of the game, and physical fitness (Krüstrup et al., 2010). In particular, cardiovascular endurance is a crucial factor that enables referees to maintain decision-making accuracy throughout the full 90 minutes of a match.

Comprehensive knowledge of the laws of the game, and physical fitness (Krüstrup et al., 2010). In particular, cardiovascular endurance is a crucial factor that enables referees to maintain decision-making accuracy throughout the full 90 minutes of a match. In addition, referees must demonstrate strong emotional regulation and conflict management skills to handle pressure from players, coaches, and spectators while maintaining impartiality. Effective communication and leadership are also vital, as referees need to clearly convey decisions and manage the flow of the game. Furthermore, technical skills such as positioning, anticipation of play, and continuous learning through feedback and rule updates contribute to their overall performance and professional development (IFAB, 2024; Krüstrup et al., 2010). Collectively, these attributes highlight the multifaceted nature of refereeing, emphasizing that successful referees combine physical, cognitive, and interpersonal competencies.

2.2.2 Roles of Soccer Referees

Soccer referees hold a central role in ensuring the proper conduct of matches, going beyond mere rule enforcement. In addition to their authority in enforcing the laws, soccer referees play a vital role in maintaining fairness during the game. They manage various on-field situations, ensure player safety, and coordinate effectively with assistant referees and players. Primarily, they are responsible for applying the 17 Laws of the Game consistently to all players, promoting fair play and ethical behavior (IFAB, 2024).

Furthermore, referees actively manage on-field situations, ensuring player safety and controlling conflicts that may arise among players, coaches, or spectators.

Effective communication and leadership are essential in this context, as referees must clearly convey decisions, coordinate with assistant referees, and maintain the flow of the game without bias (Gülle, 2017; Krüstrup et al., 2010).

Moreover, the psychological aspects of refereeing are critical to their role. Decision-making under pressure, rapid judgment in complex scenarios, and emotional regulation are indispensable skills. Physical fitness also directly impacts performance, as referees must remain close to the play and sustain high levels of concentration throughout the match (Raab et al., 2020; Helsen & Bultynck, 2003).

Collectively, the role of a soccer referee integrates cognitive, physical, and interpersonal skills. Their presence ensures that the match proceeds according to the rules while preserving fairness, safety, and the spirit of the game.

2.2.3 Knowledge of the Laws of the Game

Soccer referees must thoroughly understand the Laws of the Game as set by IFAB (2024). This involves knowing all 17 rules, referees are required to cultivate a comprehensive understanding of their practical application in a variety of match scenarios, which can range from straightforward to highly intricate. The Laws are intended not only to define specific technical requirements but also to safeguard the “spirit of the game,” encouraging officials to consider fairness, player welfare, and respect for all participants in every decision they make. In situations where the rulebook does not provide a definitive answer—such as slight irregularities in field markings, unexpected player behavior, or unusual match events—referees are expected to exercise prudent judgment and interpret the Laws with both consistency and fairness.

Staying up-to-date with periodic amendments and clarifications issued by IFAB is also critical. Modifications may address aspects such as goalkeeper possession limits, procedures for dropped balls, the interpretation of offside, or the management of restarts. Because these adjustments are implemented prior to each competitive season, referees must integrate any changes into their decision-making processes to ensure rules are applied correctly and uniformly across matches.

Modern football officiating increasingly relies on collaborative teams, including assistant referees, fourth officials, and — when available — the Video Assistant Referee (VAR) system. VAR is employed to review only situations considered a "clear and obvious error" or a "serious missed incident," such as disputed goals, penalty decisions, direct red card offenses, or cases of mistaken identity. Despite technological support, the on-field referee retains ultimate authority, making final decisions either from their own judgment or after consulting VAR findings.

In addition to rule knowledge, effective referees must possess strong communication and management skills. Clear signaling, concise verbal explanations, and coordinated teamwork among officiating staff are vital to ensuring that players, coaches, and spectators understand and accept decisions. These competencies help maintain control over the match, reduce disputes, and uphold the integrity of the game.

Practical Examples of Laws in Action

1.Offside and VAR in Premier League (Luis Díaz, Liverpool vs Tottenham, 2023): A goal by Luis Díaz was initially disallowed for offside. VAR intervention did not overturn the decision in time, highlighting the critical importance of real-time communication and correct interpretation between officials and technology.

2.Goal-line controversies prior to technology implementation: Before goal-line technology, high-profile incidents—such as Frank Lampard's disallowed goal in the 2010 FIFA World Cup—demonstrated that human error could significantly affect match outcomes, ultimately motivating FIFA to adopt additional technological support.

3.VAR in Women's World Cup 2019: A goal scored by Cameroon was overturned due to a marginal offside decision detected by VAR. This case illustrates how referees must apply the Laws consistently while also managing the perception of fairness among players and spectators.

Through understanding both the technical details and practical applications of the Laws, referees can make informed, equitable decisions that respect the rules and the spirit of football, ensuring the game proceeds smoothly and maintains its integrity.

2.2.4 Physical Fitness Requirements and Classification of Soccer Referees

Physical Requirements and Classification of Soccer Referees: Soccer referees are generally categorized into different levels based on the level and responsibilities of the matches they officiate. The most common classifications include:

1.FIFA Referees: Senior referees certified by the International Federation of Association Football (FIFA) to officiate international competitions, such as the World Cup and intercontinental tournaments.

2.National Referees: Senior referees certified by national soccer associations, responsible for top domestic leagues, cups, and selected international matches.

3.VAR Referees: Referees overseeing regional leagues and competitions, such as state leagues and regional cups.

4.Club-level Referees: Referees officiating matches within clubs, typically selected and trained by the clubs themselves.

In addition, referees can be categorized according to roles and responsibilities, including on-field referee, assistant referee (touch judge), fourth official, and video assistant referee (VAR). Regardless of level or role, all referees are required to undergo professional training and assessment to ensure they possess sufficient skills and knowledge for effective match enforcement.

Classification of Youth Soccer Referee Potential: The classification of youth referees is essential for comprehensively evaluating abilities and ensuring that a referee’s true capacity to manage matches is accurately reflected on the field. This research establishes four principal dimensions for grouping referees, integrating physical readiness and professional experience:

The classification of youth football referee potential is a supremely important process for comprehensively evaluating abilities, ensuring that the referee's true capacity to effectively manage the match is reflected on the field of play. This research establishes the principal dimensions for referee grouping, considering factors related to physical readiness and professional experience in overseeing competitions.

1. Body Composition

Body Composition serves as a fundamental indicator highly critical to the referee's performance. This focuses on analyzing Body Fat Percentage and Lean Body Mass. Assessment can be conducted using standard measurement tools such as the Skinfold Caliper or Bioelectrical Impedance Analysis (BIA). An optimal body composition enables the referee to execute agile and swift movements throughout the game and, crucially, mitigates physical load, thereby helping maintain concentration levels and the accuracy of their rulings at every critical juncture.

2. Muscular Power (Strength)

Muscular Power in both the upper and lower body is a necessary mechanical factor for on-field operation. This can be evaluated via Maximal Resistance Testing, such as the 1 Repetition Maximum (1RM) test for key movements like the Squat, Leg Press, or Bench Press. A higher degree of muscle strength directly facilitates rapid initial acceleration, swift changes of direction, and the maintenance of stable posture while moving. These elements are vital for reducing the risk of injury and enhancing the ability to reach the optimal decision-making position.

3. Cardiovascular and Circulatory System Endurance

This endurance metric is a key indicator of the referee’s ability to sustain functional quality throughout the entire 90-minute duration of the match. Such capacity can be assessed using recognized tests, including the Yo-Yo Intermittent Recovery Test. Referees who demonstrate proficiency in running and possess a high rate of rapid recovery between high-intensity phases of play can prevent fatigue that directly impairs the quality of their diagnoses and decisive game management.

4. Experience and License Level (Experience)

Experience and license level constitute crucial contextual variables used for appropriate sampling and control. This dimension encompasses the number of years spent officiating youth football games, the number of matches refereed at various levels of importance, and the level of professional license obtained (e.g., FIFA, National, Regional). Incorporating the dimension of experience allows for an in-depth and reliable

analysis of the differences in HIIT training outcomes between highly experienced and less experienced groups.

Therefore, the Classification framework used in this research, by integrating these three dimensions of physical capability alongside experience, enables a comprehensive evaluation of the effects of High-Intensity Interval Training (HIIT). This approach not only assesses physical changes but also allows for a clearer interpretation of the correlation between the altered physical fitness and the ability to perform duties on the pitch. This is intended to serve as a vital conceptual framework for the future development of youth referee training programs.

In China, referee grading is influenced by multiple factors, including physical performance, penalty distance coverage, enforcement stability, mental health, and team performance. For example, the physical performance and penalty coverage of Chinese Super League referees vary according to match type and half (Jinying Jiang, 2022). According to the Chinese Football Association (CFA) statutes, referees are divided into four levels: Level 3, Level 2, Level 1, and National Level. Local member associations manage the registration, training, and assessment of Level 3, Level 2, and Level 1 referees (HONG Jia-yun, 2002). These grading levels highlight the structured approach of the Chinese Football Association in developing referees' skills and ensuring consistent officiating standards across different match levels.

2.2.5 Physical Demands and Training for Referees

Soccer referees play a critical role in match management and face significant physical demands (Su Zi, 2023). High-caliber referees require stamina, agility, and speed to maintain focus, track the ball, and remain in optimal positions for accurate decision-making (Tao Rancheng, 2013). Modern soccer's high tempo and rapid transitions between attack and defense further increase these demands, requiring referees to sustain continuous movement with minimal recovery periods (Dong Qing, 2021).

For youth soccer referees, this stage represents an ideal period for implementing scientific and structured training programs. Refereeing itself is a form of high-intensity intermittent exercise, where periods of exertion and rest are dictated by the match dynamics. To prepare for the Yo-Yo Intermittent Recovery Test Level 1, which is used by the Chinese Soccer Association to assess referee fitness, training should focus on Aerobic and anaerobic endurance, Speed and agility, Muscular strength and power.

Recommended training includes strength exercises (e.g., barbell squats), speed drills (e.g., 40-meter sprints), and interval running, with High-Intensity Interval Training (HIIT) widely recognized as an effective method. HIIT simulates the variable-speed running patterns encountered during matches, providing optimal preparation for referees' physical demands (Su Zi, 2023).

2.2.6 Psychological Attributes

Soccer is a complex sport that requires both physical skills and cognitive processing. Players must be able to make rapid decisions, assess changing situations on the field, and adapt effectively to dynamic game conditions. In addition, team coordination, communication, emotional regulation, and concentration are critical factors that contribute to effective performance in soccer.

Given these demands, psychological factors play a significant role in influencing performance outcomes in soccer. Several researchers have identified and categorized the psychological attributes of soccer players into multiple dimensions, including motivation and commitment, self-confidence, concentration and emotional regulation, and decision-making under pressure (Weinberg & Gould, 2019; Gucciardi & Dimmock, 2008).

These psychological attributes are essential for enabling players to cope with competitive stress and adapt to team strategies and opponent's tactics. Consequently, psychological factors influence not only individual performance but also overall team outcomes in soccer (Hanin, 2000; Fletcher & Sarkar, 2012).

The psychological profile of soccer referees is recognized as an essential determinant of officiating success, involving strong psychological qualities such as situational awareness, self-control, stress resilience, and decision-making under pressure. These mental competencies enable referees to make rapid and accurate judgments in complex competitive environments and manage match dynamics effectively. Research indicates that referee performance is closely linked to psychological skill levels, self-efficacy, and the ability to cope with high-pressure situations. For example, studies on amateur soccer referees have shown that higher levels of self-efficacy are associated with lower impulsivity, suggesting that confidence in one's officiating ability supports better psychological regulation and decision-making in match contexts.

Referees are frequently exposed to stressors that can affect attention and decision-making, and managing anxiety and cognitive load is a central psychological challenge. Experimental evidence using neurological measures such as event-related potentials (ERP) has demonstrated that anxiety influences referees' cognitive processing during foul-play scenarios, highlighting the importance of understanding and managing psychological states to optimize decision outcomes under pressure.

Experience level also appears to influence psychological responses among referees. Research comparing psychological responses and confidence levels in referees with varying levels of experience indicates that more experienced referees tend to exhibit higher self-esteem and confidence with lower levels of anxiety, which supports more effective performance in competitive settings. Because soccer referees operate in highly demanding and unpredictable environments, psychological training and resilience development are critical. These include observation skills, self-control and emotional regulation, rapid situational judgment, and mental toughness to withstand external pressure from players, coaches, and spectators. Studies on mental toughness and officiating suggest that higher-level referees often engage in more structured psychological skills training, which correlates with enhanced coping and performance in competition.

In summary, referees' psychological characteristics—such as self-efficacy, anxiety management, resilience, and decision-making under pressure—are supported by empirical research as foundational to effective officiating in soccer. These qualities extend beyond physical and technical ability and represent a core component of refereeing expertise.

2.2.7 Integration for Elite Performance

Effective refereeing at the elite level requires combining physical, cognitive, and psychological abilities with a thorough knowledge of the rules. Referees who integrate these skills can maintain fairness, enforce the laws properly, and ensure the smooth flow of the game, demonstrating the multifaceted demands of modern soccer officiating (Raab et al., 2020; Helsen & Bultynck, 2003).

Soccer referees are required to possess a comprehensive understanding of the Laws of the Game, as established by the International Football Association Board (IFAB, 2024). This includes mastery of the 17 Laws, the ability to apply them accurately in complex or ambiguous match situations, and continuous adaptation to rule updates. Additionally, referees must coordinate effectively with assistant referees and, when available, Video Assistant Referee (VAR) systems to ensure precise decision-making during matches.

In addition to regulatory knowledge, referees must maintain high levels of physical fitness to meet the demands of modern soccer. Cardiovascular endurance is critical for sustaining continuous movement across the full 90 minutes of play, while speed, agility, and muscular strength allow referees to maintain optimal positioning and rapidly respond to dynamic on-field situations (Krüstrup et al., 2010). Efficient recovery between high-intensity efforts is also essential to prevent fatigue from impairing decision-making accuracy. Numerous studies have demonstrated that cardiovascular load, overall fatigue, and physical exertion can directly compromise a referee's perceptual-cognitive abilities and the precision of their judgments (Helsen & Bultynck, 2003; European Journal of Sport Science, 2024). Mental fatigue can further impair

attention and inhibitory control, which are essential for correctly interpreting complex or ambiguous match situations (Nurcahya et al., 2025).

