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The Effect of Circuit Strength Training on the Muscle Strength, Speed, and Agility in Chinese Domestic Futsal Athletes

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Abstract

Background and Aims: 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 Chinese domestic futsal athletes. This study aimed to examine the effects of a 12-week circuit strength training program on muscle strength, speed, and agility in Chinese domestic futsal players aged 16-18 years.

Methodology: A total of 30 futsal athletes (balanced in gender) were randomly assigned to an experimental group and a control group. The experimental group performed 30–40 minutes of circuit strength training three times per week for 12 weeks (RPE: 6–8), while the control group maintained their routine training. Paired and independent sample t-tests were conducted to examine within- and between-group differences, with significance set at $p < 0.05$.

Results: After eight weeks, the circuit strength training group exhibited statistically significant improvements in lower limb strength, as indicated by increases in leg extension (from 80.00 kg to 85.00 kg) and leg curl (from 40.22 kg to 53.76 kg) performance, while the control group demonstrated no observable changes. Significant enhancements in speed were also evident, with the circuit strength training group achieving faster times in both the 20-meter sprint (3.48 s to 3.02 s) and the 400-meter run (84.45 s to 80.28 s). Moreover, agility performance improved markedly, with completion times decreasing from 9.56 s to 7.88 s, whereas the control group showed no statistically significant differences ($P < 0.05$).

Conclusion: Circuit strength training effectively enhances key performance indicators essential for futsal athletes, including lower limb muscle strength, agility, and speed. This study provides evidence supporting the integration of circuit strength training into futsal training programs, emphasizing its role in optimizing physical performance.

Keywords: Futsal; Circuit Strength Training; Muscle Strength; Speed; Agility

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Introduction

As the only FIFA-certified 5-a-side football variant, futsal has emerged as a global phenomenon with distinct biomechanical and tactical demands (Gamonales et al., 2018). The sport is played on a compact 40×20m pitch, which requires players to execute rapid transitions between defense and offense. These transitions, often occurring within seconds, place high demands on neuromuscular coordination, with players making frequent ball contacts and engaging in high-intensity actions. Such demands require exceptional agility, muscular power, and speed, which are critical for successful performance in futsal (Barbero-Álvarez et al., 2008).

In recent years, circuit strength training (CST) has garnered increasing attention in the athletic community, particularly as a modern training method that targets key muscle groups essential for maintaining stability, enhancing explosive power, and improving performance in sports like futsal. CST focuses on strengthening the core, midsection, glutes, and spinal muscles, all of which are crucial for maintaining proper posture and generating the explosive force required in high-intensity sports (Saibya et al., 2024). Recent studies have shown that CST can improve the rate of force development (RFD) and other measures of muscular performance, which are vital for futsal-specific skills such as agility and quick directional changes (Behm et al., 2024).

However, while CST has demonstrated positive effects in various sports, its application in futsal remains underexplored. Some studies indicate that CST can significantly improve athletic performance, while others suggest that traditional training methods may suffice for the specific needs of futsal players (Lauersen et al., 2013). Therefore, there is a need for more targeted research to assess the effectiveness of CST in futsal, particularly in terms of improving key performance indicators such as muscular power, speed, and agility.

This study seeks to address this gap in the literature by evaluating the impact of CST on the muscular power, velocity, and agility of futsal players. By utilizing a biomechanically grounded CST protocol, this research aims to provide empirical evidence on the effectiveness of CST in enhancing these critical aspects of performance in futsal. Through this investigation, the study will contribute to the development of sport-specific training paradigms, providing coaches and athletes with evidence-based insights for improving performance in futsal.

Objectives

1. To study the effect of circuit strength training on the muscle strength of futsal athletes.
2. To study the effect of circuit strength training on the speed of futsal athletes.
3. To study the effect of circuit strength training on the agility of futsal athletes.

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Literature Review

Futsal

Futsal is a dynamic, five-a-side variant of football that enjoys worldwide popularity and is the only five-a-side format officially endorsed by FIFA. The sport is characterized by a compact playing area, which promotes continuous engagement and frequent transitions between defense and offense. This environment not only creates an exhilarating match experience but also enhances players' abilities in close control, rapid decision-making, speed, and agility. A notable feature of futsal is the use of a smaller, low-rebound ball, which further emphasizes precision in ball control and gameplay (Gamonales et al., 2018).

