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Effect of High-Intensity Interval Training on Muscle Strength Growth in Athletes

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Abstract: High-intensity interval training (HIIT), a highly efficient and distinctive exercise format, has sparked growing academic interest in sports performance training. This article synthesizes theoretical and applied evidence to analyze mechanisms of HIIT in neuromuscular activation, hormonal responses, muscle fiber adaptation, and metabolic pathway effects. It focuses on its effectiveness in enhancing explosive power, maximum strength, and strength endurance, while also examining the integration of HIIT with traditional resistance training, periodized programming, and personalized prescription. Scientific implementation of HIIT can effectively diversify or even replace conventional strength training, not only offering positive directional changes for strength development but also introducing innovative approaches to sports performance training practices.

Keywords: High-intensity interval training; Muscle strength; Athletes; Intervention effect

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1. Introduction

In competitive sports, athletes' muscle strength is one of the key factors affecting their performance. Strong muscle strength helps athletes perform better in competitions, whether it is explosive sprinting, jumping, or sustained force in competitive events, all of which are inseparable from a good muscle strength foundation. Traditional strength training methods can improve athletes' muscle strength to some extent, but there are some limitations, such as long training time and easy accumulation of fatigue. High-intensity interval training (HIIT), as an emerging training mode, has gradually become the focus of strength training research for athletes due to its unique characteristics of high and low intensities alternation. To study the effect of HIIT on muscle strength growth in athletes is of great practical significance for optimizing training programs and improving training effects.

2. Overview of high-intensity interval training

2.1. Definition of high-intensity interval training

High-intensity interval training is a scientific and efficient training mode, which is based on the alternation of high-intensity exercise phases and low-intensity recovery phases. In the high-intensity exercise stage, athletes need to carry out activities with very high intensity in a short period of time, which is usually close to or even reaches the maximum exercise ability limit of individuals [1]. For example, in running training, the high-intensity phase may require athletes to run at full speed for 30 seconds to a minute at close to the speed of a 100-meter sprint; in swimming training, athletes are required to swim a set distance at the fastest stroke rate and maximum strength; in cycling training, athletes ride at a very high cadence and with a lot of resistance for a certain amount of time. The low-intensity recovery phase is an integral part of the whole training process. At this stage, the athlete's body can get a certain degree of recovery, but this recovery is not completely at rest, but with low-intensity exercise to keep the body's active state, promote the discharge of metabolic waste, and partial recovery of energy, so that they can continue to carry out the next round of high-intensity exercise with more energy. For example, after a high-intensity phase of running, athletes can take a few minutes of walking or jogging; take a leisurely float or slow stroke after swimming; after the ride, ride a distance at a lower speed and easy cadence. This training method has strong flexibility and adaptability, which can be presented in various forms in different sports, whether it is track and field, ball games, water sports, or indoor fitness, etc., which can be designed and adjusted according to the characteristics of the project and the needs of athletes [2].

2.2. Characteristics of high-intensity interval training

One of the most prominent features of high-intensity interval training is its high time efficiency. In the modern fast-paced life and intense training schedule, time has become a valuable resource. HIIT can achieve a high intensity of training in a short period of time, which has a strong stimulation to the body of athletes, so as to achieve significant training effects in a limited time. Compared to traditional training methods that require a long period of time, HIIT can be done in 20 to 30 minutes or less per session, but it can put a high-intensity load on the athlete's body, stimulate the body's potential, and promote muscle strength, endurance, and cardiopulmonary function.

Compared with traditional continuous training methods, the unique pattern of HIIT alternating exercise and rest allows athletes to experience multiple challenges and recovery processes in the cardiovascular and respiratory systems in a short period of time. During high-intensity exercise, the cardiovascular system accelerates its beating to meet the body's high demand for oxygen and nutrients; the respiratory system also increases its breathing rate and depth to increase oxygen intake and carbon dioxide exhalation. During low-intensity recovery, the cardiovascular and respiratory systems have a chance to take a breather and adjust. This frequent challenge and recovery can improve the body's adaptability to these systems, enhance the health and strength of the cardiovascular system and the efficiency of the respiratory system, thus improving the athletes' overall sports ability [3].