Equally important are psychological attributes, which influence referees' performance under pressure. High self-confidence enables referees to make decisive calls, whereas emotional regulation and conflict management ensure impartiality during confrontational situations with players, coaches, and spectators (Gülle, 2017). Concentration, focus, effective communication, leadership, and continuous learning further enhance referees' ability to manage matches successfully. Training programs that integrate psychological skill instruction, deliberate practice, and scenario-based drills have been proven to improve both the accuracy and consistency of on-field decisions (Saputra et al., 2025).

In summary, effective soccer officiating relies on the integration of physical fitness, cognitive skills, psychological resilience, and comprehensive mastery of the rules. Collectively, these qualities highlight the multifaceted nature of soccer refereeing, emphasizing that top-level referees combine knowledge, fitness, and psychological competence to uphold fairness, integrity, and the smooth flow of the game (Raab et al., 2020; Helsen & Bultynck, 2003).

2.2.8 Maintaining fairness

In soccer, fairness is a fundamental principle that requires all participants to compete under the same rules and conditions, ensuring impartiality and preventing favoritism. This concept extends beyond mere rule enforcement to include the idea of Fair Play, which encourages athletes and teams to act ethically, respectfully, and responsibly during competition (IFAB, 2024; FIFA, 2022). Fair Play promotes behaviors such as acknowledging the opponent's efforts, avoiding unnecessary aggression, and maintaining composure, even in high-stakes situations. In non-competitive or friendly matches, the focus of Fair Play shifts toward fostering enjoyment, collaboration, and mutual respect among players, rather than solely prioritizing the outcome of the game. Referees are pivotal in upholding these standards, as their decisions and conduct

directly influence both the fairness of the match and the ethical climate on the field (IFAB, 2024; FIFA, 2022). **2.2.9 Factors Affecting Referee Decision-Making**

Referee decisions in soccer are influenced by multiple factors, including match context, psychological stress, and experience level. Research on referees in the Chinese Football Super League indicates that match type and game halves affect referees' physical positioning and decision-making distances, demonstrating adaptive perceptual strategies in response to game dynamics (Jiang et al., 2022). Psychological factors such as anxiety can alter cognitive processing during foul judgments, impacting decision accuracy even among experienced referees (Frontiers in Psychology, 2024). Moreover, studies examining neural and cognitive mechanisms have shown that high-level referees display distinct cognitive patterns when judging fouls, suggesting that experience and perceptual-cognitive strategies contribute to decision quality (Shui et al., 2025). These findings highlight that refereeing in soccer is a complex process affected by contextual, psychological, and experiential variables, which together shape the accuracy and consistency of decisions.

Academic Examples of Situations

1.Penalty Decision

Situation: A home team player dribbles into the penalty area and is lightly pushed by an opponent, but the referee's view is partially obstructed by other players.

Influencing Factors: Referee's perception and viewpoint: Limited visual clarity can delay or reduce the accuracy of decisions (Jiang et al., 2022).

Psychological pressure: High-stakes matches or loud crowd noise may increase referee hesitation (Frontiers in Psychology, 2024).

Experience: Experienced referees tend to make quicker and more confident decisions.

2.Repeated Fouls in a Heated Situation

Situation: An away team player commits repeated fouls late in the match, and home team players protest dramatically to draw the referee's attention.

Influencing Factors: Player behavior: Players' gestures or dramatization can sometimes sway the referee's judgment (Plessner & Betsch, 2001).

Match context pressure: Close scores or decisive moments increase the pressure to make fair decisions.

Concentration and self-control: Referees must manage emotions and make impartial decisions.

3.Decisions in High-Stakes Matches

Situation: In a league final, both teams play aggressively with frequent collisions.

Influencing Factors:

Competition context: Important matches require referees to evaluate and apply sanctions carefully.

Physical and mental fatigue: Continuous decision-making may reduce accuracy over time.

Coordination with assistant referees: Effective communication is necessary to ensure correct judgments.

2.3 Referee Grading System in China

The referee grading system in Chinese soccer is a centralized, state-supervised framework administered by the Chinese Football Association (CFA) to standardize officiating quality and integrity across all levels of competition (CFA, 2023). It functions as a hierarchical certification ladder integrated with a dynamic, performance-based management regime, particularly for the professional leagues.

At its core, the system categorizes referees into distinct levels, from local beginners to National and International levels. Advancement requires passing rigorous theoretical, physical, and practical assessments. A pivotal reform is the implementation of a strict "Promotion and Relegation" system for referees in the Chinese Super League, China League One, and China League Two. This annual mechanism mandates that underperforming referees in each tier be relegated, replaced by top performers from the league below, creating direct accountability (CFA, 2024).

A referee's performance is evaluated through a multi-dimensional framework. Key criteria include Professional Competency (decision accuracy, fitness, match control), Theoretical Knowledge, and Professional Ethics (integrity and conduct). Academic research has contributed to formalizing these criteria, with studies constructing evaluation index systems that weigh technical skills, psychological stability, and moral conduct (Su, 2023; He, 2024). This process is supported by a structured Pingyi (assessment and review) system where expert panels analyze controversial decisions to ensure consistency and fairness (Zhu, 2023).

The system is underpinned by comprehensive training and strict governance. The CFA mandates frequent, standardized training sessions to unify the interpretation of rules. Integrity measures are stringent, featuring oversight mechanisms. Furthermore, the integration of technology, such as the expanded use of Video Assistant Referee (VAR) systems, is a key focus to support on-field decisions. Ultimately, this grading system represents a critical, evolving component of China's broader project to professionalize soccer and restore public trust in the sport's fairness.

2.4 Physical Demands According to Competition Level

The physical demands in soccer vary significantly depending on the level of competition. Understanding these demands is essential for developing appropriate training programs and ensuring optimal performance for both players and referees. Both players and referees face increased physiological and biomechanical stress as the competition level rises. Key points include:

1.Running Distance

The physical requirements in soccer vary considerably depending on the competitive level. Elite-level matches, including professional leagues and international tournaments, present referees and players with considerably higher physiological and biomechanical challenges. In such games, referees may cover 10–12 km per match, while central midfield players often traverse 10–13 km, reflecting the constant pace, repeated high-intensity efforts, and complex tactical interactions typical of top-tier soccer. To meet these demands, referees must possess well-developed

aerobic capacity, anaerobic power, and agility, ensuring they can maintain proper positioning and accurate decision-making throughout the match.

At lower or amateur competition levels, the physical workload is comparatively reduced. Referees generally cover 7–10 km per match, owing to slower game tempo, fewer high-intensity actions, and simpler tactical structures. Variations in physical demands are shaped not only by the intensity of the match but also by team strategies and patterns of ball possession, which influence the frequency of sprints, directional changes, and prolonged movement (Castagna et al., 2007). Recognizing these differences is essential for designing tailored training programs that prepare referees and players to handle the specific physical and cognitive requirements associated with their level of competition.

2.High-Speed and Sprint Efforts

At higher levels of soccer competition, referees and players are exposed to more frequent high-speed runs and sprints due to the faster pace of play, rapid transitions between attack and defense, counterattacking opportunities, and aggressive pressing strategies. In professional matches, referees may perform approximately 20–40 sprints per game, reflecting the necessity to constantly reposition themselves to maintain clear sightlines on critical events. By contrast, referees officiating at amateur or lower-level competitions typically engage in far fewer high-intensity efforts, as the overall game tempo and tactical complexity are reduced.

These repeated bursts of high-speed activity are essential not only for maintaining optimal field positioning but also for ensuring accurate observation of fouls, offsides, and other key match incidents. The ability to sustain such efforts requires a combination of anaerobic capacity, muscular power, and agility, allowing referees to respond quickly to unpredictable situations while minimizing the risk of fatigue-induced errors (Krustrup et al., 2002). Consequently, training programs for elite referees emphasize repeated sprint ability, interval endurance, and movement efficiency to meet the physical and cognitive demands of high-level competition.

3.Heart Rate Intensity

Referees officiating at elite levels are exposed to substantial cardiovascular demands throughout a match. Average heart rates for professional referees typically range from 150 to 170 beats per minute (bpm), with peak values often exceeding 1 8 0 bpm during moments of intense activity, such as fast breaks, counterattacks, or critical foul situations. In contrast, referees officiating in lower-level or amateur competitions generally experience a reduced cardiovascular load due to slower game tempo, fewer high-intensity sprints, and less complex tactical play.

Monitoring heart rate provides valuable insight into the internal physiological load experienced by referees during matches. This information is essential for developing scientifically-informed training programs that target cardiovascular endurance, anaerobic capacity, and recovery strategies. By understanding heart rate patterns and the variability of load across competition levels, trainers can design level-specific conditioning regimens that enhance referees' ability to maintain optimal positioning, attentional focus, and decision-making accuracy throughout the game (Krustrup et al., 2002; Weston et al., 2012).

4.Fatigue and Recovery

Fatigue tends to accumulate more rapidly in elite-level soccer due to the higher intensity of play, increased frequency of sprints, and extended match durations, including stoppage time. This progressive physical and mental fatigue can adversely affect referees' decision-making, positioning, and attentional focus, particularly during the final stages of a match when crucial incidents often occur. The combination of repeated high-intensity efforts and cognitive demands increases the risk of lapses in judgment or delayed reactions, highlighting the importance of managing both physical and mental load throughout the game.

To mitigate the effects of fatigue, proper recovery strategies are essential. These include structured nutrition plans, adequate hydration, and active recovery protocols, which help restore energy reserves, maintain muscle function, and support cognitive alertness. Implementing such strategies is particularly critical for

referees officiating multiple matches over a season, as it ensures consistent performance and reduces the risk of injury or suboptimal decision-making (Weston et al., 2004). Understanding the interplay between fatigue, physical demands, and cognitive performance allows for the development of evidence-based training and recovery programs tailored to the specific requirements of elite-level refereeing.

5.Implications for Training

Elite referees require structured and periodized training programs specifically designed to meet the physical and cognitive demands of high-level soccer matches. These programs typically focus on enhancing aerobic endurance to sustain continuous movement, speed and agility to react quickly to play developments, and repeated sprint ability to manage frequent high-intensity bursts without compromising performance. Incorporating drills that simulate match scenarios allows referees to maintain optimal positioning, attentional focus, and decision-making accuracy even under fatigue.

In contrast, amateur or lower-level referees generally benefit from general cardiovascular conditioning and basic agility training. While they do not face the same frequency or intensity of sprints as professional referees, developing overall fitness helps maintain mobility, reduce fatigue, and support consistent officiating throughout the match. Tailoring training programs according to the referee's competitive level ensures that physical preparation is both efficient and relevant, preventing overtraining in lower-level referees while optimizing performance in elite officials (Weston et al., 2012; Krustrup et al., 2002).

Therefore, understanding the physical demands of soccer referees across different competition levels is essential, as it enables the design of effective training and recovery strategies, which in turn ensure optimal performance, accurate decision-making, and sustained officiating quality.

2.5 Physical Fitness of Soccer Referees

Physical fitness is a fundamental requirement for soccer referees, as it enables them to keep up with the fast pace of the game, maintain optimal positioning, and make accurate decisions throughout a match. It encompasses cardiovascular endurance, speed, agility, muscular strength, and the ability to perform repeated high-intensity efforts under fatigue. Developing and maintaining these fitness components is essential for effective officiating at all levels of competition.

2.5.1 Body Composition of Soccer Referees

1. Body Fat Percentage

The physical conditioning of soccer referees is a pivotal factor influencing their capability to sustain accurate decision-making across the entire 90-minute duration of a match. Officials are required to maintain continuous movement patterns, execute repeated short bursts of speed (sprints), perform swift changes in direction, and exert high-intensity efforts to effectively keep up with the flow of play. This physical effort occurs concurrently with significant cognitive demands, including maintaining optimal positioning, keen observation, and impartial judgment (Krustrup et al., 2010). Therefore, the role necessitates that referees possess a highly developed profile encompassing cardiovascular endurance, anaerobic power, speed, agility, muscular strength, and joint flexibility.

The Role of Body Composition and Training Strategy

Beyond core performance attributes, body composition, particularly the percentage of body fat, is a key determinant of overall fitness and match performance outcomes. Lower levels of body fat are often correlated with superior endurance, agility, and recovery capability. Conversely, excessive body fat can detrimentally affect speed and accelerate the onset of fatigue during recurring high-intensity activities.

High-Intensity Interval Training (HIIT) has been established as an highly effective training intervention for simultaneously boosting both aerobic and anaerobic capacities. Furthermore, HIIT contributes to the reduction of body fat mass by significantly elevating energy expenditure and stimulating Excess Post-exercise Oxygen

Consumption (EPOC) (Buchheit & Laursen, 2013; Su Xiaoying, 2020). Through the strategic incorporation of HIIT into their training routines, referees can achieve dual benefits: enhancing their physical output while optimizing their body composition. This integration ultimately fosters greater operational efficiency and resilience required for match-day duties.

2. Muscle Mass

Muscle mass, defined as the total weight of skeletal muscle in the body, is an important component of physical fitness for soccer referees. Adequate muscle mass supports muscular strength, stability, and force production, all of which contribute to effective movement patterns during matches, including repeated sprinting, acceleration, deceleration, and changes of direction. Referees with well-developed muscle mass are better equipped to perform these demanding actions without premature fatigue, which in turn helps maintain optimal positioning and perceptual accuracy throughout a game.

Empirical research on the anthropometric profiles of soccer referees has demonstrated that elite referees possess body composition characteristics more similar to soccer players than to non-athletic populations, suggesting that high levels of muscle mass and overall physical conditioning are typical at higher levels of officiating (Piccio et al., 2023). Specifically, studies assessing body composition in referees found that levels of muscle mass can vary, with some reported averages (e.g., ~38.2% ± 3.1% in a sample of referees), indicating a substantial proportion of lean tissue that contributes to performance during high-intensity efforts (Anthropometric profile of soccer referees, 2020). Research also highlights the role of nutritional status and training in maintaining favorable body composition, as excessive fat mass can be negatively correlated with sprint performance and endurance, whereas lean mass supports physical exertion and recovery (Effect of body composition on performance, 2023).

In the context of officiating, maintaining sufficient muscle mass is therefore not merely a matter of physique, but a functional fitness attribute that underpins movement efficiency, resilience against fatigue, and the capacity to sustain

high-intensity physical actions throughout a match — all of which are linked to better overall refereeing performance.

3. Cardiovascular Endurance

Cardiovascular endurance, also known as aerobic capacity, refers to the ability of the heart, lungs, and circulatory system to supply oxygen efficiently to working muscles during sustained physical activity. For soccer referees, high levels of cardiovascular endurance are essential, as matches often require continuous movement over 90 minutes or more, covering distances between 7–12 km per game, depending on the level of competition. Adequate aerobic fitness allows referees to maintain optimal positioning, attentional focus, and rapid decision-making throughout the match, while delaying the onset of fatigue.

