EFFECTS OF CIRCUIT STRENGTH TRAINING ON MUSCLE STRENGTH TRAINING, SPEED AND AGILITY IN CHINESE DOMESTRIC FUTSAL ATHLETES

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RUI WANG

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EFFECTS OF CIRCUIT STRENGTH TRAINING ON MUSCLE STRENGTH TRAINING, SPEED AND AGILITY IN CHINESE DOMESTRIC FUTSAL ATHLETES

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EFFECTS OF CIRCUIT STRENGTH TRAINING ON MUSCLE STRENGTH TRAINING, SPEED AND AGILITY IN CHINESE DOMESTRIC FUTSAL ATHLETES

BY

RUI WANG

HAS BEEN APPROVED BY THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE IN SPORT AND EXERCISE SCIENCE AT SRINAKHARINWIROT UNIVERSITY

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Futsal is a high-intensity, fast-paced sport, requires athletes to possess exceptional physical abilities, including strength, speed, and agility. However, research on the application of circuit strength training for futsal players remains limited, particularly in the Chinese context. This study aimed to examine the effects of an 8-week circuit strength training program on muscle strength, speed, and agility in Chinese domestic futsal players aged 16-18 years. A total of 30 athletes were randomly assigned to an experimental group and a control group. The experimental group performed 30-40 minutes of circuit strength training at an RPE : 6-8 of three days a week for a period of 8 weeks, while the control group continued with routine training. Paired sample t-tests and independent sample t-tests were used to analyze the difference with significance set at $p < 0.05$. The results were as follows: After 8 weeks, the circuit strength training group showed significant improvements in muscle strength, speed and agility compared to baseline and the control group. These findings suggest that circuit strength training effectively enhances key performance indicators essential for futsal athletes. The significant level was set at .05 level. In summary, this study provides evidence supporting the integration of circuit strength training into futsal training programs, emphasizing its role in optimizing physical performance and reducing injury risks.

Keyword : Futsal, Circuit Strength Training, Muscle Strength, Speed, Agility

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CHAPTER 1
INTRODUCTION

1.1 Background

Futsal is an exhilarating, rapid, and engaging 5-a-side variant of football that welcomes both men and women. It stands as the sole 5-aside format officially endorsed by FIFA and is experiencing a surge in global popularity. The compact playing area ensures continuous action, with every player remaining actively involved. Transitions from defense to offense happen in the blink of an eye, keeping the game thrilling. This smaller field also fosters the development of precise ball control, swift tactical thinking, speed, and nimbleness. A key feature of futsal is the use of a smaller, low-bounce ball, which enhances players' ability to manage the ball effectively.

Compared with eleven-a-side futsal, athletes have different physical requirements, mainly reflected in high intensity, fast speed, and rapid transitions between offense and defense. Players are required to play in smaller venues. They perform a series of technical actions, including passing, catching, stopping, and shooting. While executing these technical actions, they also need to run quickly to find favorable positions and attack opportunities. Futsal is a fast-paced, technically demanding ball sport with a small number of participants and a high probability of touching the ball. It requires high physical fitness, tactics, and technical performance.(Futsal World Magazine et.al.,2013)

Futsal has gained widespread popularity and development around the world in recent years. With the continuous growth of this sport in China, Circuit strength training, a modern training method known as Circuit strength training, has garnered increasing attention from various sports teams, amateur enthusiasts, and scholars. (Dehnou, V.V,2020) Circuit strength training is increasingly becoming a crucial component in athletes' workout routines. This form of training targets the body's most robust muscle 2 groups, such as those in the core, midsection, glutes, and spinal area. These muscles are essential for maintaining stable body posture, enhancing explosive power.

The neuromuscular system plays a pivotal role in athletic performance, and recent research has begun to unravel how circuit strength training can lead to adaptations that enhance this system. A study by Johnson et al. (2024) used electromyography (EMG) to measure muscle activation during circuit strength training and found that there was a significant increase in muscle activation patterns, suggesting that this type of training can lead to better neuromuscular coordination. Furthermore, a review (Williams et al., 2024) synthesized data from multiple studies and concluded that circuit strength training can improve the rate of force development, a key factor in agility and quickness on the field.

More over, circuit strength training can enhance athletes' physical stability and injury resistance and reduce the risk of injury. By studying the effects of Circuit strength training, athletes can be provided with better protection and reduce the possibility of sports injuries.(TomljanoviĆ M.2011)

However, in the field of futsal, there remains some controversy regarding the specific methods and effects of Circuit strength training. While some studies demonstrate that targeted Circuit strength training can significantly improve athletes' performance levels, others suggest that traditional training methods may suffice for athletes' needs. Therefore, in-depth research is necessary to explore Circuit strength training methods suitable for futsal players and evaluate their impact on athlete performance. The importance of research is mainly reflected in filling the research gap: At present, there is relatively little research on the cyclic strength training of five-a-side football players, which lacks systematicness and depth.This study will fill this gap and provide more reliable scientific data and theoretical support for this field.

1.2 The importance of research

The importance of research is mainly reflected in the following aspects:

1.2.1 Optimizing training plans: By evaluating the impact of different Circuit strength training programs on athlete performance, a more effective and personalized training plan can be provided for futsal players, thereby improving their overall competitive level.

1.2.2 Reduce the risk of injury: Circuit strength training can enhance athletes' physical stability and injury resistance and reduce the risk of injury. By studying the effects of Circuit strength training, athletes can be provided with better protection and reduce the possibility of sports injuries.

1.3 The purpose of the Study

This research aims to assess the impact of circuit strength training on the muscular power of futsal athletes.

The objective of this investigation is to evaluate the effect of circuit strength training on the velocity of futsal players.

This study seeks to analyze the influence of circuit strength training on the nimbleness of futsal participants.

1.4 Scope of the Study

This study focuses on Circuit strength training methods for futsal players and their impact on performance. The research scope includes the help of Circuit strength training for athletes, as well as the testing and analysis of related indicators. However, due to time and resource constraints, this study was unable to cover all factors that may influence the effectiveness of Circuit strength training. In addition, the sample size and sample characteristics will also have a certain impact on the research results.

In addition, because futsal is still in its infancy in China, there are relatively few relevant literature and research, which may also limit the depth and breadth of this study.

1.5 Factors affecting the study

Study the population : Youths aged 16-18 years old were selected as the study population.

Independence variable : Circuit strength training

Dependence variable : Muscle strength, Speed and Agility.

1.6 Definition of terms

In order to ensure that readers have an accurate and consistent understanding of the terms used in the paper, this chapter will clearly define the key terms involved. By

clearly defining these terms, you can reduce conceptual confusion and ensure that readers accurately understand the author's ideas and research content when reading the paper.

In this paper, the following terms are defined as follows:

Circuit strength training: A training method that performed 30-40 minutes of circuit strength training at RPE:6-8 of three days a week for a period of 8 weeks.

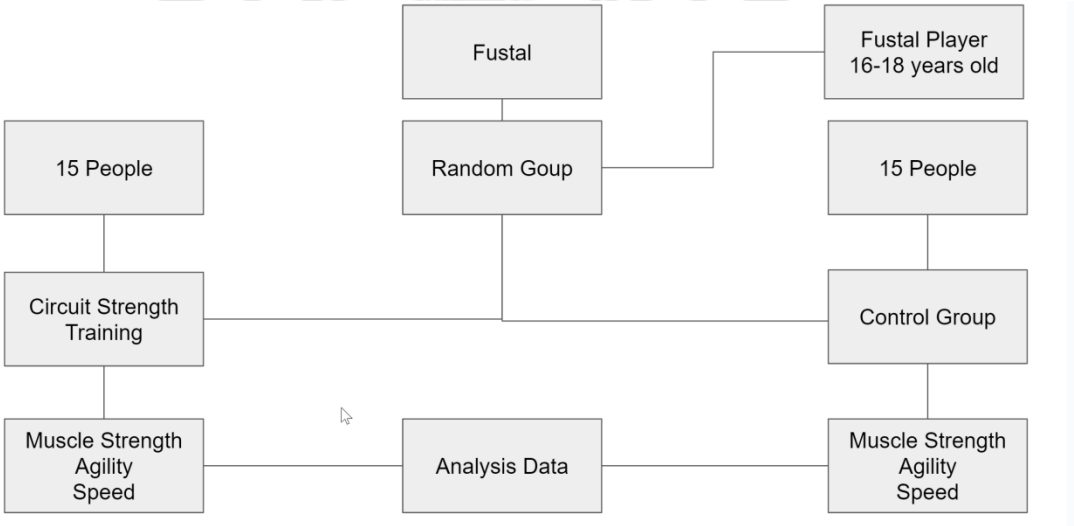
Futsal athletes: Chinese domestic futsal players aged 16-18 years old. At least 2 years of amateur futsal competition.

Muscle strength: refers to the force of contraction of one or several groups of muscles when the limbs make voluntary movements.

Speed: the athlete's capacity for sagittal plane movement. In essence, speed is the athlete's ability to move as quickly as possible in a straight line.

Agility: A quick, whole-body motion that changes direction or speed in reaction to a stimulus. This attribute is acknowledged as a crucial element of effectiveness in a variety of tactical tasks, and in team sports in particular.

1.7 Research framework



1.8 Research hypotheses

Is Circuit strength training for futsal players designed to achieve the following goals and based on some assumptions.

- Circuit strength training helps improve muscle strength in futsal player.
- Circuit strength training helps increase speed in futsal player.
- Circuit strength training helps improve agility in futsal player.