Empirical studies have documented the physical demands of futsal. For example, Spyrou et al. (2020) highlight the sport's sporadic and high-intensity nature, where players often cover between 3000 and 4500 meters per match. Additionally, nearly 25% of the distance covered involves high-intensity efforts, with players executing approximately 26 sprints per game (Caetano et al., 2015). Physiological responses during matches have shown that players' heart rates exceed 85% of their maximum for most of the game duration (Ayarra et al., 2018), and blood lactate concentrations typically surpass the anaerobic threshold (Milioni et al., 2016). These findings underscore the importance of both anaerobic and aerobic energy systems in futsal performance (Castagna & Alvarez, 2010).

In addition to its physical demands, futsal offers cognitive and technical benefits, such as enhanced decision-making under pressure and improved tactical awareness (Davids et al., 2013). The sport's inherent challenges foster creativity and adaptability, which are essential for success on the court (Sarmento et al., 2018). As such, futsal is not only a platform for physical development but also a critical tool for nurturing comprehensive athletic skills that are transferable to larger football formats (Travassos et al., 2017).

Circuit Strength Training

Circuit strength training has emerged as a focal point in recent sports science literature due to its dual role in enhancing muscular strength and cardiovascular endurance. Research has demonstrated that incorporating circuit strength training can lead to improvements in balance, shooting power, speed, and agility (e.g., studies summarized by Gahreman et al., 2020). Furthermore, the specific targeting of core muscle groups — the "circuit" muscles, including those in the waist, abdomen, buttocks, and back — contributes significantly to performance improvements in futsal.

Recent advances in circuit strength training research have highlighted several key aspects:

(1) Neuromuscular Adaptations: Lim et al. (2024) used electromyography (EMG) to reveal significant increases in muscle activation patterns during circuit strength training, indicating

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improved neuromuscular coordination. A review by Hocalar and Kahraman (2024) further concluded that this training modality enhances the rate of force development, which is critical for agility and quickness on the field.

(2) Metabolic Pathways: Circuit training can optimize both anaerobic and aerobic metabolic capacities, thereby enabling players to sustain high velocities over extended periods and recover rapidly between bouts of high-intensity effort (Imanudin et al., 2019).

(3) Injury Prevention and Posture: By strengthening the core, circuit training contributes to improved posture and reduced risk of injuries related to twisting and sudden directional changes, common in futsal (Gene-Morales et al., 2021).

The integration of technological advancements, such as wearable sensors and fitness tracking applications, has further refined circuit training by providing real-time feedback, personalized exercise prescriptions, and remote coaching capabilities, all of which can be particularly beneficial for futsal players.

Futsal Physical Performance

Futsal performance is multifaceted, relying on a combination of muscle strength, speed, and agility.

Muscular strength is defined as the ability of a muscle or group of muscles to generate force. It is essential for executing fundamental motor tasks such as jumping, sprinting, and changing directions (Robergs, 1997). Suchomel (2016) emphasizes that enhanced muscular power, which is closely linked to improved force-time characteristics, is vital for overall athletic performance. The literature consistently indicates that increases in muscle strength contribute to faster and more effective execution of sport-specific skills while simultaneously reducing injury risk.

Speed is a decisive factor in many athletic disciplines and is influenced by stride frequency, stride length, and mechanical factors (Jeffreys, 2013). Recent research (e.g., Loturco et al., 2020; Morin et al., 2012) has elucidated the key elements that underpin sprint performance. However, practical application often reveals a gap between controlled experimental findings and on-field training outcomes (Haugen & Tønnessen, 2013). These discrepancies highlight the need for sport-specific speed training methods that address both the biomechanical and environmental variables encountered during competition.

Agility integrates multiple physical capacities—including muscular power, speed, flexibility, and balance—with cognitive elements such as reaction time and decision-making. It is a critical performance determinant in sports that require rapid changes in direction and speed (Delextrat, 2015). Research has shown that elite athletes often demonstrate superior agility, which distinguishes starters from non-starters in team sports (Scanlan et al., 2015). Furthermore,

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position-specific agility training, which considers the unique movement demands of different roles within the team, is essential for maximizing on-field performance (Stojanovic et al., 2019). The integration of cognitive elements into agility drills further enhances the capacity for real-time decision-making during high-pressure situations (Kutlu & Doğan, 2018).