Empirical studies indicate that elite referees display cardiovascular profiles comparable to professional soccer players, with average heart rates of 150–170 bpm during matches and peaks exceeding 180 bpm during high-intensity phases such as counterattacks or sprints (Krustrup et al., 2002). Research also emphasizes that aerobic endurance supports the ability to recover quickly between repeated high-intensity bouts, which is critical for sustaining performance across multiple matches or tournaments (Weston et al., 2004). Maintaining cardiovascular fitness through structured interval training, long-distance running, and high-intensity drills is therefore a cornerstone of physical preparation for soccer referees at all competition levels.

In summary, these physical fitness components are not only important for the referee's movement and endurance but also directly impact their decision-making performance. By maintaining sufficient muscle mass, cardiovascular endurance, agility, and fatigue resistance, referees are able to keep pace with the game, position themselves effectively, and make consistent, accurate decisions under the complex and high-pressure conditions of modern soccer.

2.5.2 Muscular Strength of Soccer Referees

Muscular strength in the lower limbs and core is essential for soccer referees, as it supports efficient movement, postural stability, and rapid reaction to match developments. Lower limb strength provides the explosive power required for fast

acceleration, deceleration, and repeated sprinting, while core stability allows effective force transfer between the upper and lower body during dynamic actions. These physical capabilities enable referees to maintain optimal positioning, closely follow the play, and make accurate decisions during key incidents.

Studies indicate that greater lower body strength is closely linked to improvements in speed and change-of-direction performance, which are critical for referees who frequently reposition themselves in response to evolving game situations. Training programs that enhance lower limb and core muscle strength improve dynamic balance and movement efficiency, reducing fatigue and minimizing the risk of errors during matches (Cai, Yin, & Yun, 2025).

Assessment of muscular strength for referees typically involves standardized measures such as one-repetition maximum (1RM) tests for exercises like squats or leg presses, as well as functional performance tests including vertical jumps and isokinetic strength evaluations. These assessments quantify a referee's capacity to produce muscular power necessary for high-intensity movements and inform individualized strength-conditioning programs that enhance movement performance and officiating effectiveness (Tianjin Institute of Physical Education Journal, 2025).

In summary, sufficient lower body and core strength is crucial for soccer referees, as it directly impacts speed, agility, positioning, and ultimately, the accuracy of their on-field decisions.

2.5.3 Cardiovascular Endurance

Cardiovascular endurance, often referred to as aerobic fitness, is the ability of the heart, lungs, and circulatory system to deliver oxygen efficiently to the muscles during extended periods of physical activity. In the context of soccer refereeing, this attribute is fundamental. Referees are required to move continuously across the pitch for 90 minutes or more, often covering distances similar to midfield players while simultaneously observing gameplay and making instantaneous decisions. According to Castagna et al. (2007), "a high level of aerobic capacity allows referees to sustain physical activity without a significant decline in cognitive performance," emphasizing

that endurance is not only a physical requirement but also a cognitive necessity for consistent decision-making.

Aerobic Capacity and VO_2max

Maximal oxygen uptake (VO_2 max) is a standard measure of aerobic capacity and represents the maximum volume of oxygen an individual can utilize during intense exercise. Referees with higher VO_2 max values can maintain optimal running intensity and recover faster from repeated sprints, which is crucial for keeping pace with the flow of a professional match. As Castagna et al. (2007) highlight, "referees with superior VO_2 max demonstrate the ability to remain physically active and alert, particularly during critical phases of the game when decision-making demands are highest." This illustrates that cardiovascular endurance directly influences both the mobility and perceptual acuity of referees on the field.

Yo-Yo Intermittent Recovery Test

The Yo-Yo Intermittent Recovery Test (Yo-Yo IR1) has emerged as a highly practical and reliable tool for assessing the physical fitness of soccer referees, particularly their capacity to perform repeated high-intensity efforts while maintaining rapid recovery. Unlike traditional endurance tests, the Yo-Yo IR1 simulates the intermittent nature of soccer, requiring repeated 20-meter sprints interspersed with brief recovery periods. This closely mirrors the movement patterns referees experience during matches, including frequent accelerations, decelerations, and directional changes (Castagna et al., 2005).

One of the primary advantages of the Yo-Yo IR1 is its ability to evaluate both aerobic endurance and anaerobic recovery. Referees with higher Yo-Yo scores are better equipped to sustain high-speed movements throughout a game, particularly during critical moments when decision-making demands are elevated, such as monitoring offside positions or fouls in the final stages of a match (Castagna et al., 2007). As Castagna et al. (2005) state, "Yo-Yo performance is closely linked to the referee's capacity to sustain repeated sprints, recover quickly, and execute accurate

judgments under fatigue," emphasizing the direct relevance of this test to match officiating performance.

Moreover, the Yo-Yo IR1 test provides practical benefits for training and performance monitoring. It is time-efficient, requires minimal equipment, and can be conducted on standard-sized fields, allowing conditioning coaches to assess referees' endurance and recovery capacity frequently. The results can guide individualized training programs, ensuring referees develop sufficient cardiovascular fitness, muscular endurance, and repeated sprint ability to meet the physical and cognitive demands of elite-level soccer (Krustrup et al., 2003).

In summary, the Yo-Yo Intermittent Recovery Test offers a scientifically validated method to evaluate and enhance the physical preparedness of soccer referees. By reflecting the specific movement patterns and intensity fluctuations of a match, it enables referees to maintain optimal positioning, attentional focus, and decision-making accuracy even under conditions of accumulated fatigue. Its integration into referee training programs represents a crucial step toward maximizing both physical performance and officiating effectiveness in competitive soccer.

2.6 High-Intensity Interval Training: HIIT

High-Intensity Interval Training (HIIT) refers to a conditioning approach that alternates brief periods of demanding physical activity with phases of active recovery or rest. In the context of soccer refereeing, HIIT is highly appropriate because officiating requires repeated changes in movement intensity, including rapid accelerations, decelerations, and short bursts of high-speed running. Throughout a match, referees must continuously shift between low-intensity activities such as walking or jogging and high-intensity actions such as sprinting, all while maintaining accurate positioning and cognitive focus.

The fundamental concept of HIIT is to expose the body to workloads performed at or near maximal intensity, thereby challenging both the cardiovascular and metabolic systems. Although HIIT sessions are typically shorter than traditional endurance training, they induce substantial physiological responses, including enhanced aerobic fitness,

improved oxygen delivery, and greater metabolic efficiency. These adaptations are particularly beneficial for soccer referees, who must sustain repeated high-intensity efforts over the full duration of a match and minimize performance decline during the final phases of play.

In addition, the stop-and-go nature of HIIT closely mirrors the recovery demands experienced by referees during competition. The ability to rapidly regain physiological readiness between intense actions is essential for officials who must reposition themselves quickly to observe decisive moments. By systematically training the body to alternate between exertion and recovery, HIIT supports improved cardiovascular function, reduced fatigue accumulation, and sustained attentional capacity. As a result, HIIT is widely recognized as a time-efficient and sport-specific training method that aligns well with the physical and perceptual requirements of modern soccer refereeing.

2.6.1 Training Formats Relevant to Soccer Referees

High-Intensity Interval Training (HIIT) can be organised in a range of formats depending on specific performance goals and the competitive context in which an official operates. A typical configuration involves brief periods of intense exercise, often lasting 10–30 seconds, interspersed with recovery episodes of equal or slightly extended duration. For referees, these sessions are frequently constructed around locomotor tasks that mimic match realities, such as shuttle runs, change-of-direction drills, and bursts of fast running interspersed with active or passive recovery. Such design helps replicate the movement economy and intermittent demands encountered on the pitch, thus enhancing movement efficiency, repeated sprint capacity, and positional adjustment throughout the game while containing overall training time.

Research that synthesises scientific studies related to referees indicates that HIIT not only improves physical performance but may also benefit psychological readiness (e.g., concentration and stress resilience), compared with alternative training modalities such as small-sided games alone. The review found HIIT produced meaningful gains in sprinting ability as well as mental health dimensions beyond those

of conventional conditioning, although methodological heterogeneity among studies was noted, highlighting the need for further tailored interventions. This evidence suggests that appropriately structured HIIT regimens can improve the multidimensional fitness profile required for high-level match officiating.

Studies also support the utility of physiologically guided HIIT prescriptions, such as those based on intermittent fitness tests (e.g., the "30-15 IFT"), to individualise intensity and recovery ratios more effectively. Although this research primarily involves players rather than referees, the principle of matching interval intensities to characteristics of intermittent sport performance has direct relevance for conditioning referees who must manage rapid accelerations and decelerations repeatedly throughout a match.

Collectively, these findings reinforce that properly formatted HIIT protocols allow match officials to build necessary physical capacities without excessive volume that could increase injury risk. They offer a time-efficient strategy that aligns with the intermittent nature of officiating demands, thereby supporting sustained high performance and more consistent decision-making from kick-off to final whistle.

2.6.2 Energy Systems Involved in HIIT

High-Intensity Interval Training (HIIT) places considerable stress on multiple physiological energy systems, requiring the body to rapidly shift between anaerobic and aerobic metabolism. During short bouts of maximal or near-maximal effort, energy is primarily supplied by the phosphagen system (ATP-PCr) and the anaerobic glycolytic pathway, which support explosive actions such as sprinting, sudden accelerations, and rapid changes of direction. These movements closely resemble the high-intensity locomotor demands experienced by soccer referees during counterattacks, transitions, and critical match situations.

As HIIT sessions progress and recovery intervals become increasingly constrained, reliance on the aerobic energy system becomes more pronounced. Aerobic metabolism plays a crucial role in replenishing phosphocreatine stores, clearing metabolic by-products, and maintaining repeated high-intensity output across

successive efforts. Research led by Chinese scholars has demonstrated that HIIT significantly enhances aerobic power and oxygen utilization efficiency, allowing individuals to sustain repeated bouts of intense activity with reduced fatigue accumulation (Zhang et al., 2019; Tong et al., 2016).

Studies conducted within Chinese sport science institutions have also highlighted that the combined activation of anaerobic and aerobic systems through HIIT results in superior improvements in repeated sprint ability and recovery capacity when compared with continuous endurance training. Li et al. (2018) reported that intermittent training protocols improved both anaerobic power output and post-exercise recovery kinetics in athletes engaged in stop-and-go sports, emphasizing the relevance of HIIT for roles that require sustained attentional and physical performance under fatigue.

For soccer referees, these physiological adaptations are particularly important, as match officiating demands repeated high-intensity movements interspersed with brief recovery periods rather than continuous running. Enhanced aerobic efficiency enables referees to recover more rapidly between sprints, while improved anaerobic capacity supports decisive movements necessary for optimal positioning and visual control of play. Consequently, HIIT serves as an effective conditioning strategy that simultaneously develops cardiovascular endurance, metabolic resilience, and repeated high-intensity performance, all of which are essential components of modern soccer officiating.

2.6.3 Excess Post-Exercise Oxygen Consumption (EPOC)

One notable physiological phenomenon associated with High-Intensity Interval Training (HIIT) is Excess Post-Exercise Oxygen Consumption (EPOC), which describes the sustained elevation in oxygen uptake that occurs after the cessation of exercise. This prolonged oxygen demand reflects the body's process of re-establishing physiological equilibrium, including the resynthesis of phosphocreatine, removal of accumulated metabolites such as lactate, and the gradual normalization of heart rate, ventilation, and body temperature.

Research conducted by Chinese scholars has demonstrated that HIIT elicits a significantly greater EPOC response compared with moderate-intensity continuous exercise, primarily due to the higher metabolic disturbance induced by repeated high-intensity efforts (Zhang & Ji, 2018; Li et al., 2020). These findings indicate that the magnitude of EPOC is closely linked to exercise intensity and the extent of anaerobic contribution during training, both of which are characteristic features of HIIT protocols.

From a performance perspective, the elevated post-exercise oxygen consumption associated with HIIT contributes to improvements in metabolic efficiency and aerobic function. Studies from Chinese sport science institutions have reported that repeated exposure to HIIT enhances mitochondrial enzyme activity and accelerates recovery of high-energy phosphates, thereby improving tolerance to successive bouts of intense activity (Zhou et al., 2019). Such adaptations are particularly relevant for soccer referees, who must repeatedly engage in high-intensity movements while recovering rapidly enough to maintain optimal positioning and visual coverage of play.

Over time, the cumulative effects of HIIT-induced EPOC support sustained physical output and may indirectly benefit perceptual and decision-making performance by delaying the onset of fatigue-related declines. Given the intermittent and demanding nature of match officiating, the enhanced recovery capacity and aerobic support associated with EPOC make HIIT a highly effective conditioning strategy for modern soccer referees.

2.6.4 HIIT and Decision-Making Performance of Soccer Referees

Beyond its well-documented physiological effects, High-Intensity Interval Training (HIIT) has been shown to play a meaningful role in preserving cognitive performance under conditions of physical fatigue. As fatigue accumulates during prolonged or high-intensity activity, cognitive functions such as sustained attention, reaction speed, and perceptual judgment are known to decline, potentially compromising decision accuracy in time-critical situations. For soccer referees, who must continuously interpret dynamic play and make instantaneous decisions, the interaction between physical fatigue and cognitive efficiency is particularly relevant.

Research conducted by Chinese scholars has demonstrated that HIIT-induced improvements in cardiorespiratory fitness and recovery efficiency are associated with enhanced tolerance to fatigue-related cognitive decline. Liu et al. (2019) reported that individuals who completed structured HIIT programs maintained higher levels of attentional focus and faster reaction times following exhaustive exercise compared with those who performed traditional continuous endurance training. These findings suggest that improved aerobic capacity and faster physiological recovery may buffer the negative effects of fatigue on executive functioning.

Additional evidence from studies in China indicates that HIIT can positively influence perceptual–motor performance, particularly in tasks requiring rapid information processing and spatial awareness (Zhang et al., 2020). Such adaptations are highly applicable to soccer referees, who must sustain optimal positioning and visual access to play while simultaneously processing multiple sources of information, including player movements, ball trajectory, and potential infringements.

By enhancing both physical resilience and recovery capacity, HIIT enables referees to maintain elevated levels of alertness and movement precision during the latter stages of a match, when decisive incidents are more likely to occur. Consequently, HIIT should be regarded not solely as a conditioning method aimed at improving physical fitness, but also as a performance-support strategy that indirectly contributes to consistent and accurate decision-making in competitive soccer environments.

2.6.5 Benefits of High-Intensity Interval Training (HIIT) on Physical Fitness in Soccer Referees

High-Intensity Interval Training (HIIT) has emerged as an efficient conditioning approach that enhances multiple aspects of physical fitness critical for soccer referees. Specifically, by alternating between bouts of near-maximal effort and recovery periods, HIIT closely simulates the intermittent nature of match play, making it particularly suitable for officials who must maintain both physical and cognitive performance throughout a game. Moreover, evidence from international and Chinese studies highlights several key advantages.