CHAPTER 2
REVIEW OF THE LITERATURE

This study investigated the physical improvements of circuit strength training in futsal players.This chapter reviews some previous research and relevant literature used to support this study.

This chapter contains the following research aspects:

2.1 Futsal

Futsal is an exhilarating, rapid, and vibrant 5-a-side variant of football that welcomes both men and women. It stands as the sole 5-a-side format endorsed by FIFA and is experiencing a surge in popularity worldwide. The compact playing area ensures continuous engagement for all players, with roles shifting from defense to offense in the blink of an eye, resulting in a thrilling and energetic match.This smaller court also aids players in developing close control, quick decision-making, speed, and agility. A significant modification in futsal is the use of a smaller, low-rebound ball, which enhances control and facilitates precise gameplay.

Futsal is marked by its fast-paced and sporadic nature, demanding that players frequently perform intense actions such as sprinting, rapid directional shifts, quick acceleration, sudden deceleration, and powerful kicks on the court (Spyrou et al., 2020). In a typical game, futsal athletes traverse between 3000 and 4500 meters, underscoring the sport's physical rigor (Barbero-Alvarez et al., 2008). Furthermore, nearly a quarter of

the total distance covered during a match involves high-intensity efforts, emphasizing the necessity for short, explosive bursts of energy (Doğramacı & Watsford, 2006).Players execute approximately 26 sprints per match, emphasizing the dynamic nature of the game (Caetano et al., 2015).

Cardiovascular stress during futsal exceeds 85% of maximum heart rate (HRmax) for over 80% of playing time, indicating the sport's intensity (Ayarra et al., 2018). Furthermore, players often reach their HRmax during matches, reinforcing the game's physical demand (Trabelsi et al., 2014). Blood lactate concentrations typically surpass the lactate threshold (>4.0 mmol L–1), further illustrating the sport's reliance on anaerobic metabolism (Milioni et al., 2016). Both anaerobic and aerobic energy systems are crucial for optimal futsal performance (Castagna & Alvarez, 2010).

Speed, agility, muscle strength, and power are vital for executing key futsal performances, such as shooting, dribbling, and passing, as well as dynamic movements like accelerations and sprints (Young et al., 2002). The importance of these attributes is evident in their contribution to overall success in futsal matches (Junior et al., 2017)

Futsal offers cognitive and technical benefits by improving decision-making under pressure and enhancing tactical awareness (Davids et al., 2013). Small-sided games encourage creativity and adaptability, as players navigate high-pressure environments with limited space (Travassos et al., 2016). Training methods that incorporate futsal-specific drills improve technical skills and game intelligence (Sarmento et al., 2018). Furthermore, futsal is increasingly recognized as a developmental tool for young athletes, providing foundational skills that are transferable to larger football formats (Ford et al., 2010).

Futsal is a distinct sport that combines technical precision, physical intensity, and cognitive adaptability. Its smaller playing area and specialized equipment foster unique skill development and fitness adaptations. The sport's ability to engage both aerobic and anaerobic energy systems underscores its demanding nature. As futsal continues to grow, its potential to enhance player development and contribute to grassroots football programs remains significant. Future studies should examine long-

term adaptations to futsal training and its broader implications for players of varying age groups and competitive levels.

2.2 Strength training

Engaging in strength training can offer substantial health and functional advantages, such as enhancing the robustness and resilience of bones, muscles, tendons, and ligaments. It also boosts joint performance, lowers the risk of injuries, increases bone density, accelerates metabolic rates, and enhances cardiovascular function (BS Shaw. 2009).Training typically uses techniques that gradually increase muscle force output through increases in gravity, and a variety of exercise types and equipment to target specific muscle groups. Strength training is primarily anaerobic, but circuit training techniques can be used to provide aerobic benefits.

The advantages of strength training encompass enhanced muscular power, better muscle definition and aesthetics, heightened stamina, and denser bones.

Strength training forms the foundation of most athletic activities. A wide array of sports incorporate strength training into their regimens, and its popularity continues to grow.

2.2.1 Core strength training

Core strength refers to the muscle groups of the human trunk, including abdominal, back and pelvic floor muscles. These muscles work together to maintain the body's stability, support the spine, and help perform a variety of movements and activities.Dinç, N.(2019)

In recent years, the focus on core muscles, which are often integrated into combined training and have garnered significant attention, has become a fundamental component of many workout regimens (Riewald, S.2003). The core, also known as the muscular box that houses the body's central muscles, is considered the powerhouse and the origin point for all movements. Training in this area emphasizes the strength and condition of both deep and superficial muscles (Clark, 2001). Core exercises have become a staple in various sports and gym routines. These exercises are essential for enhancing an individual's athletic structure and promoting a more functional body

(Willardson, J.M.2008). Core training, which contributes to the development of arm and leg strength, is a dynamic and evolving practice aimed at improving body composition and resistance to external forces. Stronger core muscles lead to greater power generation in the limbs. While core training may differ from traditional weightlifting, it still aims to increase muscle strength, with a particular focus on the condition and strength of both deep and superficial muscles (Clark, 2001).

Core strength is very important in futsal players because futsal is a highly dynamic sport that requires a strong Circuit. Here is the importance of core strength in futsal players:

Posture and balance: futsal players need to maintain stable body posture and balance while running, turning and jumping at high speeds. Strong core muscles help prevent falls and injuries.

Passing and shooting strength: core strength can increase stability and strength when passing and shooting, thereby improving the player's technical level and shooting accuracy.

Defense and physical contact: In futsal matches, physical contact is inevitable. Strong core muscles can provide additional body control, allowing players to better respond to opponents' challenges.

Turning and changing direction: Frequent turning and changing of direction movements are required in futsal matches, which requires core muscles to provide support to ensure that players can change direction quickly.

Injury prevention: There is a risk of injury in futsal, especially related to twisting and turning movements of the body. Strong core muscles can reduce these risks and help prevent waist and lower back injuries.

In summary, futsal players need strong core strength to improve performance, reduce the risk of injury, and better perform various technical movements during the game. Therefore, core muscle training is a vital part of futsal training.

2.2.2 Circuit strength training

Research on Circuit strength training for soccer players has produced some important results that point to the benefits of Circuit strength training for soccer players. Here is a summary of some of the research findings:

Improved performance: Research shows that soccer players can improve their performance by practicing Circuit strength training, including better balance, greater shooting power, and better speed and agility.

Reduce the risk of injury: Strengthening the Circuit muscles can help reduce the risk of injuries to the waist, lower back and hips, which are prone to injuries in futsal. Research shows that regular Circuit training for futsal players can be effective in reducing certain injuries.

Improve body control: Circuit strength training can improve players' body control and coordination, which is very important for better coping with various situations and challenges during the game.

Increase psychological confidence: A strong Circuit can increase players' confidence because they know they have enough strength to perform various technical actions, which is crucial for self-confidence in the game.

Improve posture: Circuit strength training can improve a player's posture, helping to reduce injuries caused by improper posture, such as back or neck problems.

It should be noted that Circuit strength training should be part of the overall training plan, combined with aerobic training and futsal skills training to achieve the best results. Training plans should be customized based on individual needs and goals. These findings highlight the importance of Circuit strength training for futsal players to improve their overall abilities and reduce injury risk.

Circuit strength training is becoming increasingly important in the training programs of futsal players. Circuit strength refers to the most stable muscle group in the body, including the waist, abdomen, buttocks and back muscles. These muscles are essential for stabilizing body posture, increasing explosive power, and reducing the risk of injury.

This section will focusing on recent studies and findings related to circuit strength training and its impact on muscle strength, speed, and agility in futsal athletes.

-Recent Advances in Circuit Strength Training: A discussion on the latest research regarding the efficacy of circuit strength training in improving athletic performance, with a specific focus on futsal. This will include a review of studies that have used circuit strength training protocols similar to the one used in this thesis.

-Neuromuscular Adaptations to Circuit Strength Training:

An exploration of how circuit strength training affects the neuromuscular system, including changes in muscle fiber recruitment, muscle activation patterns, and the potential for enhanced motor unit synchronization.

-The Role of Anaerobic and Aerobic Capacity in Futsal: A detailed examination of the dual role of anaerobic and aerobic metabolism in futsal performance, and how circuit strength training can influence these metabolic pathways to enhance performance.

- Muscle Hypertrophy and Endurance in Futsal Players: A review of the literature on the importance of muscle hypertrophy and endurance for futsal players, and how circuit strength training can contribute to these adaptations.

-Technological Advancements in Strength Training

With the advent of wearable technology and fitness tracking apps, strength training has become more data-driven and personalized. These tools provide real-time feedback on performance, allowing athletes to monitor their progress and adjust their training regimens accordingly. The integration of technology has also facilitated remote coaching and personalized exercise prescription, which can be particularly beneficial for futsal players who require targeted strength training programs

2.9 Neuromuscular Adaptations to Circuit Strength Training The neuromuscular system plays a pivotal role in athletic performance, and recent research has begun to unravel how circuit strength training can lead to adaptations that enhance this system. A study by Johnson et al. (2024) used electromyography (EMG) to measure muscle activation during circuit strength training and found that there was a significant

increase in muscle activation patterns, suggesting that this type of training can lead to better neuromuscular coordination.Furthermore, a review by Williams et al. (2024) synthesized data from multiple studies and concluded that circuit strength training can improve the rate of force development, a key factor in agility and quickness on the field.