Conceptual Framework

The conceptual framework (see Fig.1) illustrates how circuit strength training is hypothesized to improve muscle strength, speed, and agility in futsal athletes.

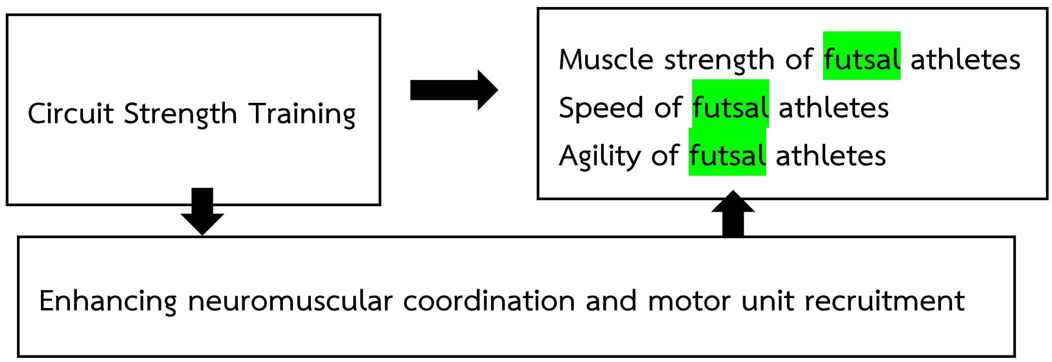

Figure 1 Conceptual Framework

Mothodology

This study examines the effects of circuit resistance training on the muscle strength, speed, and agility of futsal athletes. A comprehensive experimental design was adopted, incorporating a randomized controlled trial over 12 weeks, detailed as follows.

Research Design and Participants

A total of 30 male futsal players aged 16–18 years were recruited. The sample size was determined using the G*Power program (power = 0.8, α = 0.05) to ensure adequate statistical power. Participants were selected based on inclusion criteria (e.g., at least 2 years of amateur futsal competition experience, no cardiovascular or neurological disorders, and availability for more than three training sessions per week over at least six weeks) and exclusion criteria (e.g., prior professional futsal training, current injury, or illness). Simple random sampling was employed to allocate participants equally into two groups: the experimental group (Group A, n = 15) and the control group (Group B, n = 15). Each participant was assigned an identifier (e.g., A1–A15 for the experimental group, B1–B15 for the control group) to facilitate data tracking and analysis.

Intervention Protocol

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The control group maintained their habitual strength training and daily routines, whereas the experimental group engaged in a circuit resistance training program. This program consisted of 30-40 minute sessions conducted three times per week for 12 weeks at a perceived exertion level of 6-8 on the RPE scale. The circuit training was structured in two phases:

Weeks 1-2:

Exercises: Seven core training exercises (alternate lateral lunge, crunch, quick side step, reverse crunch, quick squat jump, high knee run, side-to-side jump).

Protocol: 20 repetitions per station, 30 seconds rest between stations, and three complete circuits per session.

Weeks 3-8:

Exercises: The same seven core exercises.

Protocol: 30 repetitions per station, 30 seconds rest between stations, and four complete circuits per session.

A detailed description of each exercise (e.g., alternate side lunges, crunches, quick lateral steps, reverse crunches, quick squat jumps, high knee runs, and side-to-side jumps) was provided to ensure standardization across training sessions.

Data Collection

Data were collected through both physical function tests and performance metrics recorded during competitive play. Measurements were taken at baseline (pre-test) and immediately following the 12-week intervention (post-test).

Muscle Strength Testing:

Leg Extension and Leg Curl 1RM: Maximum weight (in kg) was assessed using the Bimai MT990 leg weight machine.

Speed Testing:

(1) 20-Meter Sprint Test: Assessed short-distance speed and explosive power.

(2) 400-Meter Run Test: Evaluated mid-to-long distance speed and endurance.

Agility Testing:

T-Test for Agility: Participants performed a standardized T-test, with timing recorded via an electronic stopwatch. The test protocol required athletes to sprint forward, sidestep laterally, and backpedal to the start, with markers positioned at 9.14 m and 4.57 m intervals to define the course.

Additional tools, such as steel tape measures, professional cameras for motion analysis, and electronic weighing scales for relative strength indexing, were used to ensure precision in data collection.