1. Endurance Development

First, HIIT contributes to significant improvements in both aerobic and anaerobic endurance, enabling referees to perform at high intensity across the duration of a match. By repeatedly challenging the cardiovascular system, it leads to enhanced oxygen uptake (VO_2max) and overall stamina. Consequently, referees are able to sustain optimal positioning and maintain attentional focus even during extended periods of play (Buchheit & Laursen, 2013). In addition, research from China has demonstrated that structured HIIT programs enhance endurance performance in referees and players, which supports consistent work rates under the demands of competitive matches (Li et al., 2019).

2. Speed and Agility

In addition to endurance, effective officiating requires rapid accelerations, decelerations, and frequent directional changes. HIIT improves neuromuscular coordination, lower-limb power, and recruitment of fast-twitch muscle fibers, which collectively enhance sprinting capability and agility. For instance, studies in England have demonstrated that repeated sprint-based HIIT drills improve both linear speed and multidirectional agility (Iaia et al., 2009). Similarly, Chinese research indicates that HIIT interventions increase movement efficiency, speed, and agility in referees, which facilitates better coverage of the field and faster reactions to dynamic play situations (Wang et al., 2020).

3. Recovery and Fatigue Management

Furthermore, HIIT promotes more efficient recovery between bouts of high-intensity activity. The alternation of exertion and rest stimulates physiological adaptations that accelerate lactate clearance, enhance energy replenishment, and maintain performance across consecutive efforts. As a result, referees experience reduced performance deterioration due to fatigue during matches or across successive games in a competitive season. This is supported by evidence from England, which shows improved post-exercise recovery following HIIT (Buchheit & Laursen, 2013).

Similarly, Chinese studies confirm that referees who engage in HIIT are able to maintain higher intensity activity for longer periods with lower perceived fatigue (Li et al., 2019).

Overall, by enhancing endurance, speed, agility, and recovery efficiency, HIIT equips soccer referees with specific physiological adaptations that support sustained performance and accurate decision-making on the field. Importantly, the consistency of findings across both Western and Chinese studies underscores the global applicability of HIIT as a practical and sport-specific conditioning strategy for match officials.

2.6.6 HIIT and Soccer Referees

Suitability of HIIT for Referee Movement Patterns

High-Intensity Interval Training (HIIT) is particularly suitable for soccer referees because it mirrors the intermittent and unpredictable movement patterns observed during matches. Referees are required to constantly reposition themselves, cover large distances, and perform repeated high-intensity sprints interspersed with periods of low-intensity jogging or walking (Castagna et al., 2007). Unlike players, referees must maintain a high level of vigilance while tracking multiple players and potential fouls, meaning that both physical and cognitive demands occur simultaneously. HIIT replicates this start-stop nature, improving the ability to sustain repeated sprints, accelerate quickly, and recover efficiently between high-intensity efforts (Buchheit & Laursen, 2013).

Preparation for Match Performance

Implementing HIIT in a referee's training program enhances their readiness for match-specific physical demands. Elite referees performing HIIT show improvements in aerobic capacity, VO_2 max, repeated sprint ability, and muscular endurance—all critical for maintaining positioning and observing game incidents accurately (Li, Zhang, & Wang, 2019). Furthermore, HIIT contributes to the development of mental resilience, enabling referees to maintain attentional focus and decision-making accuracy even during late-game fatigue (Wang, Li, & Chen, 2020). This combination of physiological and cognitive benefits ensures that referees can perform consistently throughout the entirety of the match, regardless of game intensity or duration.

Practical Applications

Typical HIIT protocols for referees include short bouts of high-intensity running (1 5 –6 0 seconds) at near-maximal effort, followed by low-intensity recovery periods. Training sessions are usually conducted 2–3 times per week and are integrated with endurance and agility drills to ensure comprehensive conditioning. Studies in China and internationally demonstrate that structured HIIT programs tailored to referees improve sprint performance, aerobic capacity, and overall match fitness, making them highly effective for preparing officials for elite-level competition (Li et al., 2019; Weston et al., 2012).

Conclusion

Overall, HIIT is a highly effective training method for soccer referees because it addresses the unique physical and cognitive demands of officiating. By simulating match-specific movement patterns and intensities, HIIT helps referees enhance endurance, sprinting ability, agility, and decision-making performance, ensuring consistent and accurate officiating across all levels of competition.

2.7 Related Research

This section reviews the existing body of literature on High-Intensity Interval Training (HIIT) across key physical and physiological domains relevant to athletic performance. The review is structured to examine the effects of HIIT on foundational physical fitness components, muscular strength and power, and cardiovascular endurance parameters, drawing upon established empirical evidence.

2.7.1 Research on HIIT and Physical Fitness Components

Research on HIIT and Physical Fitness Components

HIIT has been extensively studied for its efficacy in modifying body composition, a critical aspect of athletic readiness. Meta-analytic evidence consistently demonstrates that HIIT protocols are highly effective for reducing body fat percentage, with reductions comparable to or exceeding those from moderate-intensity continuous training, despite a lower time commitment (Viana et al., 2019). The metabolic demands of repeated high-intensity bouts, coupled with the significant excess post-exercise

oxygen consumption (EPOC), promote substantial caloric expenditure and fat oxidation (Laforgia et al., 2006). Concurrently, studies indicate that when combined with adequate nutritional protein intake, HIIT can help preserve or even induce modest increases in muscle mass, particularly in trained individuals (Shiraev & Timbar, 2012). This is attributed to the potent anabolic hormonal response (e.g., growth hormone, testosterone) elicited by high-intensity efforts, which supports muscle protein synthesis (Wewege et al., 2022). Therefore, HIIT presents a time-efficient strategy for athletes to optimize their body composition by reducing adiposity while maintaining lean muscle tissue.

2.7.2 Research on HIIT and Muscular Strength

The impact of HIIT on muscular strength, particularly in the lower body, is a growing area of investigation. While traditional resistance training remains the gold standard for maximal strength development, HIIT protocols that incorporate high-load, explosive movements (e.g., sprint intervals, plyometric-based circuits) have shown promise. Research on lower-body muscles suggests that sprint interval training (SIT) can lead to significant improvements in strength and power output, comparable in some cases to traditional resistance training in the early phases (Alvarez et al., 2021). Power and strength development through HIIT is likely mediated by neural adaptations—including improved motor unit recruitment, synchronization, and firing rate—as well as by morphological changes in fast-twitch muscle fibers (Osawa et al., 2018). This makes HIIT a valuable tool for developing sport-specific strength-endurance, where the ability to reproduce forceful movements under fatigue is essential, a quality directly transferable to the repeated sprint demands of officiating (Buchheit & Laursen, 2013).

2.7.3 Research on HIIT and Cardiovascular Endurance

HIIT is perhaps most renowned for its profound effects on cardiovascular endurance. This is most objectively measured by improvements in VO_2max, the gold standard metric for aerobic capacity. Numerous meta-analyses confirm that HIIT is superior to, or at least as effective as, moderate-intensity continuous training (MICT) in elevating VO_2max, often in a fraction of the time (Weston et al., 2014). Beyond

laboratory measures, field-based tests like the Yo-Yo Intermittent Recovery Test show that HIIT specifically enhances the ability to perform repeated high-intensity runs with brief recovery periods—a direct reflection of match-fitness in team sports (Iaia et al., 2009). Furthermore, HIIT improves recovery capacity between intense bouts. This is linked to enhanced buffering of metabolic by-products, improved cardiovascular stability (quicker heart rate recovery), and increased mitochondrial density and oxidative enzyme activity, which allows for faster phosphocreatine resynthesis and more efficient energy production (Bishop et al., 2011).

2.7.4 Research on HIIT and Muscular Strength

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2.7.5 Research on HIIT and Cardiovascular Endurance

High-Intensity Interval Training (HIIT) has been widely examined in sports science literature as an efficient training modality for enhancing cardiovascular endurance. The defining characteristic of HIIT is the alternation between short periods of high-intensity exercise and brief recovery intervals, a structure that closely mirrors the intermittent nature of football-related activities. Given these characteristics, HIIT has been considered particularly suitable for improving the physical fitness of soccer

referees, especially at the junior level, where match demands involve continuous movement interspersed with frequent high-intensity efforts.

Extensive research has demonstrated that HIIT is effective in improving maximal oxygen uptake (VO_2max), which is regarded as a primary indicator of aerobic fitness. Improvements in VO_2 max following HIIT have been attributed to both central and peripheral physiological adaptations, including enhanced cardiac output and improved oxygen utilization within skeletal muscle (Gibala et al., 2006; Buchheit & Laursen, 2013). Earlier experimental findings also reported that high-intensity intermittent exercise can elicit significant aerobic adaptations despite relatively short training durations (Tabata et al., 1996). These adaptations are particularly relevant for soccer referees, who must sustain prolonged physical activity while maintaining optimal positioning and decision-making accuracy throughout match play.

In addition to laboratory-based measures, field tests are commonly used to assess cardiovascular endurance in football contexts. Among these, the Yo-Yo Intermittent Recovery Test has been widely adopted due to its ability to evaluate repeated high-intensity running performance combined with short recovery periods. This test reflects the physiological demands of football more accurately than continuous endurance tests. Previous studies have shown that training programs incorporating HIIT result in significant improvements in Yo-Yo test performance, indicating enhanced intermittent endurance capacity (Bangsbo et al., 2008). Furthermore, research focusing specifically on soccer referees has identified a strong relationship between Yo-Yo test outcomes and match-related physical performance, emphasizing the practical relevance of this assessment for referee conditioning (Castagna et al., 2007).

Recovery capacity is another critical component of cardiovascular endurance, particularly in sports requiring repeated bursts of high-intensity activity. HIIT has been shown to positively influence recovery-related physiological responses, such as faster heart rate recovery following exercise and improved metabolic efficiency during rest intervals (Hazell et al., 2010). Enhanced recovery capacity allows referees to

rapidly regain physiological readiness between intense actions, thereby supporting consistent physical performance across the duration of a match.

In summary, the existing body of literature supports the effectiveness of HIIT in improving cardiovascular endurance through multiple mechanisms, including increases in VO_2 max, enhanced intermittent running performance as assessed by the Yo-Yo Test, and improved recovery capacity. These findings highlight the suitability of HIIT as a conditioning strategy for junior soccer referees, whose performance depends on sustained aerobic fitness, repeated high-intensity movement, and efficient physiological recovery.

2.8 Chapter Summary and Research Gap

2.8.1 Summary of Concepts and Previous Study Findings

This chapter has established the theoretical and empirical foundations of HIIT. The related research confirms that HIIT is a potent stimulus for improving body composition (Viana et al., 2019), developing sport-relevant muscular strength and power (Alvarez et al., 2021), and significantly enhancing cardiovascular endurance and recovery metrics critical for intermittent-sport athletes (Weston et al., 2014; Buchheit & Laursen, 2013).

2.8.2 Limitations of Previous Research

Despite the robust evidence supporting HIIT, notable limitations exist in the literature. A significant portion of studies has been conducted on homogeneous adult populations, often focusing on sedentary individuals, recreational athletes, or well-trained team-sport players (e.g., outfield soccer players) (MacInnis & Gibala, 2017). There is a paucity of longitudinal research examining the specific effects of structured HIIT protocols across different phases of a competitive season. Moreover, many studies utilize generic protocols that may not be optimized for the unique physiological and competitive demands of specific officiating roles (Weston et al., 2015).

2.8.3 The Need for Studies on Youth Soccer Referees

This review highlights a critical and underexplored niche: the application of HIIT for youth soccer referees. This population faces unique challenges; they must develop and maintain a high level of fitness comparable to players to keep pace with play, but their training is often self-directed and unsupported compared to team athletes (Weston et al., 2015). The physiological demands on referees—characterized by repeated high-intensity sprints and constant movement—make HIIT an ostensibly ideal training modality (Buchheit & Laursen, 2013). However, empirical evidence validating specific, effective, and safe HIIT protocols for enhancing the match performance and fitness development of youth referees is virtually absent, representing a significant gap in sport science research.

CHAPTER 3
RESEARCH METHOD

This chapter will discuss ethical considerations, participant characteristics, research methods and approaches, and data analysis. Methods as well as data analysis.

Research Design

This study will utilize a true experimental parallel design to examine the effects of variables such as body fat content, muscular strength, and cardiovascular endurance in a high interval training (HIIT) and control group. Participants signed a written informed consent. In addition, psychiatric complaints, such as depression and anxiety, were confirmed by a physician. If the results of the above tests were normal, they were included in this study. This study will be an experimental study using random sampling method. This study investigates the impact of High interval training on soccer referee's body composition, muscle strength and cardiovascular endurance. 30 youth referee between the ages of 18 and 20 made up the sample, which was simple random sampling divided into two groups consisting of 15 participants in the mini-trampoline exercises and 15 participants in the control group. The control group went about their normal lives while the exercise group performed 30 minutes of high interval training program at 60 to 80% of their maximum heart rate three days a week for a period of 8 weeks. One week prior to the start of the training program, participants will be assessed for their body composition, muscle strength and cardiovascular endurance and the first group will undergo a high-intensity interval training (HIIT) program, with pre-determined heart rates and training intensities per interval during most of the training; the second group will serve as a control group (CON) without any training intervention. Prior to starting exercise, participants will receive instructions on the study procedures. After 8 weeks of training, body composition, muscle strength and cardiovascular endurance fitness assessments will be repeated.

Sample Selection:

To represent the population, the G*Power programme was employed to calculate the sample size. With a power level of 0.8 and an alpha error of 0.05, a sample of 30 adolescent Soccer referees was selected for the study. This sample was divided into an experimental group and a control group, each comprising 15 participants, using simple random sampling. This grouping facilitated comparison of performance differences between groups following the intervention.

Random Sampling:

To ensure representativeness and reliability, random sampling was employed. This involved selecting 30 adolescent Soccer referees without deliberate bias, thereby minimising selection bias. This approach enhances the reliability and generalisability of findings, making them more applicable to other adolescent Soccer referees within the population.

Group ID:

The experimental group is designated as Group A, while the control group is labelled as Group B. Each referee is also individually identified within their respective group. In summary, the study population comprised junior soccer referees. Sample selection considered skill levels and health status, employing random sampling to enhance representativeness and reliability. Group identifiers were utilised to distinguish between different groups and participants. These measures contribute to ensuring the scientific validity and credibility of the research.