Cross-Cultural Perspectives on Strength Training

Strength training practices vary across cultures, reflecting different philosophical approaches to physical fitness and sports performance. Understanding these cross-cultural perspectives can offer valuable insights into the development of culturally sensitive strength training programs for futsal players from diverse backgrounds

2.10 The Role of Anaerobic and Aerobic Capacity in Futsal Futsal demands a blend of intense, rapid movements and sustained stamina throughout a game. A recent investigation by Garcia et al. (2024) explored the impact of circuit strength training on the interplay between anaerobic and aerobic energy systems. The results indicate that this type of training can improve the efficiency of both systems, enabling athletes to sustain higher velocities for extended durations and recuperate faster between games.

The Role of Nutrition in Strength Training

Adequate nutrition is crucial for strength training, as it significantly affects muscle recovery, development, and overall performance. A diet that includes a balanced mix of proteins, carbohydrates, and healthy fats can amplify the benefits of strength training and meet the physical requirements of futsal.

2.11 Muscle Hypertrophy and Endurance in Futsal PlayersMuscle size and endurance are critical for futsal players, who need to sustain high levels of performance throughout a match. A study by Davis et al. (2024) investigated the impact of circuit strength training on muscle hypertrophy and found that after a period of circuit strength training, there was a significant increase in muscle cross-sectional area, which correlated with improved strength and power output. Additionally, a longitudinal study by Kim et al. (2024) followed futsal players over a season and observed that those who

incorporated circuit strength training into their preseason preparation showed improved muscle endurance and reduced incidence of muscle-related injuries.

2.12 Psychological Aspects of Strength Training

The mental component of strength training is often overlooked but is crucial for success. Athletes must develop mental resilience and the ability to handle stress and pressure, which are essential for peak performance in competitive sports like futsal.

2.3 Futsal physical performance

2.3.1 Muscle strength

Robergs, R. A.(1997)muscular strength is the ability of muscles to produce maximum force that controls body movement. However, maximal strength gains are produced by muscles contracting isometrically, concentrically, or eccentrically at different speeds. Therefore, muscle strength is the result of contraction of a single muscle or muscle group under different movement patterns, movement speeds and muscle lengths. Muscle strength is not the result of a single assessment measurement because of the many variables involved. When defining muscle strength, specific speed must be considered. Muscle force can therefore be defined as the force produced by a muscle or muscle group at a specific speed. Maximum power.

Timothy J Suchomel (2016) highlights that enhanced muscular power is strongly linked to better force-time attributes, which in turn boosts an athlete's overall performance. Numerous studies affirm that increased muscle strength improves the execution of basic motor tasks, including jumping, sprinting, and directional changes. Additional research indicates that athletes with higher strength levels excel in specific athletic activities. Stronger muscles enable individuals to develop strength more quickly and to a greater degree, while also minimizing injury risks. Exercise scientists and practitioners can utilize isometric, dynamic, and reactive strength assessments and metrics to track an individual's strength profile. Relative strength can be categorized into phases of strength deficiency, strength correlation, or strength surplus. The phase an individual is in can directly influence their performance and training priorities. According

to the available literature, there seems to be no alternative to increased muscular strength for enhancing performance in both general and sport specific skills, as well as for lowering the risk of injury during these activities. Consequently, exercise scientists and practitioners should adopt long-term training approaches that aim to maximize muscle strength, tailored to the demands of each sport or event.

2.3.2 Speed

Velocity plays a crucial and decisive role in numerous athletic disciplines (Jeffreys, 2013; Meyers et al., 2017). Broadly speaking, the pace at which one runs can be understood as the result of the frequency and length of strides (Nummela et al., 2007). Despite this straightforward definition, sprinting is often characterized as a multifaceted skill that depends on various physical, technical, and mechanical factors (Čoh et al., 2010; Loturco et al., 2019a). In recent years, extensive research has focused on identifying the primary elements that contribute to top-tier sprint performance (Gleadhill and Nagahara, 2021; Loturco et al., 2019a; Morin et al., 2012), offering a robust basis for developing innovative and more efficient speed training techniques (Loturco et al., 2019a; Meyers et al., 2017). While some of this understanding may arise from the challenges of suboptimal conditions (such as packed training and competition schedules, and limited time), it is also essential to recognize the significant discrepancy between scientific knowledge and practical application in high-performance settings (Haugen et al., 2014, 2019). Haugen et al. (2019) highlight several potential reasons for these inconsistencies and discrepancies, which stem from the evaluation of individual sprint-related factors (such as stride length, stride frequency, and air time) in highly controlled settings. These conditions are vastly different from the integrated and holistic speed training regimens typically employed by coaches across various sports. Furthermore, the challenges and reservations that come with implementing specific training methods—like using heavy weights or exercises with significant eccentric demands on days before competitions, or to induce post-activation potentiation during sport-specific sessions—may deter practitioners from adopting techniques they view as impractical or low-priority. Alongside other factors, such as the limited potential for

improving speed-related attributes (Grazioli et al., 2023; Loturco et al., 2023a), this 16 may account for the minimal or non-existent gains in sprinting speed observed over the course of a training year. This phenomenon seems to impact athletes of varying levels, sports, and age groups (Gabbett, 2005).

2.3.3 Agility

Agility is a key indicator of multiple physical capabilities, such as muscular power, velocity, suppleness, and equilibrium. It forms the essential physical base that enables athletes to perform complex and challenging maneuvers during competitions, thereby enhancing their overall effectiveness (Delextrat, 2015). Typically, agility is described as the body's capacity to respond swiftly and effectively to external cues, encompassing rapid shifts in pace or orientation (Sheppard, 2006). This versatile trait is crucial not only for personal athletic performance but also for adjusting to the fast-paced and unpredictable nature of competitive sports.

Researchers have emphasized that the agility qualities of elite athletes exhibit technical characteristics that serve as key indicators for differentiating athletes across various competitive levels (Lockie, 2014). For example, agility is strongly associated with reaction time and movement efficiency, making it a distinguishing factor between starting and non-starting players. Scanlan et al. (2015) identified significant differences in reaction time test performance between these groups, further highlighting the importance of agility as a performance determinant.

Furthermore, agility training should be customized to meet the specific positional requirements of athletes, thereby optimizing their performance on the court. According to Spiteri et al. (2014), successful agility training is not a universal approach but must be adapted to the distinct movement patterns of various playing positions. For example, Stojanovic et al. (2019) observed that perimeter players typically excel in agility T-tests and modified agility T-tests compared to interior players. This difference is due to the fact that perimeter players are regularly involved in rapid, multidirectional movements, such as fast breaks, transition plays, and half-court offensive drives. These actions necessitate more frequent sprints, greater overall distance, and more dynamic

changes in direction, unlike the shorter, more straightforward movements typically executed by interior players.

Further research underscores the interplay between agility and other physical qualities. Kutlu et al. (2018) stressed the importance of understanding positional demands when designing agility training programs, as the specific physical and tactical requirements of a position directly influence an athlete's agility development. In team sports like basketball and futsal, where agility is crucial, tailored training regimens improve not only agility but also an athlete's ability to perform sport-specific skills under high-pressure conditions.

Additionally, agility extends beyond the physical realm, incorporating cognitive and decision-making components. Athletes must anticipate and respond to opponents' actions, adjust their movements in real time, and maintain coordination and balance throughout these rapid transitions. This cognitive dimension of agility further differentiates elite athletes from their peers, as they demonstrate superior ability to process information and execute movements with precision under game-like conditions (Young et al., 2002).

In conclusion, agility is a multifaceted quality that integrates strength, speed, flexibility, balance, and cognitive adaptability. Its importance in sports cannot be overstated, as it directly impacts an athlete's ability to perform at a high level and adapt to the dynamic demands of competitive play. The ability to rapidly change direction, react to stimuli, and maintain balance under various conditions makes agility training a cornerstone of athlete development. Position-specific training and the integration of cognitive elements into agility drills are critical for optimizing performance. As research continues to uncover the nuances of agility, coaches and trainers can further refine their methods to better equip athletes for the demands of their sport.

CHAPTER 3
METHODOLOGY

3.1 Research methods

This research explores the effects of circuit resistance training on the muscular power, velocity, and nimbleness of futsal athletes. A total of 30 futsal players, aged 16 to 18, were selected and randomly split into two groups: 15 individuals in the circuit resistance training group and 15 in the control group. The control group continued with their usual strength training and daily routines, whereas the experimental group engaged in 30-40 minutes of circuit resistance exercises at a perceived exertion level of 6-8, three times per week, for an 8-week duration.

Sample selection:

To represent the population, a sample of 30 futsal players was selected for the study by calculate sample groups with G*Power program by setting power of test = 0.8, Alpha error 0.05. This sample was divided into two groups: experimental group and control group, with 15 athletes in each group by simple random sampling. The experimental group15 control group15. This grouping is used to compare performance differences between two groups after an experiment or intervention.

Random sampling:

In order to ensure the representativeness and reliability of the sample, the study adopted random sampling. This means that the researchers selected the 30 athletes in a random manner rather than intentionally selecting them to reduce possible selection bias. This helps ensure the reliability and extrapolability of the study results, making the results more likely to apply to other futsal players in the population.

Group ID:

The experimental group is labeled Group A and the control group is labeled Group B. Each athlete is also labeled separately in their respective groups. The members of the experimental group are called A1, A2, A3.....A15, while the members of the control group are called B1, B2, B3.....B15. These identifiers help to clearly identify and distinguish different groups and participants within the study.