Data Analysis

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Descriptive statistics (means and standard deviations) were computed for all measured variables. Group differences after the 8-week intervention were analyzed using independent t-tests, while paired-sample t-tests compared pre- and post-test results within each group. Furthermore, correlation analyses were conducted to examine the relationship between circuit resistance training and changes in physical performance indicators. The data were interpreted to establish whether circuit resistance training significantly enhances muscular power, velocity, and agility in futsal athletes.

Content Validity

To evaluate the content validity of the circuit strength training program, the Item-Objective Congruence (IOC) test was conducted. Three experts in sports science and futsal training reviewed and rated each training item on a scale of 1 (not relevant), 0 (neutral), and +1 (highly relevant). All items achieved an average score of 1.00, indicating strong consensus regarding the relevance and appropriateness of the training components.

Ethical Considerations

Ethical approval was obtained from the relevant institutional review board. Informed consent was secured from all participants (or their legal guardians in the case of minors) after a thorough briefing on the study's objectives, procedures, potential risks, and benefits. Confidentiality and anonymity were maintained through secure data storage and coding of participant identifiers. Participants were informed of their right to withdraw at any stage without penalty. Continuous monitoring ensured that any adverse events were promptly addressed, thereby safeguarding the physical and psychological well-being of the athletes throughout the study.

Results

This study aims to evaluate the impact of circuit strength training on the muscle strength of futsal athletes; to assess the effect of circuit strength training on the speed of futsal athletes; and to analyze the influence of circuit strength training on the agility of futsal athletes. The study involved 30 male futsal players, divided into two groups: the experimental group (15 participants) and the control group (15 participants). The research results are shown as follows:

The first part of Table 1 presents the basic demographic and physical characteristics of the participants. There were no significant differences in age ($P>0.05$) and height ($P>0.05$) between the experimental and control groups, ensuring that the two groups were comparable before the intervention.

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Table 1 Comprehensive research results (X±S)

Test Index	Time Point	Experimental Group (N=15)	Control Group (N=15)
1. Characteristics of subjects			
Age (years)	-	17.21 ± 1.12	17.45 ± 1.06
Height (cm)	-	174.23 ± 7.32	173.47 ± 8.42
2. Muscle Strength			
Leg Extension 1RM	0 weeks	80.00 ± 5.00	80.42 ± 5.78
	12 weeks	85.00 ± 3.26#*	82.07 ± 3.78
Leg Curl 1RM	0 weeks	40.22 ± 4.03	41.64 ± 4.18
	12 weeks	53.76 ± 4.11#*	39.90 ± 3.88
3. Speed			
20m Sprint (s)	0 weeks	3.48 ± 0.10	3.55 ± 0.11
	12 weeks	3.02 ± 0.10#*	3.39 ± 0.09
400m Run (s)	0 weeks	84.45 ± 3.63	85.86 ± 2.90
	12 weeks	80.28 ± 2.96#*	83.52 ± 3.80
4. Agility			
T-Test Agility (s)	0 weeks	9.56 ± 0.25	9.21 ± 0.31
	12 weeks	7.88 ± 0.22#*	8.83 ± 0.18

Noted: # indicates a significant change within the experimental group between week 0 and week 12 ($P < 0.05$).

* indicates a significant difference between the experimental and control groups after 12 weeks ($P < 0.05$).

$P < 0.05$ denotes a statistically significant difference, while $P > 0.05$ indicates no significant difference.

Objective 1. Changes in Muscle Strength

Leg Extension 1RM:

0 weeks: Experimental Group: 80.00 ± 5.00, Control Group: 80.42 ± 5.78

12 weeks: Experimental Group: 85.00 ± 3.26#*, Control Group: 82.07 ± 3.78

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Both the experimental and control groups showed improvement. However, the experimental group demonstrated a significantly greater increase (P<0.05) compared to the control group. The control group did not show a significant change (P>0.05).

Leg Curl 1RM:

0 weeks: Experimental Group: 40.22 ± 4.03, Control Group: 41.64 ± 4.18

12 weeks: Experimental Group: 53.76 ± 4.11#*, Control Group: 39.90 ± 3.88

The experimental group experienced a significant improvement (P<0.05), while no significant change occurred in the control group. The experimental group had a more pronounced increase in leg strength compared to the control group.

Objective 2. The third part of Table 1 shows changes in speed before and after the 12-week intervention.