Inclusion Criteria

1. Age: 18–20 years old, registered referee with the Chinese Soccer Association.

2. No cardiovascular or neurological disorders.

3. Must commit to attending at least three training sessions per week for a minimum of six consecutive weeks.

Exclusion Criteria

1. Referees who have not obtained the corresponding level certificate are not allowed to participate.

2. Referees who are unwell or injured will not participate in the training.

Athletic training programs

The exercise group performed 30-minute RPE-based cyclic strength training three times weekly for eight weeks.

RPE SCALE	
1	Nothing
2	Very Easy
3	Easy
4	Comfortable
5	Somewhat Difficult
6	Difficult
7	Hard
8	Very Hard
9	Extremely Hard
10	Maximal/Exhaustion

Figure 2 RPE scale

All participants will be required to maintain their daily routines. The High-Intensity Interval Training (HIIT) group will undergo 30-minute sessions three times weekly for eight weeks, with consistent duration and energy/oxidation consumption monitored via heart rate monitoring devices to ensure experimental and training effectiveness. Participants assigned to the control group will be instructed to maintain normal daily activities throughout the study without altering their habits. Maintaining consistent daily routines and unaltered behaviors is crucial for accurately evaluating the effectiveness of the intervention. During exercise, both groups will be observed to confirm normal behavior, training at target intensity, and reaching target heart rate. Total

oxygen consumption will be measured every two weeks. The HIIT protocol in this study will be based on training intensity measurements using maximum heart rate per minute. Participants will gradually warm up on a bicycle ergometer, progressively increase intensity to elevate heart rate, reach 50% of the target heart rate (BPM) within one minute, then achieve 120-140 BPM (60-70% of maximum heart rate) within one minute, followed by 140-170 BPM (70-80% of maximum heart rate) within one minute. Each group will rest for 2 minutes. The specified heart rate levels per minute will be maintained throughout the training process.

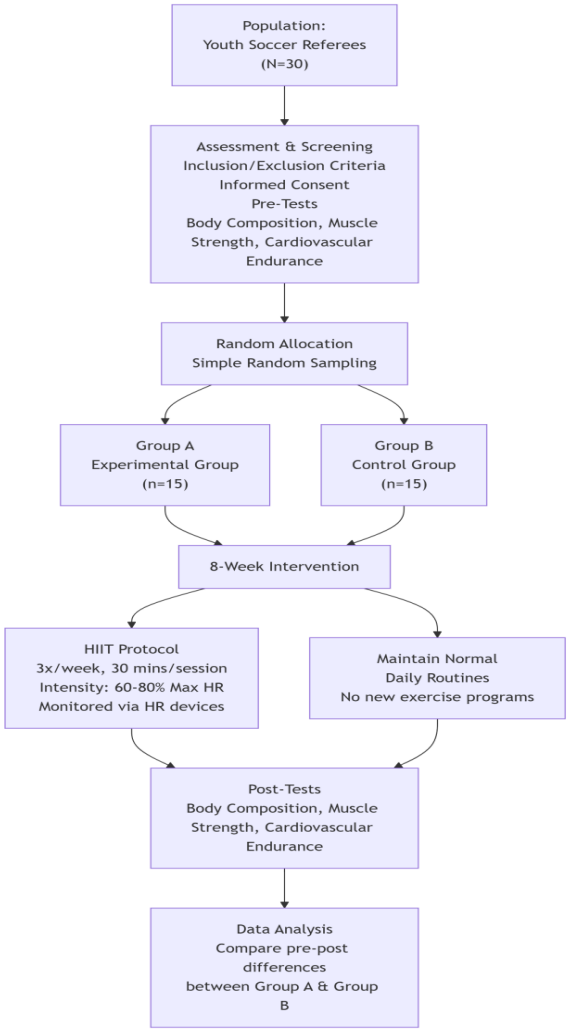

Figure 3 HIIT Intervention Flowchart for Youth Soccer Referees RPE scale

High-intensity interval training (HIIT) program includes 3 sets of aerobic exercise and 3 sets of anaerobic exercise to target the whole body, lower body, upper body and core. Each set of exercise uses body weight resistance for 60 seconds, and the rest between sets is 2 minutes.

1. Leg Raises: Participants will begin standing upright with feet hip-width apart and arms relaxed at the sides of the body in a ready position. Then begin by raising the right knee toward the chest while raising the left arm toward the chest. Participants will quickly switch to raising their left knee toward their chest while raising their right arm in front of them. They will continue to alternate knees and arms in a running motion, moving as fast as possible. The goal of the participant is to lift their knee to their chest as much as possible while maintaining a fast pace and proper posture. They will repeat this movement as many times as possible in 60 seconds. 120-140 BPM (beats per minute)(60-70% of HR max) within 1 minutes.

2. Explosive Step Up: Start by placing one foot on top of the box (or whatever you are using). Leap from your foot on top of the box and jump off the box into the air. While in the air, switch to the other foot on the box. Touch the ground with your other foot and bounce up hard, mostly from the foot on top of the box. Jump up as high as you can, exerting force from the foot on the box, and switch to landing the other foot on the box. Keep alternating until you have completed all the movements. Do not jump up in order to simply tap the box with your toes. Use your arms to help push as you jump. Swing your arms back as you land, and raise your arms up high as you jump. 140~170 BPM/min (70-80% HR max) with 1 minute .

3. Alternating Side Hops: Stand straight, feet hip-width apart, step out to the side with your left leg, bend your left knee, push your hips back, return to the starting position, and repeat the move with your right leg. 120~140 BPM/min (60-70% HR max) with 1 minute .

4.Scissor Jump: When jumping, the feet will form a scissor kick. It will often be associated with a swinging position of the feet, which is conducive to the balance of the body. The scissor kick is to make the body better balanced. The center of gravity is

in the middle of the body, and the scissor kick position can be very good to follow the trend of slight backward leaning. 140~170 BPM/min (70-80% HR max) with 1 minute.

5. Lateral Step-In: Standing on one side of a step, lift the leg on the side close to the step and ascend the step and follow the same approach coming down, performing a 30-second workout on one side of the leg, doing it as fast as possible. 120~140 BPM/min (60-70% HR max) with 1 minute.

6.Squat jump: 140~170 BPM/min (70-80% HR max) with 1 minute.Rest for 2 minutes after completing all 6 exercises. Perform 3 rounds of the circuit

Participants of the study

According to (Wang Jing Turn 2014 20) the advantages of training college student soccer referees, this study based on the Jieyang City Soccer Association of Guangdong Province in the Chinese Soccer Association system registered referees in line with the age of 18-20 years of age of the young national second and third level referees in the 83 referees from the sampling of 30 referees, the selected participants will be using a stratified random sampling technique were divided into control and experimental groups.

Research Instrument.

To ensure the accuracy and reliability of the data, specialized research tools and equipment were used in this study.

Muscle Strength Assessment

A weight machine training device was used to assess the athletes' leg extension and leg curl strength. The Bimax MT990 Leg Weight Machine was employed to evaluate the participants' ability to perform leg extension and leg flexion movements. The maximum weight (1RM) was determined and recorded in kilograms.

Body composition was assessed using a Yunmai Goodlight Mini 3S Smart Body Fat Scale, a professional and rechargeable intelligent device designed for accurate body fat assessment. The measurements included body weight, body mass

index (BMI), and body fat percentage, which were automatically recorded and displayed by the device.

Cardiovascular endurance testing

Conqueror KQ50 Standard Training Cones: Used to mark key points on the testing field for the Yo-Yo test. The cones guided participants along the correct path during the Yo-Yo test in synchronization with the test audio signal.

Steel Tape Measure: Used to accurately measure and position each cone to ensure a precise and standardized layout of the testing field.

Professional Video Camera: Used to record the entire testing process of each participant. The recorded footage was later utilized to analyze and validate movement performance during the test.

Sound System: Used to ensure that the Yo-Yo test audio signal was played clearly and consistently during each trial.

Data collection

The data collection process in this study was systematically organized to ensure accuracy, reliability, and validity of the findings. The procedures were as follows:

Pre-test Assessments

One week prior to the training intervention, baseline measurements were conducted for all participants. Assessments included body composition, muscle strength, and cardiovascular endurance. Standardized protocols and calibrated instruments were used to ensure consistency across participants.

Intervention Monitoring

Participants in the HIIT group underwent an 8-week training program, three sessions per week, with exercise intensity monitored using heart rate monitors to ensure compliance with the target heart rate zones (60–80% HRmax).

The control group was instructed to maintain their normal daily routines without altering their physical activity habits. Adherence to the program was monitored by direct observation and weekly check-ins.

Post-test Assessments

At the end of the 8-week intervention, the same assessments conducted in the pre-test phase (body composition, muscle strength, cardiovascular endurance) were repeated.

All measurements were taken under identical conditions to reduce variability and ensure comparability of pre- and post-test data.

Ethical considerations

In this study, a number of ethical principles were strictly applied to safeguard the welfare, rights and respect of all participants. Each participant or legal representative of a minor participant provided a informed consent form. They were informed in detail about the objectives of the study, the methodology, possible risks and advantages, and their right to discontinue participation at any time without repercussions. This ensured that participation at was both voluntary and based on a thorough understanding of the research. In addition, privacy and anonymity were strictly protected. All personal details and data collected throughout the study were securely stored and only accessible to members of the research team.

In addition, the research program was thoroughly evaluated and endorsed by the Institutional Ethics Committee, confirming that it meets the necessary ethical guidelines for all research, including human participants. The review process ensured that the research adhered to the principles of beneficence, non-maleficence and impartiality. The physical and psychological well-being of the participants was maintained throughout the study. Measures were taken to minimize any potential risks associated with circuit strength.

Data analysis

In this study, the collected data will be analyzed using statistical methods. Firstly, descriptive statistics will be performed on the indicators obtained from the physical fitness tests of the two groups of athletes, independent t-test: between groups after 8 weeks, paired samples t-test: pre-test-post-test within groups.

CHAPTER 4
FINDINGS

4.1 Basic information of the research object

Table 1 Basic information of the research object (X±S)

Group	N	Age (years)	Height (cm)	Weight (kg)
Experimental group	15	19.05±2.1	172.6±5.4	61.7±2.3
Control group	15	19.02±2.5	172.4±5.6	61.5±1.9

The table presents the baseline characteristics of participants in both the experimental and control groups prior to the intervention. The data indicate that the physical attributes of individuals in the two groups are generally comparable, with no significant differences observed (P>0.05). This suggests that the random selection process was effective in ensuring group equivalence at the outset of the study.

4.2 Comparison of body composition between the 8-week intervention groups

Table 2 Intra-group Comparison of Body Composition (Mean $\pm$ SD)

Group	Variable	Pre-test (Week 0)	Post-test (Week 8)	P-value
Experimental	Body Fat Percentage (%)	21.13±4.34	18.00±3.05*	< 0.05
	BMI (kg/m^2)	20.71±2.18	19.27±1.99*	< 0.05
Control	Body Fat Percentage (%)	20.93±3.47	21.20±4.06	> 0.05
	BMI (kg/m^2)	20.69±2.09	20.58±2.04	> 0.05

Table 3 Inter-group Comparison of Body Composition After 8 Weeks (Mean ± SD)

Variable	Experimental Group (n=15)	Control Group (n=15)	P-value
Body Fat Percentage (%)	18.00 ± 3.05	21.20 ± 4.06*	0.021
BMI (kg/m^2)	19.27 ± 1.99	20.58 ± 2.04	0.086

4.2.1 Comparative analysis of body fat percentage

According to Table 2, we can observe the changes in body fat percentage and BMI in the experimental and control groups before and after the intervention. At the beginning of the intervention, that is, week 0, the average body fat percentage of the experimental group was 21.133, with a standard deviation of 4.340. This indicates that the body fat percentage values of individuals in the experimental group are centered around 21.133, and the differences between individuals are relatively large. The standard deviation of 4.340 reflects this degree of dispersion. In contrast, the average body fat percentage of the control group in week 0 was 20.933, with a standard deviation of 3.474, which was slightly lower than that of the experimental group, and the data within the group were more concentrated.

After 8 weeks of intervention, the body fat percentage of the experimental group decreased significantly, with the average value dropping to 18.000 and the standard deviation decreasing to 3.047. This shows that after the intervention, not only did the body fat percentage of the experimental group decrease overall, but the individual differences within the group also decreased. This change may reflect the effectiveness of the intervention measures in reducing body fat percentage. However, the body fat percentage of the control group showed an upward trend after the intervention, with the mean value increasing to 21.200 and the standard deviation

increasing to 4.057, indicating that the difference in body fat percentage between individuals in the control group increased.

Regarding BMI, before the intervention, the experimental group had an average BMI of 20.71 with a standard deviation of 2.18, while the control group had an average BMI of 20.69 with a standard deviation of 2.09. The BMI of both groups was quite similar, with relatively large individual differences. After 8 weeks of intervention, the BMI of the experimental group decreased to 19.27, with a standard deviation of 1.99, indicating that the BMI of the experimental group not only decreased, but the individual differences within the group also reduced. The BMI of the control group decreased slightly to 20.58, with a standard deviation of 2.04, but individual differences remained relatively large.

Through statistical analysis, intra-group comparison showed that the body fat percentage and BMI of the experimental group changed significantly before and after the intervention ($p<0.05$), indicating that the intervention measures had a significant impact on the body fat percentage and BMI of the experimental group. Inter-group comparison also showed that after 8 weeks of intervention, there was a significant difference in body fat percentage and BMI between the two groups ($p<0.05$), further supporting the effect of the intervention measures. Overall, the body fat percentage and BMI of the experimental group decreased significantly after 8 weeks of intervention, while the body fat percentage of the control group increased slightly and BMI decreased slightly, highlighting the role of the intervention measures in regulating body composition.

Table 4 Intra-group Comparison of Muscle Strength (Mean ± SD)

Group	Variable	Pre-test (Week 0)	Post-test (Week 8)	P-value
Experimental	1RM Leg Extension (kg)	77.02±6.52	81.65±8.06*	< 0.05
	1RM Leg Curl (kg)	35.41±7.16	39.99±6.56*	< 0.05
Control	1RM Leg Extension (kg)	79.16±7.62	69.25±5.70	> 0.05
	1RM Leg Curl (kg)	35.64±6.46	35.37±6.83	> 0.05

Table 5 Inter-group Comparison of Muscle Strength After 8 Weeks (Mean ± SD)

Variable	Experimental Group (n=15)	Control Group (n=15)	P-value
1RM Leg Extension (kg)	81.65±8.06	69.25±5.70*	0.001
1RM Leg Curl (kg)	39.99±6.56	35.37±6.83*	0.039

4.3.1 Comparative analysis of 1RM

According to Table 5, we can observe the changes in 1RM Leg Extension and Leg Curl of the experimental group and the control group before and after the intervention. At the beginning of the intervention, which is week 0, the average 1RM for Leg Extension in the experimental group was 77.022 kg, with a standard deviation of ±6.521. This indicates that the 1RM values for individuals in the experimental group were centered around 77.022 kg, with relatively large individual differences, as reflected by the standard deviation of ±6.521. In contrast, the average 1RM for Leg Extension in the control group was 79.161 kg, with a standard deviation of ±7.624, which was slightly higher than that of the experimental group, with similar variability within the group.