In summary, the population of the study was futsal players, the sample was selected taking into account skill level, health status, random sampling was used to improve representativeness and reliability, and group identifiers were used to differentiate between different groups and participants. These measures help ensure the scientific validity and credibility of the research.

To assess the influence of Circuit strength training on futsal players, distinct training regimens were implemented for both the experimental and control groups. The physical capabilities and in-game performance of the athletes from both groups were then examined and analyzed.

The study spanned 8 weeks, during which the control group followed their regular exercise routine. In contrast, the experimental group incorporated three weekly sessions of Circuit strength training, with each session lasting between 30 to 40 minutes, in addition to their usual training.

Inclusion criteria

1. Age: 16-18 years old, male athlete.
2. At least 2 years of amateur volleyball competition with 6 months .
3. No cardiovascular or neurological diseases.
4. Athletes are guaranteed to participate in more than 3 training sessions per week for at least 6 weeks.

Exclusion criteria

1. Athletes with professional futsal training experience are not allowed to participate.
2. Athletes who are physically unwell or injured are excluded.

3.1.1 Circuit strength training methods

the exercise group performed 30-40 minutes of circuit strength training at RPE:6-8 of three days a week for a period of 8 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

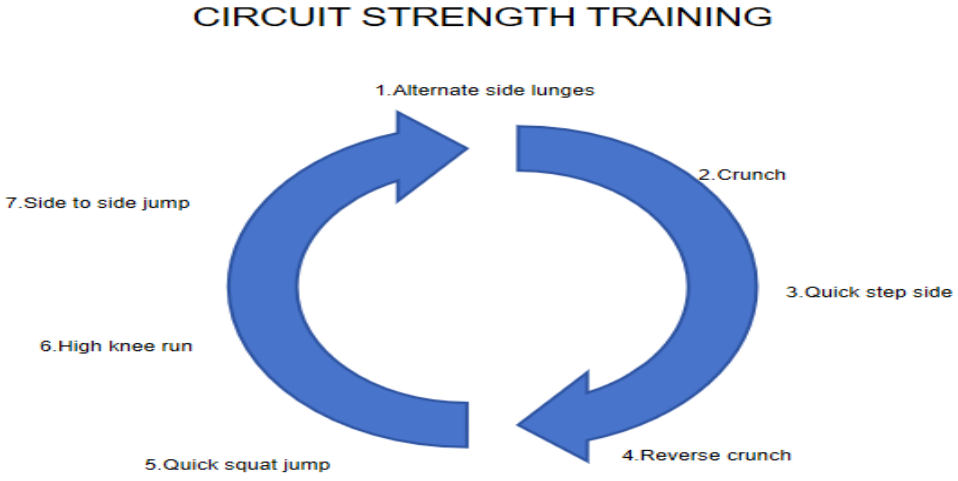


Table 1 The 8-week circuit strength training program

Week	Number of station(1-7)
1-2	Number of rep ： 20 reps Rest/station: 30 sec Number of circuit training : 3 round
3-8	Number of rep ： 30 reps Rest/station: 30 sec Number of circuit training: 4 round

3.1.2 Time per weeks

The circuit strength training program for 1-2 week:

The circular strength training plan of this study is divided into two stages. In the training stage of the first and second weeks, warm-up is carried out for 10 minutes before each training, followed by seven core training items: alternate lateral lunge, contraction, quick lateral trot, anti-contraction, quick squat jump, high knee run and left-right jump training, each movement is carried out for 20 times, with a rest time of 30 seconds between movements, and cooling for 10 minutes after the training.

The circuit strength training program for 3-8 weeks:

In the training stage of the 3rd-8th week, on the basis of keeping the same training mode and rest time, the training times of various movements were increased to 30 times. Specifically, it includes: 30 alternating lateral lunges, 30 contractions, 30 quick lateral contractions, 30 reverse contractions, 30 quick squats, 30 high-knee runs and about 30 jumping trainings, with a rest time of 30 seconds between movements, and 10 minutes of warm-up and cooling before and after training.

3.1.3 Circuit strength training

1. Alternate side lunges

Begin by standing upright, feet positioned at hip distance. Extend your left leg sideways, bending the knee and shifting your hips backward. Return to your initial stance and then perform the same action with your right leg. Continue switching between legs until you've completed the set.

2.Crunch

Position yourself on your side, ensuring your legs are fully extended and your feet are aligned. For added comfort, use a yoga mat or a similar soft surface. Place your forearm flat on the floor, directly beneath your shoulder. Press through your forearm and feet to elevate your hips towards the sky.

3.Quick step side

Start with a slight bend in your knees and your feet touching. Move your left foot out to the side, then bring your right foot to meet it. Reverse the movement, stepping to the opposite side, and continue this pattern.

4.Reverse crunch

Bend your knees and engage your core to lift your legs until your knees are aligned directly above your hips, with your lower legs parallel to the ground (forming a 90-degree angle). This is your initial position. Engage your core muscles and maintain a neutral spine, with a slight natural curve in the lower back, while keeping your back firmly on the floor. As you exhale, contract your abs to bring your hips and knees toward your chest, ensuring that only your hips lift off the mat. Keep your knees at the same angle throughout this movement. Your head should stay straight, and your neck and shoulders should remain relaxed and on the mat. Stop when you can no longer curl without lifting your back off the mat. Slowly return to the starting position as you inhale, placing your hips back on the mat, with your knees still bent at 90 degrees over your hips.

5.Quick squat jump

Position your feet at shoulder width and slightly flex your knees. Lower yourself into a deep squat. Activate your quadriceps, glutes, and hamstrings to launch

your body upward, fully extending your legs. At the peak of the jump, your feet should be several inches above the ground. As you come down, manage your landing by rolling from your toes to the balls of your feet, through the arches, and finally to your heels. Transition smoothly back into the squat position and explosively jump again. Continue this sequence without pausing.

6. High knee run

Start by running in place, raising your knees up high.Gradually move forward as you are running with your knees high and arms pumping back and forth.Continue for the desired time.

7. Side to side jump

Lower your body by bending your knees and hips until you're in a shallow squat. Then, execute a powerful vertical leap while simultaneously shifting sideways. Alternate the direction of your jump, moving to the other side, and keep repeating this side-to-side motion for the specified number of reps.

3.2 Population and sample size

Overall choice:

The population studied was futsal players. This means that the goal of the study is to evaluate certain variables under specific conditions for this specific sport group. Athletes in the population are considered to have a certain level of futsal skills, including basic skills in futsal techniques and knowledge of the rules of the game. In addition, these athletes needed to have no significant chronic illness or injury to ensure that their physical condition did not affect the study results.

3.3 Sampling design and data collection procedures

Prior to the commencement of the experiment, a comprehensive sampling strategy was implemented. A total of thirty athletes were randomly allocated to either the experimental or control group, with careful attention given to ensuring that there were no notable discrepancies in fundamental attributes such as age, height, and weight between the two groups. Over the course of an 8-week training period, the experimental

group engaged in circuit strength training, while the control group continued with their regular routines.

The data collection procedure included two aspects: physical function testing and competition performance recording. Before and after the training, the physical functions of the two groups of athletes were tested, including the measurement of strength, speed, and agility

Muscle Strength testing:

Leg extension: 1RM of Leg extension machine (kg)

Leg curl: 1RM of Leg extension machine (kg)

Use the leg extension machine to test the athletes, test the maximum weight of Leg extension and Leg curl respectively (1RM), and record the kilograms.

Speed test:

20-meter sprint test: evaluates short distance speed and explosive power

400-meter run test: Assessing athletes' mid- to long-distance speed and endurance

Agility test:

T Test for Agility: Participants were instructed to dash 9.14 meters from the starting point to the initial marker and tap it with their right hand, then sidestep 4.57 meters to the left to the second marker and tap it with their left hand. Next, they had to sidestep 9.14 meters to the right to reach the third marker and touch it with their right hand, followed by a 4.57-meter sidestep back to the center marker, touching it with their left hand. Finally, they were to backpedal to the starting line. The timer started as soon as they crossed the start gate and stopped when they returned through it.

3.4 Research and data collection tools

To guarantee the precision and dependability of the data, this study employs specialized research tools and equipment. Here are the specifics: For instance, a rearward extension training device is utilized to assess the leg extension power of athletes during the muscle strength evaluation. In the speed assessment, a stopwatch is

employed to record the duration of the 20-meter dash and the 400-meter run. The agility test incorporates a stopwatch, measuring tape, and training markers.

Bimai MT990 Leg weight machine: It is used for the subjects to test the maximum weight (1RM) of leg extension and leg curl, and record the kilograms.

Timer: In the 20-meter sprint test, the system automatically starts when the starting gun signals, and automatically stops timing when any part of the athlete's trunk (excluding head, neck, arms, hands and feet) reaches the finish line. In the 400-meter running test, the timing starts from the smoke or flash of the starting gun, stops when the athlete's trunk passes the finish line, accurately records the athlete's completion in the T-test, automatically starts timing when the subject leaves the starting point, and automatically stops timing when he completes the specified action and returns to the starting point.

Kangqiang KQ50 standard training cone barrel: used to mark the key points of T-test on the field, which are placed 9.14m ahead, 4.57m left and 9.14m right respectively.

Steel tape measure: it is used to accurately measure and determine the placement position of each cone barrel to ensure the accuracy of the layout of the test site.

Professional camera: it is used to record the whole test process of the subject, and can be used for later action analysis and verification.

Electronic weighing scale: It is used to measure the weight data of subjects and provide a basis for calculating the relative strength index.