In addition, HIIT can greatly increase the fun and variety of training. The traditional continuous training method is often more monotonous and boring, which is easy to make athletes feel tired and bored, affecting their enthusiasm and the effectiveness of training. HIIT can design a variety of training programs by changing the parameters such as high- and low-intensity exercise forms, time, and intensity. For example, in a training session, athletes can alternate between different forms of exercise, such as sprinting, followed by skipping rope, and then burpees; they can also change the length and intensity of each stage to make the training full of

variation and challenge. This diversity and interest can stimulate athletes' enthusiasm in training, reduce the fatigue of a single training method, and make athletes more active in training, so as to improve the quality and effect of training.

3. Intervention mechanism of high-intensity interval training on muscle strength growth in athletes

3.1. Intervention on the neuromuscular system

The neuromuscular system serves as the central control for muscle movement. HIIT activates more motor units through intense exercise stimulation, particularly fast-twitch muscle fibers. These fibers are characterized by rapid contraction speed and high strength, which play a crucial role in enhancing athletes' explosive power and maximal strength. During the high-intensity phase of HIIT, athletes need to exert force quickly, which prompts the central nervous system to recruit and activate motor units more efficiently, improving neuromuscular coordination and contraction efficiency. Long-term HIIT training can cause adaptive changes in the neuromuscular system, enhance the control ability of nerves to muscles, and thus promote the growth of muscle strength [4].

3.2. Intervention on the hormonal environment

Hormones play an important role in regulating muscle strength growth. HIIT can cause changes in hormone levels, especially the secretion of anabolic hormones such as testosterone and growth hormone. High-intensity exercise stimulates the body to produce more testosterone and growth hormone, which promote protein synthesis and muscle cell proliferation and differentiation, helping to increase muscle size and strength. At the same time, HIIT has a pulse effect on hormone secretion, which can rapidly increase hormone levels in a short period of time, providing a favorable hormonal environment for muscle strength growth. Empirical evidence shows that after a six-week HIIT program, salivary testosterone levels increased by approximately 12% and growth hormone by 15%, whereas changes in control groups were negligible (< 3%) [4].

3.3. Intervention on muscle fiber type and metabolic pathway

An athlete's muscles are made up of different types of muscle fibers, including fast and slow muscle fibers. Fast muscle fibers are responsible for rapid, powerful contractions, while slow muscle fibers are better suited for long, low-intensity exercise. HIIT can selectively stimulate the growth and development of fast muscle fibers, increasing the proportion of fast muscle fibers, so as to improve the explosive force and strength output ability of athletes [5]. In addition, HIIT can also affect muscle metabolic pathways and improve muscle energy supply efficiency and metabolic capacity. Through high-intensity exercise, muscles need to produce energy quickly to meet the needs of exercise, which promotes adaptive changes in metabolic pathways in muscle cells to improve energy production and utilization efficiency, providing a material basis for muscle strength growth.

4. Effect of high-intensity interval training on muscle strength growth in athletes

4.1. Explosive power

HIIT can effectively improve the explosive power of athletes by simulating sport-specific explosive movements such as sprinting and jumping. Previous intervention studies demonstrated a 4–7% increase in countermovement jump height after 6–8 weeks of HIIT compared to ~2–3% in control groups [6]. In the proposed design, athletes

are expected to achieve approximately +8 cm improvement in countermovement jump following HIIT supplementation, versus +3 cm in the control condition. These findings indicate that HIIT provides a stronger neuromuscular stimulus for explosive performance.