After 8 weeks of intervention, the experimental group showed a significant increase in 1RM for Leg Extension, with the average value increasing to 81.649 kg, and the standard deviation decreasing to ±8.059. This indicates that not only did the 1RM of the experimental group increase overall, but individual differences within the group also decreased. This change likely reflects the effectiveness of the intervention measures in improving the strength for Leg Extension. However, the 1RM for Leg Extension in the control group remained relatively stable, with the average value changing slightly to 69.247 kg, and the standard deviation decreased to ±5.697, showing that the control group had little change in strength.

Regarding 1RM for Leg Curl, the experimental group started with an average of 35.412 kg at week 0, with a standard deviation of ±7.16. After 8 weeks of intervention, the average 1RM for Leg Curl increased significantly to 39.986±6.561kg, with a standard deviation of ±6.561. This shows a notable improvement in strength and a decrease in variability within the group, highlighting the positive impact of the intervention measures. In contrast, the control group had a slight change in 1RM for Leg Curl, with the average value remaining almost the same at 35.368 kg at week 8, and the standard deviation slightly decreasing to ±6.832.

Through statistical analysis, intra-group comparison showed that the 1RM for both Leg Extension and Leg Curl in the experimental group changed significantly before and after the intervention ($p<0.05$), indicating that the intervention measures had a significant impact on strength improvement. Inter-group comparison also revealed a significant difference in the 1RM for Leg Extension and Leg Curl between the two groups after 8 weeks of intervention ($p<0.05$), further supporting the effectiveness of the intervention measures. Overall, the experimental group showed significant improvements in strength for both Leg Extension and Leg Curl after 8 weeks of intervention, while the control group showed little to no change, highlighting the effectiveness of the intervention in enhancing strength and physical performance

4.4 Comparison of cardiovascular endurance between 8-week intervention groups

Table 6 Intra-group Comparison of Cardiovascular Endurance (Mean ± SD)

Group	Variable	Pre-test (Week 0)	Post-test (Week 8)	P-value
Experimental	Yo-Yo Time (min)	17.98±1.82	19.23±0.46*	< 0.05
	Yo-Yo Distance (m)	1798.0±182.3	1923.3±45.8*	< 0.05
	VO2 Max (ml/kg/min)	51.50±1.82	52.56±0.46*	< 0.05
Control	Yo-Yo Time (min)	17.83±1.65	17.68±1.53	> 0.05
	Yo-Yo Distance (m)	1783.3±165.3	1768.0±152.8	> 0.05
	VO2 Max (ml/kg/min)	51.38±1.65	51.25±1.53	> 0.05

Table 7 Inter-group Comparison of Cardiovascular Endurance After 8 Weeks (Mean ± SD)

Variable	Experimental Group (n=15)	Control Group (n=15)	P-value
Yo-Yo Time (min)	19.23±0.46	17.68±1.53*	< 0.001
Yo-Yo Distance (m)	1923.3±45.8	1768.0±152.8*	< 0.001
VO2 Max (ml/kg/min)	52.56±0.46	51.25±1.53*	0.004

4.4.1 Comparative analysis of cardiovascular endurance

Table 7 shows the changes in cardiovascular endurance in the experimental group and the control group before and after the intervention. At the

beginning of the intervention, the mean YOYO-TEST of the experimental group was 51.5032 ±1.823, and the standard deviation was ±1.823, which showed that the cardiovascular endurance test scores of the experimental group were centered around 51.5032 and there were certain differences between individuals in the group. The mean YOYO-TEST of the control group in week 0 was 51.3797 ±1.653, and the standard deviation was ±1.653. The cardiovascular endurance level was similar to that of the experimental group, and the degree of difference within the group was also relatively close.

After 8 weeks of intervention, the VO2 MAX scores of the experimental group improved significantly, with the mean value reaching 52.5557 ±0.458 and the standard deviation decreasing to ±0.458, which showed that the intervention effectively improved the cardiovascular endurance of the experimental group and made the scores within the group more concentrated. This significant improvement shows that the intervention measures have a positive effect on improving cardiovascular endurance. However, the VO2 MAX scores of the control group decreased slightly after the intervention, with the mean value becoming 51.2512 ±1.528 and the standard deviation being ±1.528, indicating that cardiovascular endurance was not improved.

Statistical analysis showed that the cardiovascular endurance of the experimental group changed significantly before and after the intervention ($p<0.05$), indicating that the intervention had a significant effect on improving cardiovascular endurance. Inter-group comparison also showed that after 8 weeks of intervention, there was a significant difference in cardiovascular endurance between the two groups ($p<0.05$), further verifying the effect of the intervention measures. Overall, the cardiovascular endurance of the experimental group was significantly enhanced after 8 weeks of intervention, while there was no significant improvement in the control group, which clearly demonstrated the effectiveness of the intervention measures in improving cardiovascular endurance.

CHAPTER 5
CONCLUSION AND DISCUSSION

This eight-week study investigated the effects of high-intensity interval training (HIIT) on the physical fitness of young Soccer referees. The findings reveal that the experimental group undergoing HIIT experienced significant improvements compared to the control group. Specifically, the training led to a notable decrease in body fat percentage, a substantial increase in muscle strength (1RM), and enhanced cardiovascular endurance as measured by the YOYO test. These results underscore that HIIT is an efficient and effective training model for enhancing the key physical attributes essential for Soccer referees, aligning well with the sport's demands.

5.1 The Influence of cyclic strength Training on the Body composition of youth Soccer referees

5.1.1 The influence of cyclic strength training on body fat percentage

The research results showed that after 8 weeks of high-intensity interval training, the body fat percentage of adolescent Soccer referees in the experimental group decreased significantly, from 21.133±4.340 in week 0 to 18.000±3.047 in week 8, a decrease of 3.133±1.293, with a decrease percentage of 14.8%. The difference was statistically significant ($p<0.05$). This significant decline indicates that high-intensity interval training can effectively reduce the body fat percentage of young Soccer referees and improve their body composition. This improvement is of great positive significance for enhancing the athletic performance of young Soccer referees and maintaining their physical health.

The body fat percentage of the control group showed different changing trends, increasing from 20.933±3.474 in week 0 to 21.200±4.057 in week 8, an increase of 0.267±0.583, with an increase percentage of 1.3%. Although the increase is relatively small, this change also suggests that in the absence of effective intervention, the body fat percentage of youth Soccer referees may tend to rise over time. There was no significant difference in body fat percentage between the experimental group and the

control group at the initial stage of the experiment, which provided a good basis for us to compare the effects of the two different intervention methods. After 8 weeks of intervention, the body fat percentage of the experimental group was significantly lower than that of the control group, and the difference between the two groups was statistically significant ($p<0.05$), which further confirmed the effectiveness of high-intensity interval training in reducing the body fat percentage of teenage Soccer referees.

The results of the study indicate that after 8 weeks of high-intensity interval training, the BMI of the experimental group of young Soccer referees significantly decreased, from 20.71±2.18 in week 0 to 19.27±1.99 in week 8, a decrease of 1.44±2.18, with a reduction percentage of 6.96%. This change is statistically significant ($p<0.05$). This significant reduction suggests that high-intensity interval training can effectively reduce the BMI of young Soccer referees, improve their body composition, and contribute to enhanced athletic performance and overall health.

The BMI of the control group showed smaller changes, increasing from 20.69±2.09 in week 0 to 20.58±2.04 in week 8, a change of 0.11±0.18, with an increase percentage of 0.53%. Although the change is relatively small, it indicates that in the absence of effective intervention, the BMI of young Soccer referees may tend to increase slightly over time. At the beginning of the experiment, there was no significant difference in BMI between the experimental group and the control group, which provided a good basis for comparing the effects of the two intervention methods. After 8 weeks of intervention, the BMI of the experimental group was significantly lower than that of the control group, and the difference between the two groups was statistically significant ($p<0.05$), further validating the effectiveness of high-intensity interval training in reducing the BMI of young Soccer referees.

HIIT is an efficient training method that combines high-intensity exercise with a short recovery period, which can promote the adaptation of the muscles and cardiovascular system. The uniqueness of this training mode lies in its ability to produce significant training effects in a relatively short period of time. It is an ideal training

method for young Soccer referees with relatively tight schedules. In futsal matches, flexibility and fast movement are of vital importance, and a lower body fat percentage is directly related to the improvement of these athletic abilities. Excessively high body fat percentage will increase the burden on the body, reduce the flexibility and agility of movement, thereby affecting the running and positioning of youth Soccer referees during the game, and further influencing their officiating skills. The structured nature of the HIIT training program can gradually overload the body through specific exercises, thereby leading to these positive results. This progressive overload is essential for stimulating fat breakdown and reducing body fat percentage.

A systematic review highlighted that HIIT improves both mental and physical fitness, suggesting a holistic benefit that may include fat loss(Zhang et al., 2024).The effectiveness of HIIT in reducing body fat is supported by meta-analyses indicating its role in decreasing total, abdominal, and visceral fat mass(Andreato et al., 2018).Speed-based HIIT has shown superior results in improving distance covered in fitness tests compared to traditional methods, indicating its effectiveness in enhancing performance and potentially reducing body fat(Zhang et al., 2023).

From a physiological perspective, the decrease in body fat percentage observed in the experimental group is the result of the combined effect of multiple physiological mechanisms. These mechanisms work in synergy with each other, jointly promoting the breakdown and utilization of fat, thereby achieving a reduction in body fat percentage.

1.Accelerated energy metabolism: HIIT activates multiple energy systems with its "high-intensity + intermittent recovery" training mode, including the phosphogen system, glycolytic system, and aerobic system. HIIT training induces the "afterburn effect" (EPOC) (excessive oxygen consumption after exercise) through intermittent high-intensity stimulation, enabling the body to maintain a high metabolic state for several hours or even a day after the training ends, promoting an increase in fat oxidation rate and basal energy consumption. This "afterburn effect" means that even after the training is over, the body will continue to consume energy, which is of great

significance for reducing fat storage. High-intensity exercise can significantly increase energy expenditure, especially during the recovery period after exercise. The body needs to consume a large amount of energy to return to its pre-exercise state, including restoring glycogen reserves in muscles, removing lactic acid from the blood, and regulating hormone levels, etc. These physiological processes all require energy consumption, thereby helping to reduce the accumulation of fat.

2.Hormone secretion regulation: HIIT training induces changes in the hormone environment (such as upregulation of growth hormone and adrenaline, and increased insulin sensitivity), which also provides physiological support for fat mobilization. High-intensity exercise can increase the secretion levels of adrenaline, norepinephrine, testosterone and growth hormone. Changes in these hormones can enhance fat mobilization, promote fat oxidation and improve fat-burning efficiency. Growth hormone is an important fat-breaking hormone. It can promote the breakdown of triglycerides in fat cells into fatty acids and glycerol, thus enabling fatty acids to be utilized by muscle tissue. Adrenaline and norepinephrine also have similar effects. They can activate lipase and accelerate the breakdown of fat. In addition, HIIT training can also enhance insulin sensitivity, which helps the body make better use of glucose and reduces the possibility of its conversion into fat for storage.

3.Promoting lipase activity: Research shows that HIIT can enhance the activity of lipoprotein lipase, thereby accelerating the metabolic process of triglycerides and helping to reduce fat accumulation. Lipoprotein lipase is an enzyme existing on the surface of vascular endothelial cells. It can break down triglycerides in the blood, enabling fatty acids to be absorbed and utilized by tissues. By enhancing the activity of lipoprotein lipase, HIIT training can promote fat metabolism and reduce fat storage in the body.

These mechanisms are particularly effective for teenagers. Teenagers have a relatively high metabolic rate, grow and develop rapidly, and have a large energy demand. If they are supplemented with scientific training, the fat mobilization efficiency will be stronger and the adaptation speed will be faster. Therefore, HIIT training can

more effectively help teenagers reduce body fat and improve body composition. For young referees, appropriately reducing body fat can enhance the flexibility and reaction efficiency of movements on the field, reduce the burden on the body, and thereby improve the accuracy and fairness of refereeing. At the same time, a lower body fat percentage can also reduce the risk of sports injuries, enabling young referees to perform their refereeing duties better and prolong their careers. Therefore, HIIT has a natural advantage in optimizing body composition for this age group.

Furthermore, it is worth noting that a reduction in body fat percentage is not only beneficial for athletic performance but also crucial for overall health. Excessively high body fat percentage is closely related to the occurrence of various chronic diseases, such as cardiovascular diseases, diabetes, and hypertension. Reducing body fat percentage through HIIT training can effectively prevent the occurrence of these chronic diseases and promote the physical and mental health development of young referees.

In conclusion, the results of this study indicate that HIIT training can significantly reduce the body fat percentage of young Soccer referees, which is of great significance for improving their athletic performance, maintaining physical health and promoting their career development. Future research can further explore the impact of HIIT training on the body fat percentage of Soccer referees of different age groups and different refereeing levels, as well as the effect of the combined application of HIIT training with other training methods, thereby providing more comprehensive guidance for the physical training of adolescent Soccer referees.

5.2 The Influence of cyclic strength Training on the muscle strength of junior Soccer referees

5.2.1 The influence of cyclic strength training on 1RM

The results of the study indicate that after 8 weeks of high-intensity interval training, the 1RM for Leg Extension in the experimental group of young Soccer referees significantly increased, from 77.022±6.521 kg in week 0 to 81.649±8.059 kg in week 8, an increase of 4.627±3.538 kg, with a 6.0% improvement. This change is statistically

significant ($p<0.05$). This significant improvement suggests that high-intensity interval training can effectively enhance the muscle strength of young Soccer referees, especially in Leg Extension, thereby contributing to improved athletic performance.

The 1RM for Leg Extension in the control group showed smaller changes, decreasing from 79.161±7.624 kg in week 0 to 69.247±5.697 kg in week 8, a reduction of 9.914±9.089 kg, with a -12.5% decrease. Although the reduction is relatively small, this change indicates that, in the absence of effective intervention, the muscle strength of young Soccer referees may gradually decline over time. At the start of the experiment, there was no significant difference in Leg Extension 1RM between the experimental and control groups, which provided a good basis for comparing the effects of the two intervention methods. After 8 weeks of intervention, the 1RM for Leg Extension in the experimental group was significantly higher than in the control group, and the difference between the two groups was statistically significant ($p<0.05$), further validating the effectiveness of high-intensity interval training in enhancing the leg muscle strength of young Soccer referees.