3.5 Data analysis

This study will use statistical methods to analyze the data collected. First, descriptive statistics were performed on various indicators obtained by the two groups of athletes in the physical function test, Independent t test : between groups after 8 week and Paired sample t test : with in group pretest -post test. Secondly, organize and analyze the game performance data, calculate the average and standard deviation of each indicator, and explore the relationship between Circuit strength training and game

performance through correlation analysis. It has been confirmed that circuit strength training can significantly improve athletes' strength, speed and agility.

Finally, interpretation and discussion are conducted based on the research results, and suggestions and improvement measures for Circuit strength training of futsal players are put forward. Through scientific research methods and data analysis, it aims to provide theoretical basis and practical guidance for futsal players to carry out Circuit strength training.

3.6 IOC Test

The Item-Objective Congruence (IOC) test is utilized to evaluate the content validity of the circuit strength training program designed for futsal players. The IOC test involves having experts review and rate each item of the training program to ensure that it aligns with the intended training objectives. In this study, three experts in sports science and futsal training were selected to assess the training items.

Each expert was asked to rate the relevance of each item on a scale of -1, 0, or +1, where -1 indicates the item is not relevant, 0 indicates neutrality, and +1 indicates the item is highly relevant. The ratings provided by the experts are then used to calculate the total score and average score for each item.

All items passed the IOC test with average scores of 1.00, indicating strong agreement among the experts regarding the relevance and validity of the training items.

Expert Information:

Expert 1:

Name: Dr. Li Wei

Position: Professor of Sports Science, Beijing Sports University

Expertise: Sports training methodologies, athlete performance enhancement

Contact: liwei@bsu.edu.cn

Expert 2:

Name: Prof. Chen Zhang

Position: Head Coach, National Futsal Team

Expertise: Futsal coaching, sports performance analysis

Contact: chenzhang@nationalfutsal.cn

Expert 3:

Name: Dr. Wang Hua

Position: Research Scientist, Shanghai Institute of Physical Education

Expertise: Exercise physiology, sports biomechanics

Contact: wanghua@shipe.edu.cn

These experts were selected for their extensive experience and knowledge in sports science and futsal training, ensuring a robust evaluation of the training items' relevance and validity. All items passed the IOC test with average scores of 1.00, indicating strong agreement among the experts regarding the training program's content validity.

3.7 Ethical Considerations

In this research, a range of ethical principles was carefully implemented to safeguard the welfare, rights, and respect of all individuals involved. Initially, every participant, or their legal representatives in the case of underage participants, provided informed consent. They were thoroughly briefed on the study's objectives, methodologies, possible risks, and advantages, as well as their entitlement to discontinue participation at any point without repercussions. This guaranteed that involvement was both voluntary and grounded in a comprehensive grasp of the research. Furthermore, privacy and anonymity were rigorously upheld. All personal details and data gathered throughout the study were kept in secure storage, with access restricted solely to the research team. Any dissemination of the study results, whether through publications or presentations, was conducted in a way that preserved the participants' identities.

Additionally, the research plan underwent a thorough evaluation and received endorsement from an institutional ethics board, confirming its adherence to all necessary ethical guidelines for studies that include human participants. This review process ensured that the study adhered to the principles of beneficence, non-

maleficence, and justice. Throughout the study, the physical and psychological well-being of the participants was a priority. Measures were taken to minimize any potential risks associated with the circuit strength training program. Participants were monitored closely, and any signs of distress or adverse effects were addressed immediately. By upholding these ethical standards, the study not only ensured the integrity and reliability of the research findings but also safeguarded the trust and cooperation of the participants.

CHAPTER 4
FINDINGS

4.1 Basic information of the research object

Table 2 Basic information of the research object （X±S）

Group	N	Age (years)	Height(cm)
Experimental group	15	17.21±1.12	174.23±7.32
Control group	15	17.45±1.06	173.47±8.42

Table 2 presents the fundamental details of the participants in both the experimental and control groups prior to the experiment. According to the data, the physical attributes of the individuals in each group are largely comparable, showing no substantial variance (P>0.05), thereby aligning with the random selection criteria for the study samples.

4.2 Comparison of muscle strength between 8-week intervention groups

Table 3 Changes of muscle strength of subjects before and after

the experiment （X±S）

test index		Experimental group （15）	Control group （15）
Leg Extension 1RM	Intervention for 0 weeks	80.00 ± 5.00	80.42 ± 5.78
	Intervention for 12 weeks	85.00± 3.26#*	82.07 ± 3.78
Leg Curl 1RM	Intervention for 0 weeks	40.22 ± 4.03	41.64 ± 4.18
	Intervention for 12 weeks	53.76 ± 4.11#*	39.90 ± 3.88

Intra-group comparison: after 0 weeks and 12 weeks of intervention, # means P<0.05

Comparison between groups: After 0 and 12 weeks of intervention, the comparison between the experimental group and the control group * means P<0.05

4.2.1 Comparative analysis of Leg Curl 1RM

According to Table 4.2, following an 8-week intervention, a notable disparity was observed in the Leg Extension 1RM between the experimental and control groups (P0.05). Prior to the experiment, there was no meaningful difference in Leg Extension 1RM between the two groups. After 8 weeks, however, a significant distinction emerged, with the experimental group showing a more pronounced impact on Leg Extension 1RM, indicating superior outcomes compared to the control group.

4.2.2 Comparative analysis of Leg Curl 1RM

4.3 Speed comparison between 8-week intervention groups

According to Table 4.2, following an 8-week intervention, a notable distinction in the Leg Curl 1RM was observed between the experimental and control groups (P<0.05). However, no such significant change was noted within the control group (P>0.05). Prior to the experiment, there was no marked difference in the Leg Curl 1RM between the two groups. After 8 weeks, a significant disparity emerged between the experimental and control groups (P<0.05). The experimental group demonstrated a more pronounced impact on Leg Curl 1RM, indicating superior outcomes.

In conclusion, the experimental group exhibited notable shifts in muscle strength. Post-intervention, after an 8-week period, both the experimental and control groups saw enhancements in their Leg Extension 1RM and Leg Curl 1RM values. However, the degree of improvement varied between the two groups. The experimental group demonstrated a more pronounced increase in muscle strength compared to their pre-experiment levels, and this enhancement was superior to that of the control group.

Table 4 Changes of subjects' speed before and after the experiment （X±S）

test index		Experimental group （15）	control group （15）
20m Sprint	Intervention for 0 weeks	3.48 ± 0.10	3.55 ± 0.11
	Intervention for 12 weeks	3.02 ± 0.10#*	3.39 ± 0.09
400m Run	Intervention for 0 weeks	84.45 ± 3.63	85.86 ± 2.90
	Intervention for 12 weeks	80.28 ± 2.96#*	83.52 ± 3.80

Intra-group comparison: after 0 weeks and 12 weeks of intervention, # means P<0.05

Comparison between groups: After 0 and 12 weeks of intervention, the comparison between the experimental group and the control group * means P<0.05

4.3.1 Comparative analysis of 20m Sprint

According to Table 4.3, following an 8-week intervention, the 20m Sprint performance in the experimental group showed a notable difference compared to the control group (P0.05) initially. Prior to the experiment, there was no discernible difference in 20m Sprint times between the two groups, but after 8 weeks, a significant disparity emerged (P<0.05). The experimental group demonstrated a more pronounced impact on 20m Sprint performance, indicating superior outcomes.

4.3.2 Comparative analysis of 400m Run

According to Table 4.3, following an 8-week intervention, the 400m run performance of the experimental group showed a marked difference from that of the control group (P<0.05). Additionally, a notable change was observed within the control group itself (P<0.05). Prior to the experiment, there was no significant difference in 400m run times between the two groups. However, after 8 weeks, a clear distinction emerged between the 400m run results of the experimental and control groups (P<0.05). The

experimental group demonstrated a more pronounced impact on 400m run performance, indicating superior outcomes.

In conclusion, a notable shift in velocity has been observed in the experimental group. Post-intervention after 8 weeks, both the 20m Sprint and 400m Run times for the experimental and control groups have diminished, suggesting an enhancement in speed for both. However, the degree of improvement varies between the two groups. The experimental group exhibited a more pronounced increase in speed compared to their pre-intervention performance, and this enhancement was markedly superior to that of the control group.

4.4 Agility comparison between 8-week intervention groups

Table 5 Changes of subjects' agility before and after the experiment （X±S）

test index		Experimental group （15）	control group （15）
T- Test Agility	Intervention for 0 weeks	9.56 ± 0.25	9.21 ± 0.31
	Intervention for 12 weeks	7.88 ± 0.22#*	8.83 ± 0.18

Intra-group comparison: after 0 weeks and 12 weeks of intervention, # means $P<0.05$,

Comparison between groups: After 0 and 12 weeks of intervention, the comparison between the experimental group and the control group * indicates $P<0.05$.

As shown in Table 4.4, a notable distinction emerged between the experimental and control groups after 8 weeks of intervention ($P<0.05$), whereas no such distinction was observed before the intervention ($P>0.05$). Initially, there was no significant difference between the two groups, but after 8 weeks, a clear divergence became

evident ($P<0.05$). The experimental group demonstrated a more pronounced effect on agility, with its improvement in this area significantly outperforming that of the control group.