4.2. Maximum strength

Max strength refers to the maximum amount of force an athlete can produce during muscle contraction. Although traditional resistance training is the main method to improve maximum strength, high-intensity interval training can also be used as an adjunct to promote the growth of maximum strength. HIIT increases the maximum strength output of muscles by improving neuromuscular recruitment and coordination, allowing more muscle fibers to be involved in contraction. At the same time, the regulation of the hormonal environment by HIIT also contributes to the synthesis of muscle protein and the growth of muscle cells, providing favorable conditions for maximum strength gain. In some sports that require maximum strength, such as weight lifting and throwing, the combination of HIIT training can improve the maximum strength level while maintaining good endurance.

Empirical findings have shown that athletes completing 8 weeks of HIIT combined with resistance training improved their one-repetition maximum squat and bench press by approximately 9–11%, compared with 4–6% improvements in resistance-only groups [4]. These results suggest that HIIT supplementation provides additional neuromuscular and hormonal benefits for maximal strength development.

4.3. Strength endurance

Strength endurance refers to an athlete's ability to maintain a certain amount of power output over a long period of time. In many sports, such as football, basketball, and so on, athletes need to constantly carry out sprinting, jumping, fighting, and other actions in the game, which require good strength endurance. High-intensity interval training improves muscle endurance and fatigue resistance by alternating high and low intensities, so that the bodies of athletes can constantly adapt and recover. During high intensity, the athlete's muscles need to withstand a greater load, while during low intensity, the body has the opportunity to recover and adjust. After long-term HIIT training, athletes' muscles can better adapt to the alternating stimulation of high intensity and low intensity, improve strength endurance, and enable athletes to exert better strength levels for a longer time in the competition [7].

For example, in repeated sprint protocols, HIIT participants demonstrated a 6% reduction in sprint decrement scores after six weeks, compared with only a 2% reduction in control groups. This indicates that HIIT enhances fatigue resistance and sustains muscular output across repeated high-intensity efforts [8].

5. Practical points of application of high-intensity interval training

5.1. Integration with traditional strength training

High-intensity interval training cannot completely replace traditional strength training, but should be combined with it. Traditional strength training focuses on the growth of muscle volume and absolute strength. Through heavy-weight and low-repetition schemes, it effectively stimulates muscle hypertrophy and strength development. HIIT, on the other hand, is more oriented toward improving neuromuscular coordination, explosive power, and strength endurance. The combination of the two can give full play to their respective advantages and improve athletes' muscle strength more comprehensively [8]. For example, several days of traditional strength training and several days of HIIT can be arranged in a weekly plan, and adjusted according

to the specific situation and training goals of athletes. Studies have demonstrated that athletes engaging in a combined program of resistance training plus two weekly HIIT sessions achieved approximately 6% increases in muscle cross-sectional area and a 7 cm improvement in countermovement jump performance, surpassing the gains of resistance-only programs [8].

5.2. Periodized training arrangement

In order to achieve the best training effect, high-intensity interval training needs to be arranged in a periodic way. Periodized training refers to the division of the training process into different stages according to the training goals and physical conditions of athletes. Each stage has different training intensity, training volume, and training content. In the periodization of HIIT training, the training can be divided into a basic adaptation period, an intensity improvement period, and a competition preparation period according to the actual situation of athletes. The basic adaptation period lets athletes gradually adapt to the intensity and rhythm of high-intensity interval training. The training intensity is relatively low, and the training volume is gradually increased [1]. In the intensity improvement period, the training intensity is gradually increased, and the intensity and duration of high-intensity stages are increased to further stimulate athletes' neuromuscular system and physical function. During the preparation period, the intensity and volume of training are adjusted according to the time and intensity requirements of the competition, so that athletes can perform at their best in the competition.

5.3. Consideration of individual differences

Different athletes have different physical conditions, exercise abilities, and training goals, so individual differences should be considered when performing high-intensity interval training. For young athletes whose physical functions are not fully developed, the intensity and difficulty of training should be appropriately reduced to avoid physical harm caused by overtraining. For athletes with sports injuries or chronic diseases, a comprehensive physical examination and evaluation should be conducted before HIIT training, and the training should be conducted under the guidance of a doctor or professional coach. In addition, athletes of different sports have different requirements for strength quality, so personalized HIIT training programs should be developed according to the characteristics of sports and individual conditions of athletes.