Regarding the 1RM for Leg Curl, the experimental group increased from 35.412±7.16 kg in week 0 to 39.986±6.561 kg in week 8, an increase of 4.574±9.72 kg, with a 12.9% improvement, which is also statistically significant ($p<0.05$). This indicates that HIIT training has a very significant effect on improving leg muscle strength. On the other hand, the 1RM for Leg Curl in the control group showed almost no change, increasing slightly from 35.636±6.461 kg in week 0 to 35.368±6.832 kg in week 8, an increase of -0.268±9.41 kg, with a -0.75% improvement. Although the change is small, it still shows that, without effective intervention, muscle strength may slightly decline.

In conclusion, after 8 weeks of intervention, the experimental group not only showed significant strength improvements in both Leg Extension and Leg Curl 1RM tests but also demonstrated effective enhancement in muscle strength and athletic performance compared to the control group. This further proves the significant effect of high-intensity interval training in improving the muscle strength of young Soccer referees. The improvement of muscle strength mainly stems from the adaptation of the

nervous system and the physiological changes of the muscles themselves. Although HIIT is not a traditional resistance training, the large load and rapid switching movement stimulation applied in a short period of time can effectively enhance neuromuscular coordination ability, motor unit recruitment efficiency and nerve conduction velocity. The improvement of neuromuscular coordination ability means that muscles can work more coordinately during movement and generate greater force. The improvement of the recruitment efficiency of movement units means that more muscle fibers can participate in the contraction during the movement process, thereby generating greater force. The increase in nerve conduction velocity means that nerve signals can be transmitted to the muscles more quickly, causing the muscles to contract more rapidly.

The significant improvement of 1RM in the experimental group proved the effectiveness of HIIT in strength development, especially by activating the main muscle groups of the lower limbs (such as the quadriceps, hamstrings, triceps, etc.) through explosive movements (such as in-place jumps and ground sprints), which enhanced the maximum output capacity within a unit of time. These explosive movements require the muscles to generate a great deal of strength in a short period of time, thereby effectively stimulating muscle growth and enhancing strength. More importantly, HIIT maintains the fun and diversity of training, which helps to balance exercise motivation and training compliance during the strength development process, making the training more acceptable and consistent. It is an ideal basic strength development method for teenagers.

The test results of 1RM showed that the muscle strength level of the experimental group increased from 77.022 kg to 81.649 kg, with an increase of 4.627 kg, while the change in the control group was very small, further highlighting the importance of training intervention. This indicates that HIIT training can effectively enhance the strength level of muscles, enabling young Soccer referees to better complete various technical movements on the field.

HIIT involves short periods of high-intensity exercise followed by short breaks or low-intensity recoveries. This training mode is particularly effective for enhancing aerobic and anaerobic capacity, which is crucial for strength and power (Hoshino et al., 2016) (Eigendorf et al., 2018). The adaptations caused by HIIT are not limited to metabolic improvements, but also include structural and functional changes in skeletal muscle, such as hypertrophy and changes in muscle fiber composition (Sterczala et al., 2024) (Skelly et al., 2021). Due to its high-strength characteristics, HIIT mainly recruits type II fibers. This proliferation is associated with an increase in glycolytic flux and lactic acid production, which is crucial for generating rapid energy in a short all-out effort (Tamura et al., 2024) (Zagatto et al., 2021). HIIT enhances neuromuscular activation, allowing for greater strength to be generated with maximum effort (Eigendorf et al., 2018)

The fundamental mechanism of muscle strength improvement is mainly reflected in the following aspects:

1.Neural adaptation: Repeating high-intensity movements activates high-threshold motor units, enhancing the speed and coordination of motor unit recruitment, which is an early key factor for strength improvement. This means that through HIIT training, teenage Soccer referees can mobilize more muscle fibers to participate in the movement more quickly, thereby generating greater strength.

2.Tendon and connective tissue adaptation: HIIT movements often involve rapid impact and explosive force output, which can enhance the rigidity of the musculotendon complex and improve the efficiency of force transmission. The increased stiffness of the muscle-tendon complex means that the force generated by the muscles can be transmitted to the bones more effectively, thereby improving the efficiency of movement.

3.Muscle fiber type conversion: Some studies have shown that HIIT can induce an increase in the number of type IIa (intermediate type) muscle fibers. These muscle fibers possess both strength and endurance characteristics and are conducive to enhancing compound abilities. This means that through HIIT training, young Soccer

referees can not only enhance their muscle strength but also improve the endurance level of their muscles, thereby better adapting to the demands of the game.

For young Soccer referees, muscle strength is directly related to their ability to start quickly, brake, change direction, etc. A good foundation of muscle strength is an important guarantee for referees to move efficiently on the field. In a Soccer match, referees need to frequently perform actions such as fast running, sudden stops, and changing direction, all of which require good muscle strength as support. If the muscle strength is insufficient, the referee is prone to fatigue, which affects the accuracy of the judgment and the timeliness of the movement. Therefore, enhancing muscle strength through HIIT training is of great significance for improving the refereeing skills of youth Soccer referees.

In addition, the improvement of muscle strength also helps prevent sports injuries. Strong muscles can better protect joints and ligaments and reduce the risk of injury during sports. This is particularly important for Soccer referees who need to stand and run for a long time.

In conclusion, the results of this study indicate that HIIT training can significantly enhance the muscle strength of young Soccer referees, which is of great significance for improving their athletic performance, preventing sports injuries and prolonging their careers. Future research can further explore the strength enhancement effect of HIIT training on different muscle groups, as well as the effect of the combined application of HIIT training with other strength training methods, thereby providing more comprehensive guidance for the strength training of youth Soccer referees.

5.3 The Influence of cyclic strength Training on the cardiovascular endurance of junior Soccer referees

5.3.1 The Influence of cyclic strength Training on YOYO TEST

The YOYO-TEST VO2 MAX(ml/kg/min) of the experimental group increased from 51.5032 ±1.823 in week 0 to 52.5557 ±0.458 in week 8, an increase of 1.0525 ±1.365, with an increase percentage of 2.0%, which was a significant improvement ($p<0.05$).S This significant improvement indicates that high-intensity interval training can

effectively enhance the cardiovascular endurance of young Soccer referees. Cardiovascular endurance refers to the ability of the human body to maintain exercise intensity and resist fatigue over a long period of time. For Soccer referees, good cardiovascular endurance can ensure that they maintain a good competitive state throughout the entire game and reduce the impact of fatigue on judgment and running ability.

The YOYO-TEST VO2 MAX(ml/kg/min) of the control group decreased from 51.3797 ±1.653 in week 0 to 51.2512 ±1.528 in week 8, a decrease of 0.1285 ±0.125, with a decrease percentage of 0.2%. Although the extent of the decline is relatively small, it still suggests that cardiovascular endurance may decline over time in the absence of effective intervention. There was no significant difference in the VO2 MAX(ml/kg/min) scores between the experimental group and the control group at the initial stage of the experiment, which provided a good basis for us to compare the effects of the two different intervention methods. After 8 weeks of intervention, the performance of the experimental group was significantly higher than that of the control group, and the difference between the two groups was statistically significant ($p<0.05$), which further confirmed the positive role of HIIT in improving cardiovascular endurance.

Furthermore, HIIT enhances the lactate clearance capacity and the efficiency of oxygen debt repayment, optimizes the anaerobic-aerobic conversion process, and enables individuals to recover more quickly after high-intensity exercise. Lactic acid is a metabolic product produced by muscles during anaerobic exercise. Its accumulation can lead to muscle fatigue and soreness. Improving the ability to clear lactic acid means that muscles can eliminate lactic acid more quickly, thereby delaying the occurrence of fatigue. Oxygen debt refers to the amount of oxygen that the body needs to consume after exercise to return to the state before exercise. Improving the efficiency of oxygen debt repayment means that the body can recover to the state before exercise more quickly, and thus can carry out the next exercise more quickly. This ability is highly adaptable to the actual workload of Soccer referees who frequently start and stop at high intensity during matches. In a Soccer match, referees need to

frequently perform fast running, sudden stops, changes of direction and other actions, all of which require good cardiovascular endurance as support. If the cardiovascular endurance is insufficient, the referee is prone to fatigue, which affects the accuracy of judgment and the timeliness of positioning. Therefore, improving cardiovascular endurance through HIIT training is of great significance for enhancing the officiating level of youth Soccer referees.

The improvement results of YOYO-TEST highlight the multi-level stimulating effect of HIIT on the cardiopulmonary system. This test item emphasizes "intermittent recovery", and HIIT is precisely a training form centered on alternating high-intensity and recovery phases. This form of training can effectively enhance the function of the cardiopulmonary system, thereby improving cardiovascular endurance. During the training period, the heart rate frequently reaches 85-95%HRmax, triggering a series of reactions such as enhanced myocardial function, increased pulmonary ventilation, and hemodynamic adaptation, which is conducive to the increase of VO_2max and the strengthening of the circulatory system. VO_2max refers to the maximum amount of oxygen that the body can take in during aerobic exercise, and it is an important indicator for measuring cardiopulmonary function. Through HIIT training, VO_2max can be effectively increased, thereby enhancing cardiovascular endurance.

HIIT has been linked to enhanced cardiovascular fitness, with referees achieving heart rates of 86-88% of their maximum during training sessions(Weston et al., 2004).

The glycolytic pathway is the main source of energy for high-intensity and short-time work. HIIT stimulates glycolysis by increasing the activities of key enzymes such as hexokinase, phosphofructokinase and lactate dehydrogenase (Tamura et al., 2024) (Akmali & Saghebjoo, 2020). HIIT enhances lactic acid metabolism by up-regulating monocarboxylate transporter (MCT), promoting lactic acid transport and its utilization as an energy substrate (Tamura et al., 2024) (Zagatto et al., 2021).

HIIT promotes an increase in moderate air volume (SV) and cardiac output (CO), which is crucial for delivering oxygen to muscles during high-intensity exercise. Studies show that HIIT can significantly improve SV and CO. Thereby increasing the maximum carbon dioxide level (Astorino et al., 2022) (Astorino et al., 2022) (Astorino et al., 2022) (o'g'li, 2022). HIIT enhances ventilation efficiency, as evidenced by the reduction in the slope of the carbon dioxide ventilation equivalent (VE/VCO^2). This improvement can enhance the gas exchange efficiency during exercise, which may contribute to a faster recovery speed (Okamura et al., 2024) (Okamura et al., 2023). HIIT can increase the activity of the parasympathetic nervous system, which is reflected in the improvement of HRV parameters such as high-frequency (HF) power and continuous root mean square difference (RMSSD). These changes are associated with a faster heart rate recovery after exercise (Carrasco-Poyatos et al., 2023) (Alansare et al., 2018). Although central cardiovascular adaptations (such as increased carbon monoxide) play a role, HIIT can also improve peripheral factors, such as the density of capillaries and mitochondria in skeletal muscle. These changes enhanced the body's ability to utilize oxygen at the tissue level and further increased the maximum VO^2(Astorino et al., 2022) (o'g'li, 2022). The intermittent nature of HIIT mimics the demands of high-intensity exercise, thereby leading to specific adaptations of the cardiovascular system. For instance, HIIT has been proven to increase ventricular wall thickness and improve left ventricular function, thereby supporting increased oxygen delivery during exercise (Ito et al., 2024) (O 'driscoll et al., 2018).

Its influence mechanism covers the following aspects:

1.Increased capacity of the cardiopulmonary system: Training promotes structural adaptation of the heart, such as enlarged ventricles, increased stroke volume, and enhanced oxygen supply capacity. An enlarged ventricle means that the heart can pump more blood with each contraction, thereby enhancing the oxygen supply capacity. Stroke volume refers to the amount of blood pumped out by the heart with each contraction. An increase in it also indicates an enhanced oxygen supply capacity of the heart.

2.Enhanced oxygen metabolism capacity: HIIT promotes the increase of mitochondrial density and oxidase activity in skeletal muscle, thereby improving the oxygen utilization efficiency per unit time. Mitochondria are the "energy factories" within cells, responsible for converting oxygen and nutrients into energy. Increasing the density of mitochondria and the activity of oxidase means that muscles can utilize oxygen more effectively, thereby enhancing athletic capacity.

3.Enhanced lactic acid tolerance: Repeated high-intensity stimulation enhances the body's tolerance to a high lactic acid environment, delaying the onset of fatigue. This means that through HIIT training, muscles can better adapt to a high-lactate environment, thereby delaying the onset of fatigue.

4.Structural similarity with the test item: YOYO-TEST is essentially a "high-intensity - recovery - high-intensity" model, which is highly similar to the structure of HIIT. Therefore, the effect after training has specific transfer. This means that HIIT training can effectively improve the performance in the YOYO-TEST because the movement patterns of the two are very similar.

Cardiovascular (cardiopulmonary) endurance function is the core basis for referees to move stably throughout the game. A high level of interval endurance will significantly extend their refereeing stability and decision-making quality. In a Soccer match, referees need to run for a long time and recover quickly after high-intensity running in order to make accurate judgments. Good cardiovascular endurance can ensure that referees maintain a good competitive state throughout the entire game, thereby improving the accuracy and fairness of their officiating.

In addition, the improvement of cardiovascular endurance also helps prevent the occurrence of cardiovascular diseases. Long-term HIIT training can improve the function of the cardiovascular system and reduce the risk of cardiovascular diseases. This is particularly important for Soccer referees who need to stand and run for a long time.

In conclusion, the results of this study indicate that HIIT training can significantly enhance the cardiovascular endurance of young Soccer referees, which is of great significance for improving their athletic performance, maintaining physical health and promoting their career development. Future research could further explore the impact of HIIT training on the cardiovascular endurance of Soccer referees of different ages and refereeing levels, as well as the effect of the combined application of HIIT training with other endurance training methods, thereby providing more comprehensive guidance for the endurance training of young Soccer referees.

Conclusion

Through an eight-week intervention of high-intensity interval training and the tracking analysis of three key indicators, namely body fat percentage, 1RM and YOYO-TEST, the following conclusions were drawn in this study:

1.HIIT can significantly improve body composition and reduce the body fat percentage of youth Soccer referees: The body fat percentage of the experimental group decreased significantly ($p<0.05$), indicating that HIIT can effectively promote fat metabolism and reduce fat storage, which is helpful for referees to maintain good posture and exercise efficiency. It shows rapid, stable and controllable fat regulation ability and is suitable for the training needs during the body composition optimization period.

2.HIIT effectively enhances muscle strength: The 1RM of the experimental group was significantly increased ($p<0.05$). The combined stimulation of the nervous system and the muscular system during training effectively enhanced the maximum output capacity, mainly relying on the activation of the nervous system and explosive power stimulation to achieve strength growth without additional equipment.