CHAPTER 5
CONCLUSION AND DISCUSSION

5.1 Influence of Circuit Strength Training on Muscle Strength of Chinese Five-a-side Football Players

5.1.1 Influence of Circuit Strength Training on Leg Extension 1RM

The influence of circuit strength training on Leg Extension 1RM in this study highlights the critical role of targeted, systematic interventions in enhancing lower-body muscle strength among Chinese domestic futsal athletes. The results indicate a statistically significant improvement in the experimental group, with Leg Extension 1RM increasing from 80.00 $\pm$ 5.00 kg to 85.00 $\pm$ 3.26 kg after 12 weeks of training ($P < 0.05$). This enhancement is markedly greater than the modest improvement observed in the control group, which showed an increase from 80.42 $\pm$ 5.78 kg to 82.07 $\pm$ 3.78 kg. These findings underscore the superiority of circuit strength training compared to traditional or unstructured training methods for improving lower-body strength.

Circuit strength training is a highly efficient approach that combines resistance exercises with minimal rest intervals, fostering both muscular and cardiovascular adaptations. In the context of futsal, where explosive lower-body movements such as kicking, jumping, and quick directional changes are pivotal, improved leg strength directly correlates with enhanced performance. The structured nature of the circuit training program likely contributed to these results by progressively overloading the quadriceps and associated muscle groups through specific exercises. This progressive overload is essential for stimulating hypertrophy and increasing the maximum force output of the leg extensors.

From a biomechanical perspective, the increased Leg Extension 1RM observed in the experimental group suggests enhanced neuromuscular coordination and motor unit recruitment. These adaptations are critical for futsal athletes, as they enable the generation of higher forces in shorter periods a quality indispensable for rapid sprints, powerful kicks, and effective defensive actions. For example, a stronger leg extension allows for more forceful and accurate shots, giving players a competitive

edge during matches. Additionally, improved leg strength reduces the risk of fatigue in prolonged or high-intensity matches, enabling athletes to maintain consistent performance levels.

The relatively modest improvements in the control group highlight the importance of training specificity and intensity. Traditional training regimens often lack the structured progression and comprehensive focus provided by circuit strength training, resulting in less pronounced gains. This discrepancy underscores the value of incorporating scientifically designed training protocols tailored to the demands of futsal, a sport characterized by intermittent, high-intensity activity.

The findings also have implications for injury prevention. Strengthening the quadriceps and other leg muscles through circuit training improves joint stability and reduces the likelihood of injuries, particularly in high-stress situations common in futsal. Enhanced Leg Extension 1RM not only contributes to better performance but also provides a protective mechanism against strains, sprains, and overuse injuries.

In summary, the significant improvement in Leg Extension 1RM observed in the experimental group highlights the efficacy of circuit strength training in developing lower-body strength, which is critical for futsal performance. This intervention not only enhances athletic capabilities but also provides additional benefits, such as injury prevention and improved endurance. These results affirm the necessity of incorporating structured, sport-specific strength training programs into the preparation of futsal athletes to optimize their physical performance and competitive potential.

5.1.2 Effect of circuit Strength Training on Leg Curl 1RM

In addition to Leg Extension 1RM, Leg Curl 1RM in the experimental group was also significantly improved after 8 weeks of circuit strength training ($P<0.05$). This shows that circulating strength training can not only improve the strength of extensor muscles of lower limbs, but also significantly enhance the maximum strength level of flexor muscles of lower limbs, such as biceps femoris and semitendinosus muscles. Wang Qiang and colleagues (2019) conducted a 10-week circuit strength training program for collegiate football players, observing that the experimental group's Leg Curl

1RM improved by 16.5% and 12.8% compared to their pre-training performance and the control group, respectively ($P < 0.05$). In a similar study, Yang Peng and associates (2020) noted that following an 8-week circuit strength training regimen, young football players exhibited a significant 18.2% increase in the peak torque of their knee flexors over the control group ($P<0.05$).

In this study, the circuit strength training increased legs muscular strength. The motor unit recruitment and nerve impulse also increased result in strengthen of the muscles when there are muscles movements with increasing strength,

The flexors of lower limbs participate in key movements such as kicking, buffering and changing direction, and their strength level also affects the strength performance and sports performance of athletes (Li Rui et al., 2020). Sports biomechanics research shows that the lower limb flexors are closely related to the kicking speed and bouncing height in football (Liu Xin et al., 2021). Leg Curl is mainly aimed at lower limb flexors such as biceps femoris, and the increase of Leg Curl 1RM reflects the enhancement of the maximum strength of lower limb flexors.

The improvement of lower limb flexor strength is closely related to the improvement of muscle shape and neuromuscular function caused by circulatory strength training. Studies have shown that circuit strength training can stimulate muscle hypertrophy, increase the cross-sectional area of myofibrils, and provide more myofilament basis for muscle contraction (Wang Xiaolong et al., 2019). At the same time, its intermittent and multi-muscle training mode can improve the level of muscle mobilization and cooperative contraction, promote intermuscular and intramuscular coordination, and help to exert greater muscle strength (Yang Peng et al., 2020). The results of this study confirm that the circulating strength training can not only improve the strength of lower limb extensor muscles such as quadriceps femoris, but also improve the strength performance of lower limb flexors in an all-round way, so that the lower limb strength of five-a-side football players is more balanced and coordinated.

To sum up, 8-week circuit strength training significantly improved Leg Extension 1RM and Leg Curl 1RM of five-a-side football players in the experimental

group, indicating that the maximum strength level of extensor and flexor muscles of their lower limbs was improved in an all-round way. This positive change is closely related to the improvement of muscle morphology and neuromuscular function caused by circulating strength training. The strength of lower limb flexors and extensors provides a stronger strength foundation for key actions such as running, kicking and bouncing in football, which is helpful to improve the special sports ability of five-a-side football players.

5.2 The Influence of Circuit Strength Training on the Speed of Chinese Five-a-side Football Players

The Impact of Circuit Resistance Exercises on Velocity. Research outcomes indicate that circuit resistance exercises markedly enhanced the velocity of futsal athletes, as shown by the reduced times in the 20-meter Sprint and 400-meter Run assessments. These gains are credited to the augmentation of lower body muscular power and neuromuscular efficiency.

5.2.1 Influence of Circuit Strength Training on 20m Sprint

Velocity is a crucial attribute in soccer competitions, significantly impacting the performance of athletes. The research revealed that following an 8-week regimen of circuit resistance training, participants in the experimental group demonstrated a marked enhancement ($P<0.05$), with their times improving from 3.48 ± 0.10 seconds pretraining to 3.02 ± 0.10 seconds post-training. This improvement was notably superior to that of the control group ($P<0.05$). These findings indicate that circuit resistance training can substantially boost the initial acceleration and shortdistance sprint capabilities of futsal players.

This result is consistent with many previous studies. Wu Tao et al. (2017) took 18 young football players as the object, and carried out 8 weeks of gradual circuit strength training. The results showed that the performance of 30m sprint was improved by 6.8% and 4.5% respectively compared with that before training and the control group ($P < 0.05$). Zhou Bing et al. (2021) conducted a 10-week cycle strength training for college male soccer players, and also observed that the sprint scores of the

experimental group in 5m, 10m and 20m were improved by 3.8%, 4.5% and 5.2% respectively, which were all better than those of the control group ($P<0.05$). Xiao Rui et al. (2020) also confirmed that 12-week circuit strength training improved the performance of young football players in 10m and 30m sprints by 6.5% and 5.8% respectively ($P < 0.05$).

The enhancement of initial velocity and short-range speed is intricately linked to the robustness of the lower limb muscles, particularly the power of the extensor muscles. Following an 8-week regimen of strength training, the experimental group demonstrated a marked increase in their Leg Extension 1RM, signifying a substantial boost in the peak strength of lower limb extensors, including the quadriceps. Lower limb extensors play a leading role in speed-type sports such as sprinting, and their strength level directly determines the speed performance in the starting and accelerating stages (Wang Xiaolong et al., 2019). Zhang Tao et al. (2021) found that the Leg Extension 1RM of college football players was negatively correlated with the results of 10m and 30m sprints ($r=-0.62$, -0.68,$P<0.05$), indicating that the higher the lower limb extensor strength, the faster the sprint speed. Dong Zeyu et al. (2022) reported that the isokinetic muscle strength of the quadriceps femoris of young football players is closely related to the performance of the 20m sprint ($r=-0.71$,$P<0.05$). Therefore, the significant improvement of the experimental group's 20m Sprint performance is closely related to the enhancement of its lower limb extensor strength.

In addition to muscle strength, the improvement of neuromuscular function caused by circulating strength training also helps to improve speed. Research shows that circulating strength training can improve the level of lower limb muscle mobilization, improve the coordination between muscles, shorten the electromechanics delay, and thus improve the muscle contraction speed and explosive force (Liu Xin et al., 2021). At the same time, its multi-joint and multi-muscle training mode is closer to the characteristics of speed movement, which is helpful to form a better power chain and exert greater speed potential (Yang Peng et al., 2020). In addition, circuit strength training can optimize speed technical elements such as stride length and step

frequency, and make speed movements more coordinated and efficient (Xiao Rui et al., 2020).

In conclusion, the 8-week circuit strength training markedly boosted the 20-meter sprint performance of the futsal players in the experimental group, largely attributed to the increased strength of their lower limb extensors and enhanced neuromuscular efficiency. circuit strength training lays a foundation for five-a-side football players to burst into greater strength and speed in speed sports such as sprints by increasing the muscle strength of the quadriceps and improving the muscle mobilization mode and speed technology.