6. Methods (proposed research design)

This study proposes an 8-week randomized controlled trial (RCT) to evaluate the supplementary effects of HIIT on muscular strength, explosive power, and neuromuscular function in trained athletes.

Participants: Thirty-six male athletes (aged 18–25) with at least two years of structured resistance training experience will be recruited. Sample size estimation using G*Power indicates that 18 participants per group are required to detect medium effect sizes (Cohen's d = 0.6) with 80% statistical power in a repeated measures design.

Intervention: Participants will be randomly assigned to either (1) a control group performing traditional resistance training three times per week, or (2) an intervention group following the same resistance training protocol plus two weekly HIIT sessions. The HIIT sessions will consist of 6 × 30-second all-out cycling sprints interspersed with three minutes of active recovery. The intervention will last for eight weeks.

Measurements:

Maximal strength: One-repetition maximum squat and bench press.

Explosive power: Countermovement jump assessed on a force plate, 20 m sprint time with timing gates.

Neuromuscular function: Isometric mid-thigh pull for peak force and rate of force development; surface electromyography (EMG) for muscle activation patterns.

Metabolic and hormonal markers: Blood lactate concentration, salivary testosterone, and cortisol levels.

Statistical analysis. Data will be analyzed using two-way repeated measures ANOVA (group × time) or linear mixed-effects modeling, with effect sizes and 95% confidence intervals reported. Statistical significance will be set at $P < 0.05$.

7. Limitations and future research

Despite its potential contributions, the proposed study presents several limitations. First, the relatively small sample size and restriction to trained young male athletes limit the generalizability of the findings to other populations, such as female athletes, youth, or older adults. Second, the intervention is limited to an eight-week duration, which may not fully capture long-term adaptations or potential overtraining effects associated with chronic HIIT exposure. Third, the chosen HIIT modality and parameters (cycling-based, 6 × 30 s intervals) may not generalize to all sports contexts, as sprint running or sport-specific drills could yield different outcomes.

Future research should therefore expand the diversity of participant groups, extend intervention durations, and systematically compare different HIIT modalities and parameterizations. Moreover, the integration of advanced biomechanical analyses and injury monitoring would provide deeper insight into the balance between performance enhancement and potential risks. Standardization of HIIT protocols across studies is also recommended to improve comparability and translation into applied sport settings.

8. Research prospects

Current research investigates how HIIT influences muscle strength development through neuromuscular, hormonal, and muscle-specific adaptations. Building on this foundation, an 8-week intervention comparing standard resistance training with resistance training supplemented by HIIT was proposed. The primary outcomes will include one-repetition maximum strength, countermovement jump kinetics, isometric mid-thigh pull-derived rate of force development, surface EMG activation patterns, and salivary hormonal markers. The Loughborough Powerbase and the Exercise Physiology and Biomechanics laboratories are utilized to conduct force-time and EMG analyses, while applying rigorous quantitative methods taught in the MSc Quantitative Research module to examine the mechanistic basis of observed performance changes. This proposed project aligns with faculty expertise in neuromuscular physiology and offers a direct pathway to publishable findings and applied placement opportunities.

9. Conclusion

This paper argues that HIIT represents a complementary and mechanism-driven pathway to muscular strength development. By enhancing motor-unit recruitment, stimulating acute anabolic hormonal responses, and promoting fast-twitch fiber adaptations, HIIT can contribute to improvements in explosive power, maximal strength, and strength endurance. When integrated periodically with traditional resistance training and individualized to the athlete's context, HIIT offers a time-efficient strategy to optimize performance outcomes.

The proposed experimental framework provides a feasible design for future empirical validation, particularly within high-performance environments equipped with advanced neuromuscular assessment tools.

Further research using standardized HIIT protocols and rigorous quantitative methods is required to substantiate causal mechanisms and ensure safe, evidence-based applications in sport and conditioning practice.

Disclosure statement

The author declares no conflict of interest.

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