3.HIIT significantly enhances cardiovascular endurance: The YOYO-TEST score significantly increased ($p<0.05$), demonstrating the multiple strengthening effects of HIIT on aerobic endurance, lactate threshold, and the oxygen metabolism system. By enhancing VO_2max, lactate metabolism capacity, and the regulatory function of the cardiovascular system, it provides a guarantee for physical reserve in competitions.

4.The HIIT training structure is highly compatible with the sports characteristics of Soccer referees: The intermittent, diverse and high-intensity features are highly consistent with the physical demands of frequent starts, changes of direction and sudden stops in Soccer referees' matches, which is an important way to optimize referee training.

5.HIIT training has advantages such as scientific structure, flexible methods and strong adaptability, and is particularly suitable for the group of Soccer referees who have limited time but high physical requirements.

In conclusion, high-intensity interval training is an efficient, scientific and suitable training model for improving the physical fitness of young Soccer referees. It can significantly optimize the body composition, strength level and cardiopulmonary function of young Soccer referees in a short period of time. It is recommended to promote and apply it as regular training content, providing a reliable path for the physical fitness cultivation of future young referee talents.

Recommendations of Future Studies

Based on the analysis results of this study and the observations during the training intervention process, the following suggestions are hereby put forward, with the aim of providing theoretical basis and practical guidance for the physical fitness training, training mode construction and future research of youth Soccer referees.

Expand the sample size: Future studies can expand the sample size, increase the groups of referees of different age groups, gender differences, and years of referees' experience, and attempt to introduce more abundant physiological and biochemical indicators (such as blood lactate, HRV, muscle oxygen monitoring, etc.) to achieve a comprehensive interpretation from macroscopic manifestations to microscopic mechanisms. The size of the sample will affect the representativeness of the research results. A larger sample size can improve the universality of the research results. Meanwhile, the introduction of more abundant physiological and biochemical indicators can provide a more comprehensive understanding of the influence mechanism of HIIT training on the physical functions of teenage Soccer referees.

1. Explore different training programs: In the future, we can try different HIIT training programs (such as the number of sets and frequency) to explore the best training prescription. Different HIIT training programs may produce different training effects. Therefore, exploring the best training program is crucial for improving the training effect.

2 . Extend the research period: The research period is 8 weeks. It is recommended to extend the research period to explore the long-term effects of cyclic strength training. A longer research period can evaluate the long-term impact of HIIT training on the physical functions of teenage Soccer referees more comprehensively, thereby providing a basis for formulating long-term training plans.

3. Integrate physiological and biochemical indicators: Future research can integrate various physiological and biochemical indicators to deeply explore the mechanism by which circular strength training improves athletic performance. It is recommended that future research introduce biochemical indicators (such as heart rate variability and lactic acid concentration) for in-depth mechanism verification. Combined with physiological and biochemical indicators, the impact of HIIT training on the physical functions of adolescent Soccer referees can be evaluated more objectively, and its mechanism of action can be explored in depth.

4. In light of actual match situations: It is suggested that the research results be combined with the actual match situations to more directly assess the impact of HIIT training on the refereeing skills of youth Soccer referees, thereby enhancing the practicality of the research.

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APPENDIX

APPENDIX A

The High Intensity Interval Training program consists of three sets of aerobic and three sets of anaerobic exercises targeting the total body, lower body, upper body and core, utilizing bodyweight resistance for 60 seconds each exercise and 2 minutes of rest between sets.

Leg Raises

1. Leg Raises: Participants will begin standing upright with feet hip-width apart and arms relaxed at the sides of the body in a ready position. Then begin by raising the right knee toward the chest while raising the left arm toward the chest. Participants will quickly switch to raising their left knee toward their chest while raising their right arm in front of them. They will continue to alternate knees and arms in a running motion, moving as fast as possible. The goal of the participant is to lift their knee to their chest as much as possible while maintaining a fast pace and proper posture. They will repeat this movement as many times as possible in 60 seconds. 120-140 BPM (beats per minute)(60-70% of HR max) within 1 minutes.

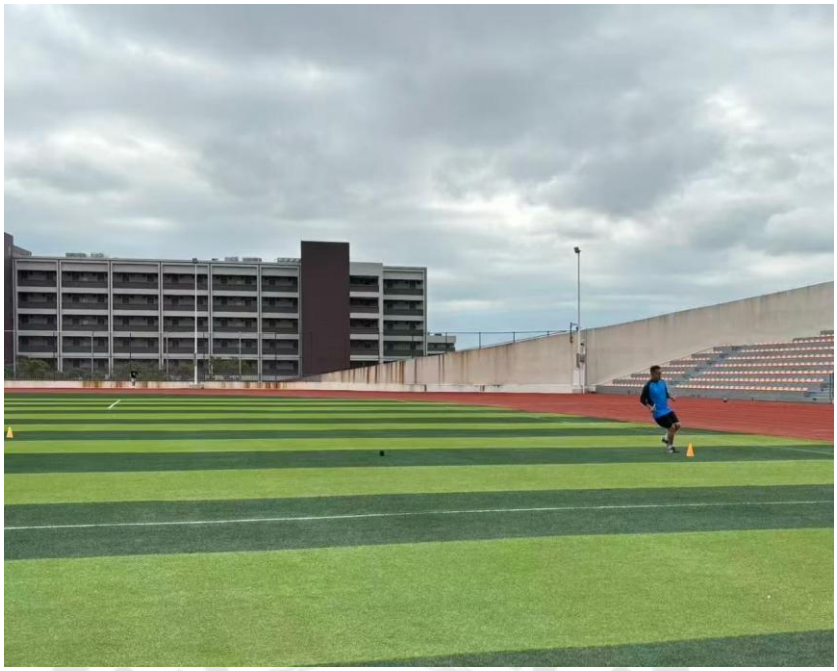

Figure 1 Explosive Step Up

2. Explosive Step Up: Start by placing one foot on top of the box (or whatever you are using). Leap from your foot on top of the box and jump off the box into the air. While in the air, switch to the other foot on the box. Touch the ground with your other foot and bounce up hard, mostly from the foot on top of the box. Jump up as high as you can, exerting force from the foot on the box, and switch to landing the other foot on the box. Keep alternating until you have completed all the movements. Do not jump up in order to simply tap the box with your toes. Use your arms to help push as you jump. Swing your arms back as you land, and raise your arms up high as you jump. 140~170 BPM/min (70-80% HR max) with 1 minute .

3. Alternating Side Hops: Stand straight, feet hip-width apart, step out to the side with your left leg, bend your left knee, push your hips back, return to the starting position, and repeat the move with your right leg. 120~140 BPM/min (60-70% HR max) with 1 minute .

4.Scissor Jump: When jumping, the feet will form a scissor kick. It will often be associated with a swinging position of the feet, which is conducive to the balance of the body. The scissor kick is to make the body better balanced. The center of gravity is in

the middle of the body, and the scissor kick position can be very good to follow the trend of slight backward leaning. 140~170 BPM/min (70-80% HR max) with 1 minute .

5. Lateral Step-In: Standing on one side of a step, lift the leg on the side close to the step and ascend the step and follow the same approach coming down, performing a 30-second workout on one side of the leg, doing it as fast as possible. 120~140 BPM/min (60-70% HR max) with 1 minute .

6.Squat jump: 140~170 BPM/min (70-80% HR max) with 1 minute .

Rest for 2 minutes after completing all 6 exercises. Perform 3 rounds of the circuit

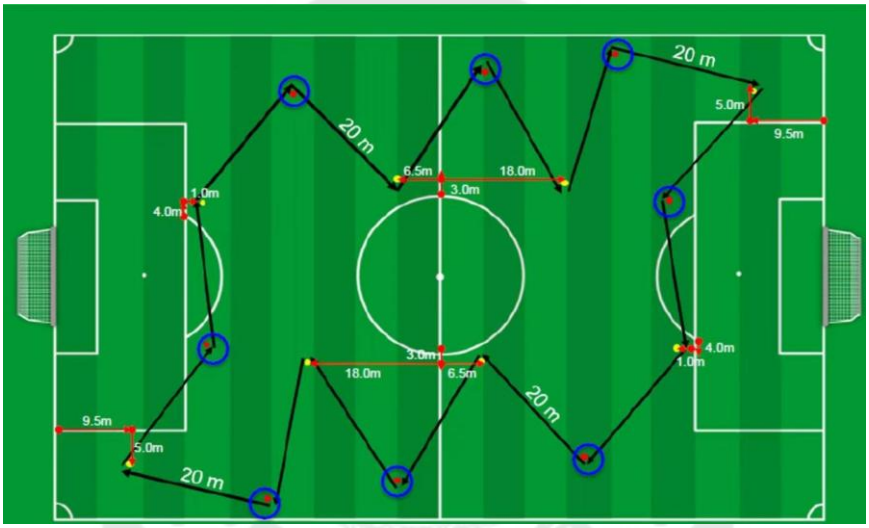

Figure 2 Schematic diagram of Yoyo test site

Note. *Schematic diagram of Yoyo test site*

https://www.thecfa.cn/qttz/20250704/36648.html

Yo-Yo Intermittent Recovery Test (Level 1) - Time Table

Speed (km/h)	10.0	12.0	13.0		13.5			14.0			
Speed Level	5	9	11		12			13			
Rep	1	1	1	2	1	2	3	1	2	3	4
Distance (m)	40	80	120	160	200	240	280	320	360	400	440
Start	00:00	00:24	00:46	01:07	01:29	01:49	02:10	02:31	02:51	03:11	03:31
Turn	00:07	00:30	00:52	01:13	01:34	01:55	02:15	02:36	02:56	03:16	03:37
Finish	00:14	00:36	00:57	01:19	01:39	02:00	02:21	02:41	03:01	03:21	03:42

Speed (km/h)	14.5								15.0							
Speed Level	14								15							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Distance (m)	480	520	560	600	640	680	720	760	800	840	880	920	960	1,000	1,040	1,080
Start	03:52	04:12	04:32	04:52	05:11	05:31	05:51	06:11	06:31	06:51	07:10	07:30	07:50	08:09	08:29	08:48
Turn	03:57	04:17	04:37	04:56	05:16	05:36	05:56	06:16	06:36	06:56	07:15	07:35	07:54	08:14	08:34	08:53
Finish	04:02	04:22	04:42	05:01	05:21	05:41	06:01	06:21	06:41	07:00	07:20	07:40	07:59	08:19	08:38	08:58

Speed (km/h)	15.5								16.0							
Speed Level	16								17							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Distance (m)	1,120	1,160	1,200	1,240	1,280	1,320	1,360	1,400	1,440	1,480	1,520	1,560	1,600	1,640	1,680	1,720
Start	09:08	09:27	09:47	10:06	10:25	10:44	11:04	11:23	11:42	12:01	12:20	12:39	12:58	13:17	13:36	13:55
Turn	09:13	09:32	09:51	10:10	10:30	10:49	11:08	11:28	11:47	12:06	12:25	12:44	13:03	13:22	13:41	14:00
Finish	09:17	09:37	09:56	10:15	10:34	10:54	11:13	11:32	11:51	12:10	12:29	12:48	13:07	13:26	13:45	14:04

Speed (km/h)	16.5								17.0							
Speed Level	18								19							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Distance (m)	1,760	1,800	1,840	1,880	1,920	1,960	2,000	2,040	2,080	2,120	2,160	2,200	2,240	2,280	2,320	2,360
Start	14:14	14:33	14:52	15:10	15:29	15:48	16:07	16:25	16:44	17:03	17:21	17:40	17:58	18:16	18:35	18:53
Turn	14:19	14:37	14:56	15:15	15:34	15:52	16:11	16:30	16:48	17:07	17:25	17:44	18:02	18:21	18:39	18:58
Finish	14:23	14:42	15:00	15:19	15:38	15:57	16:15	16:34	16:53	17:11	17:30	17:48	18:06	18:25	18:43	19:02

Speed (km/h)	17.5								18.0							
Speed Level	20								21							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Distance (m)	2,400	2,440	2,480	2,520	2,560	2,600	2,640	2,680	2,720	2,760	2,800	2,840	2,880	2,920	2,960	3,000
Start	19:12	19:30	19:48	20:07	20:25	20:43	21:01	21:20	21:38	21:56	22:14	22:32	22:50	23:08	23:26	23:44
Turn	19:16	19:34	19:52	20:11	20:29	20:47	21:05	21:24	21:42	22:00	22:18	22:36	22:54	23:12	23:30	23:48
Finish	19:20	19:38	19:57	20:15	20:33	20:51	21:10	21:28	21:46	22:04	22:22	22:40	22:58	23:16	23:34	23:52

Speed (km/h)	18.5								19.0							
Speed Level	22								23							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Distance (m)	3,040	3,080	3,120	3,160	3,200	3,240	3,280	3,320	3,360	3,400	3,440	3,480	3,520	3,560	3,600	3,640
Start	24:02	24:20	24:37	24:55	25:13	25:31	25:48	26:06	26:24	26:42	26:59	27:17	27:34	27:52	28:09	28:27
Turn	24:06	24:23	24:41	24:59	25:17	25:35	25:52	26:10	26:28	26:45	27:03	27:20	27:38	27:56	28:13	28:31
Finish	24:10	24:27	24:45	25:03	25:21	25:38	25:56	26:14	26:32	26:49	27:07	27:24	27:42	27:59	28:17	28:35

Figure 3 Schematic diagram of YOYO test grade

Note. *Schematic diagram of Yoyo test site*

https://www.thecfa.cn/qttz/20250704/36648.html

APPENDIX B

1.High Leg Raise: Participants

will begin standing upright with feet hip-width apart and arms relaxed at the sides of the body in a ready position. Then begin by raising the right knee toward the chest while raising the left arm toward the chest. Participants will quickly switch to raising their left knee toward their chest while raising their right arm in front of them.

2. Explosive Step Up

Start by placing one foot on top of the box (or whatever you are using). Leap from your foot on top of the boxand jump off the box into the air. While in the air, switch to the other foot on the box.

3. A

Stand straight, feet hip-width apart, step out to the side with your left leg, bend your left knee, push your hipsback, return to the starting position, and repeat the move with your right leg.

4.Scissor Jump

When jumping, the feet will form a scissor kick. It will often be associated with a swinging position of the feetwhich is conducive to the balance of the body. The scissor kick is to make the body better balanced. The centeiof gravity is in the middle of the body, and the scissor kick position can be very good to follow the trend ofslight backward leaning.140~170 BPM/min (70-80% HR max) with 1 minute

5. Lateral Step-In

Standing on one side of a step, lift the leg on the side close to the step and ascend the step and follow the sameapproach coming down, performing a 30-second workout on one side of the leg, doing it as fast as possible.

6.squat jump

VITA