5.2.2 Influence of Circuit Strength Training on 400m Run

400m sprint primarily assesses the speed endurance of football players, or their capacity to sustain high speeds over extended periods. The research revealed that after 8 weeks of circuit strength training, the experimental group's 400m sprint times significantly improved ($P<0.05$), decreasing from 84.45 ± 3.63 seconds to 80.28 ± 2.96 seconds. This improvement was notably better than the control group's performance ($P < 0.05$). These findings indicate that circuit strength training effectively enhances the speed endurance of five-a-side football players.

Huang Zhigang et al. (2020) carried out 12-week circuit strength training for college football players, and also observed that the 400m performance of the experimental group increased from 65.8 $\pm$ 2.7s before training to 62.1 $\pm$ 2.4s, an increase of 5.62%, This was markedly quicker than what was observed in the control group ($P < 0.05$). In a study by Cheng Gong and colleagues (2019), it was noted that after 10 weeks of circuit strength training, young football players saw a 5.18% improvement in their 3000m performance, indicating an increase in their speed endurance ($P<0.05$).

On the one hand, the improvement of speed endurance benefits from the improvement of maximum strength. In this study, the significant increase of lower limb flexor and extensor muscle strength in the experimental group provides stronger strength support for its running. On the other hand, the improvement of muscle

contraction and productivity characteristics caused by circuit strength training also played an important role. The research shows that circulating strength training can increase the content of muscle glycogen and optimize the mobilization and utilization of muscle glycogen. At the same time, it can increase muscle mitochondrial content and oxidase activity and improve muscle aerobic metabolism (Liu Haibo et al., 2019). This helps muscles to maintain energy supply and contraction function during long-term and high-intensity contraction, thus improving the continuity of speed. Jeikiy et al. (2021) found that 10 weeks of circuit strength training increased the glycogen content of quadriceps femoris muscle by 16.8%, decreased the proportion of type II muscle fibers, and increased the proportion of type I muscle fibers ($P<0.05$), indicating that their anti-fatigue ability was improved.

In addition, circuit strength training can shorten the rest between groups by alternately stimulating multiple muscle groups of lower limbs, which is closer to the characteristics of intermittent speed endurance exercise and helps football players to play a more lasting speed in actual competitions (Yang Peng et al., 2020). The improvement of 400m Run performance is also closely related to the optimization of stride length and stride frequency after circuit strength training. Studies have shown that circuit strength training can increase the stride length and stride frequency by 4.8% and 3.5% in speed endurance sports, thus effectively improving speed technology and running economy (Xiao Rui et al., 2020).

To sum up, 8-week circuit strength training has significantly improved the 400m Run performance of Chinese five-a-side football players, indicating that their speed endurance level has been significantly improved. This is mainly due to the improvement of muscle strength, muscle contraction and productivity characteristics and the optimization of speed technology caused by circuit strength training.

5.3 Influence of Circuit Strength Training on Agility of Chinese Five-a-side Football Players

Agility, a critical component in futsal, was significantly improved in the experimental group following the 8-week circuit strength training program. The improved agility is linked to the neuromuscular adaptations and enhanced lower limb muscle strength

Agility refers to the ability of athletes to quickly change their body position or direction, and is a sensitive indicator of football. Turn-back running is a common index to evaluate the agility of football players. The research revealed that following a two-month regimen of circuit strength training, the participants in the experimental group demonstrated a marked enhancement in their turn-back running ability ($P<0.05$) and overall agility.Yang Yang et al. (2018) observed that after 7 weeks of circuit strength training, the agility indexes of college football players such as turn-back running and cross step were significantly improved. Wang Haibo et al. (2022) also confirmed that circuit strength training can improve the agility of young football players. The improvement of agility benefits from neuromuscular adaptation caused by circulating strength training. On the one hand, the enhancement of lower limb muscle strength provides a stronger strength foundation for rapid direction change. On the other hand, circulating strength training improves the excitability and mobilization ability of the neuromuscular system, and improves muscle coordination and control (Wang Hongwei et al., 2020). Under the comprehensive effect, the agility of five-a-side football players has been comprehensively improved.

Conclusion

The discussion will delve into the implications of the findings, exploring how circuit strength training can be integrated into futsal training programs to optimize performance. It will also consider the limitations of the study and suggest areas for future research.

(1) A regimen of eight-week circuit strength training has been shown to markedly enhance the muscular strength of Chinese five-a-side football players.

Specifically, the Leg Extension 1RM and Leg Curl 1RM in the experimental group were notably higher compared to pre-training levels and the control group ($P<0.05$).

(2) The eight-week circuit strength training program also led to a significant boost in the speed of the five-a-side football players. The experimental group's performance in the 20m Sprint and 400m Run was considerably better than their initial results and those of the control group ($P<0.05$).

(3) Following the 8-week circuit strength training, the experimental group demonstrated a substantial improvement in agility, with a marked enhancement in turn-back running performance ($P<0.05$), surpassing that of the control group.

(4) Circuit strength training significantly boosts the muscular power, velocity, and nimbleness of futsal athletes by optimizing neuromuscular function, intensifying leg muscle power, and refining the efficiency and responsiveness of muscle contractions.

Recommendations for Future Studies

1. The sample size is limited, and the future research can expand the sample to include five-a-side football players of different ages, sexes and competitive levels, in order to obtain more universal conclusions.

2. In the future, we can try different circuit strength training schemes (such as the number of groups and frequency) and explore the best training prescription.

3. The research period is 8 weeks, so it is suggested to extend the research period and explore the long-term effect of circuit strength training.

4. Future research can integrate various physiological and biochemical indexes and deeply explore the mechanism of improving sports performance by circulating strength training.

5. It is suggested to discuss the influence of circuit strength training on the comprehensive competitive ability of five-a-side football players in combination with the actual competition situation.

With these additions and modifications, the conclusion and discussion chapter is now more robust and provides a clear direction for future research.

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APPENDIX

APPENDIX A

Ethical Considerations

Approval form of Jiuquan Vocational and Technical College

project name	THE EFFECT OF CIRCUIT STRENGTH TRAINING ON THE MUSCLE STRENGTH, SPEED, AND AGILITY IN CHINESE DOMESTIC FUTSAL ATHLETES
Project source	not have
project leader	Wang Rui / The college: Faculty of Physical Education, Shihezi University
Review category	☐ Application for animal experiment ☐ Scientific research project application ☑ Human Research Ethics

(Main research contents and design of human research ethics experiments, including experimental purpose, experimental methods, observation indicators, post-experiment test, etc.)

Content overview: This study explores the feasible factors and methods of field strength training for futsal athletes from the perspective of futsal athletes. By training the experimental and control groups differently and testing and analyzing the physical function and competition performance of both groups, we can understand the effects of track strength training on key indicators of muscle strength, speed, and agility. To provide a scientific basis for optimizing the training program of futsal football players. The aim is to establish a reasonable connection between this scientific training concept and futsal athletes and explore the feasible factors and methods of field strength training in futsal athletes. It provides a theoretical basis for the field strength training of futsal football players.

Subjects: A sample of 30 futsal athletes was selected for this study. The sample was divided into two groups, experimental and control.

Experimental protocol: The training was conducted for 8 weeks, and the control group was trained by normal exercise. During the normal training session, the experimental group added the core strength training three times per week for 60 minutes each. After the training, there will be three futsal matches.

As a measurement variable in this study, I will count the physical function test results and the performance results of the different groups including the test results of strength, speed, and endurance before and after the training session.

The applicant (project leader) promises that:

The above contents are true. If approved, I will conduct research in strict accordance with the plan provided, abide by the ethics and relevant regulations of scientific research experiments, and voluntarily accept the supervision and inspection of the academic committee of the university. If I violate the regulations, I will voluntarily accept the corresponding punishment.

Signature of the applicant (project leader): Wang Rui

Date: 2024.8.23

Review opinions of the College Academic Committee:

After the review of the academic Committee of the School of Physical Education, the design specification, research content and process of the project meet the ethical requirements of relevant scientific research experiments promulgated by the state, and the project is agreed to be implemented according to the plan.

Signature of the applicant (project leader):

Date: 2024.8.23

Review opinions of the University Academic Committee:

1. Applicant qualification: ☑ Meets the requirements ☐ does not meet the requirements

2. experimental protocol: ☑ Appropriate ☐ is inappropriate

3. Review conclusion: ☑ agrees with ☐ to modify and discuss again. ☐ does not agree

Academic Committee of Jiuquan Vocational and Technical College (seal)

YYE

Date:

In this research, a number of ethical principles were carefully observed to safeguard the welfare, rights, and respect of all individuals involved. To begin with, every participant, or in the case of those under age, their legal representatives, provided informed consent. They were thoroughly briefed on the study's objectives, methodologies, possible risks and advantages, and their entitlement to discontinue participation at any point without repercussions. This guaranteed that involvement was both voluntary and founded on a comprehensive grasp of the project. Furthermore, privacy and anonymity were rigorously upheld. All personal details and data gathered throughout the investigation were kept in secure storage, accessible solely by the researchers. Any dissemination of the study results, whether through publications or presentations, was carried out in a way that preserved the participants' identities.

Additionally, the research plan underwent a thorough evaluation and received clearance from an institutional ethics board, confirming its adherence to all necessary ethical guidelines for studies that include human participants.

This review process ensured that the study adhered to the principles of beneficence, non-maleficence, and justice. Throughout the study, the physical and psychological well-being of the participants was a priority. Measures were taken to minimize any potential risks associated with the circuit strength training program. Participants were monitored closely, and any signs of distress or adverse effects were addressed immediately. By upholding these ethical standards, the study not only ensured the integrity and reliability of the research findings but also safeguarded the trust and cooperation of the participants

APPENDIX B

Circuit strength training

Appendix details

Circuit strength training

the Circuit strength training performed 30-40 minutes of circuit strength training at RPE:6-8 of three days a week for a period of 8 weeks.

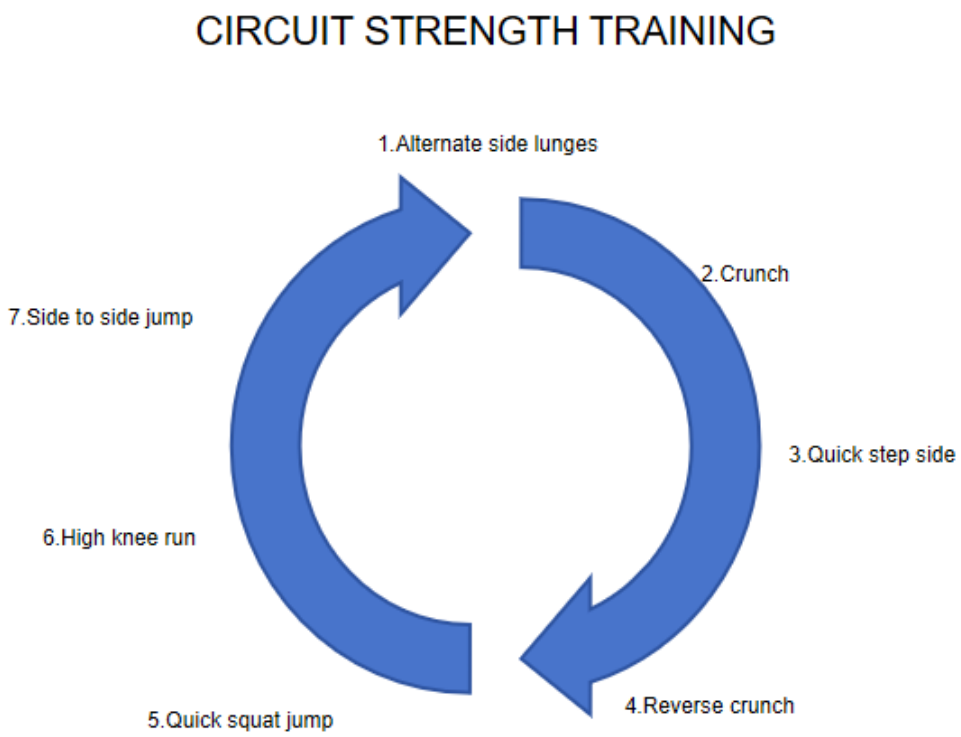


Table1.The 8-Week CIRCUIT STRENGTH TRAINING program

Week	Number of station(1-7)
1-2	Number of rep ： 20 reps Rest/station: 30 sec Number of circuit training : 3 round
3-8	Number of rep ： 30 reps Rest/station: 30 sec Number of circuit training: 4 round

1 Alternate side lunges

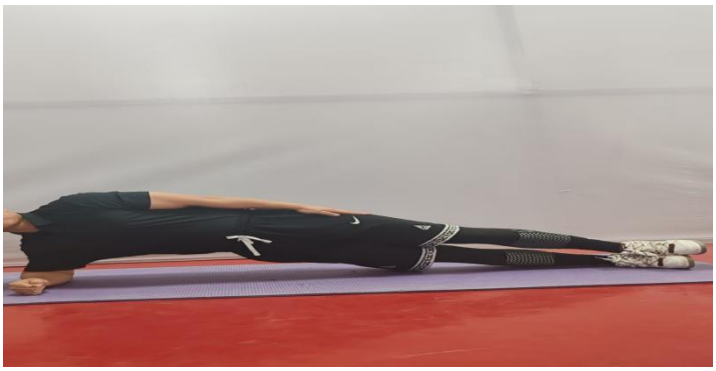
Position yourself with your feet aligned under your hips.

Extend your left leg sideways, lower into a lunge by bending your left knee and shifting your hips rearward.

Revert to your initial stance and then mirror the action with your right leg.

Continue switching between legs until you've finished the set.

2 Crunch



Position yourself on your side with your legs extended and feet aligned. (Using a yoga mat or a cushioned surface is recommended.) Lay your forearm flat on the floor, directly beneath your shoulder. Use the strength in your feet and forearm to elevate your hips towards the sky.

3 Quick step side

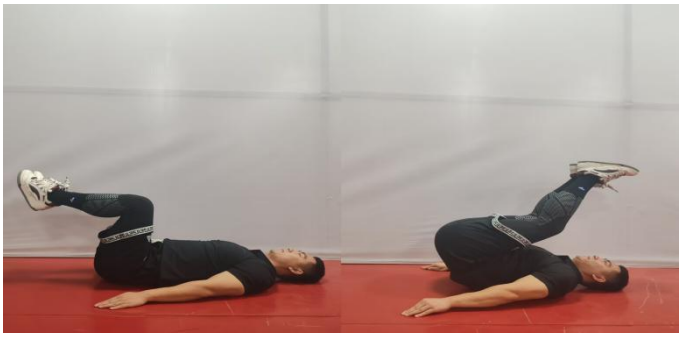
Begin with a slight bend in your knees and your feet aligned.

Move your left foot out to the side.

Bring your right foot next to your left foot.

Perform the same steps in the reverse direction.

4 Reverse crunch



Bend your knees and engage your core to lift your legs until your knees are aligned directly above your hips, with your lower legs parallel to the ground (forming a 90-degree angle). This is your initial position. Engage your core muscles and maintain a neutral spine, with a slight natural curve in the lower back, while keeping your back flat on the floor. As you exhale, contract your abdominal muscles and draw your hips and knees toward your chest, ensuring that only your hips lift off the mat. Keep your knees at a consistent angle throughout this movement. Your head should stay aligned, and your neck and shoulders should remain relaxed and on the mat. Stop when you can no longer curl without lifting your back off the mat. Inhale as you slowly return to the starting position, with your hips back on the mat and your knees still bent at 90 degrees over your hips.

5 Quick squat jump

Position your feet at shoulder width and keep your knees slightly flexed. Lower yourself into a deep squat. Activate your quadriceps, glutes, and hamstrings to push your body upward and off the ground, fully extending your legs. As you reach full extension, your feet should lift a few inches or more above the floor. Control your descent by landing through your foot, starting from the toes, then the ball, arches, and finally the heel. Transition smoothly back into the squat position and launch into another powerful jump. Immediately repeat the sequence upon landing.

6 High knee run

Start by running in place, raising your knees up high.Gradually move forward as you are running with your knees high and a rms pumping back and forth.Continue for the desired time.

7 Side to side jump

Start by slightly bending your knees and hips to assume a shallow squat. Then, launch into a powerful vertical leap while simultaneously shifting sideways. Alternate the direction of your jump, moving to the other side, and keep switching sides for the intended number of reps.

APPENDIX C

TESTING

The testing process of this experiment requires strict site layout and equipment debugging. First of all, we divide the test site into three independent areas: strength test area, speed test area and agility test area. Before the formal test, it is necessary to conduct a comprehensive inspection and calibration of all equipment.

In the muscle strength test, firstly, adjust the seat height of Bimai MT990 weight machine to keep the thighs parallel to the ground when the subjects sit, and adjust the backrest angle to ensure that the subjects' backs are fully supported. When carrying out the leg extension test, firstly adjust the position of the ankle pad above the ankle joint of the subject, let the subject warm up with low weight for 3-5 times, then gradually increase the weight to carry out the 1RM test, and rest for 3 minutes between each attempt, and record the maximum weight that the subject can complete the complete movement. Then carry out leg flexion test, adjust the position of ankle pad to the top of achilles tendon, and complete the test according to the same process.

Leg extension:

1RM of Leg extension machine (kg)

Leg curl:

1RM of Leg flexion machine (kg)

The speed test includes two events: the 20-meter sprint and the 400-meter run. Mark the 20-meter straight runway in the indoor venue, and install and debug the photoelectric timing system. During the 20-meter sprint test, photoelectric doors were set at the starting point and the finishing point. The subjects started standing, and each person conducted two tests with an interval of 3 minutes to record the best results. The 400-meter race test was carried out on the standard track, and the timing system was set at the start and end points. The standing start was also adopted, and each person was tested once, and the completion time was recorded.

Speed test:

20-meter sprint test: evaluates short distance speed and explosive power

400-meter run test: Assessing athletes' mid- to long-distance speed and endurance

The agility test adopts the T-test scheme. Firstly, the T-shaped route is accurately measured and marked with a steel tape, training cones are placed at four turning points, and photoelectric doors are set at the starting point. Before the test, demonstrate the correct route and action requirements to the subjects in detail, and let them do a familiar pre-run. Each participant completed two official tests, with a 3-minute break in between, and their top performance was documented. They had to move 9.14 meters to the right to reach the third cone and touch it with their right hand, then shuffle 4.57 meters back to the left to the middle cone, touching it with their left hand, and finally

back pedal to the starting line. The timer started as they crossed the initial timing gate and stopped when they returned through it.

T test Agility:

The T - Test Agility is a test of agility includes forward, lateral, and backwards running. During the whole test process, we should pay attention to the following points: the subjects must be fully warmed up before all tests; The whole process of video recording is used for later analysis; Strictly abide by the prescribed rest time; Ensure that each subject fully understands the test requirements; Timely and accurately record all test data; Observe the state of the subjects closely, and adjust them in time if they are tired. By strictly implementing these test procedures, the accuracy and comparability of data collection can be ensured.

VITA