20m Sprint:

0 weeks: Experimental Group: 3.48 ± 0.10, Control Group: 3.55 ± 0.11

12 weeks: Experimental Group: 3.02 ± 0.10#*, Control Group: 3.39 ± 0.09

The experimental group exhibited a significant improvement (P<0.05) in sprint performance compared to the control group. No significant difference was observed before the intervention (P>0.05), but after 12 weeks, the experimental group showed better results.

400m Run:

0 weeks: Experimental Group: 84.45 ± 3.63, Control Group: 85.86 ± 2.90

12 weeks: Experimental Group: 80.28 ± 2.96#*, Control Group: 83.52 ± 3.80

A similar trend was observed, with the experimental group demonstrating a significant improvement (P<0.05) compared to the control group, with the experimental group outperforming the control group after 12 weeks of intervention.

Objective 3. The fourth part of Table 1 shows the changes in agility, measured by the T-Test Agility.

0 weeks: Experimental Group: 9.56 ± 0.25, Control Group: 9.21 ± 0.31

12 weeks: Experimental Group: 7.88 ± 0.22#*, Control Group: 8.83 ± 0.18

The experimental group exhibited a significant improvement in agility (P<0.05), while the control group showed no significant change. Before the intervention, there was no significant difference between the two groups (P>0.05), but after 12 weeks, the experimental group demonstrated superior agility.

Discussion

The present study demonstrates that a 12-week circuit strength training program significantly improves key physical performance indicators in Chinese futsal athletes. Compared

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to the control group, the experimental group exhibited substantial gains in lower-body strength, speed, and agility. Specifically, Leg Extension 1RM increased from 80.00 ± 5.00 kg to 85.00 ± 3.26 kg ($p < 0.05$), while the control group showed only minor improvements. This aligns with Imanudin et al. (2019) and Suchomel (2016), who emphasized the importance of structured resistance protocols in enhancing neuromuscular coordination and motor unit recruitment. However, unlike these previous studies, which primarily focused on the general population or youth athletes, the current research provides targeted evidence for elite futsal players in a Chinese context. In addition, several studies have indicated that circuit training programs can effectively enhance muscle development. For instance, research conducted by Anek et al. (2011) and Anek & Bunyaratavej (2015) demonstrated that a circuit aerobic exercise program significantly increased both muscle mass and lower limb strength. This improvement is believed to stem from the heightened physical demand placed on the muscles, which leads to greater motor unit recruitment. Consequently, neural transmission to the muscles becomes more efficient, thereby enhancing muscular strength. Moreover, the activation of large motor neurons further contributes to this increase in strength.

The significant improvements in both leg extension and leg curl strength in the experimental group indicate that circuit strength training benefits not only the extensor muscles but also the flexors of the lower limbs. Balanced strength development is especially important in futsal, where rapid direction changes and kicking dynamics rely on coordinated muscle activation. This observation extends the findings of Hocalar & Kahraman (2024), who underscored the injury-preventive benefits of muscular balance in high-intensity sports by demonstrating real-world training applications in a competitive futsal setting.

In terms of speed, the experimental group reduced their 20-meter sprint time from 3.48 ± 0.10 s to 3.02 ± 0.10 s ($p < 0.05$). This improvement is slightly greater than those reported by Behm et al. (2024) and Saibya et al. (2024), possibly due to the higher training frequency and the sport-specific design of the circuit protocol. Additionally, enhanced 400-meter run performance suggests improved speed endurance, likely due to both strength gains and metabolic adaptations, such as increased mitochondrial activity and better glycogen utilization, which are consistent with findings from Milioni et al. (2016) and Spyrou et al. (2020).

Agility demonstrated a significant improvement, as evidenced by the reduced t-test times. Our study contributes further by illustrating these improvements within the context of a structured strength training circuit, rather than relying solely on technical or coordination-based agility drills. This underscores the multifaceted benefits of integrated training methods that target both force production and neuromotor control. These findings align with those of Akhmad et al. (2023), who investigated the effect of quick strength training on agility and leg

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power in futsal junior athletes. Their study concluded that increased muscle strength led to enhanced muscle power and improved agility in futsal players.

Despite the encouraging results, several limitations should be acknowledged. First, the relatively small sample size (n=30) may restrict the generalizability of the findings, especially to female or adolescent athletes. Although gender balance was considered during recruitment, the analysis did not explore potential gender-specific training responses—an area that merits further investigation given increasing attention to inclusivity in sports science research. Second, the study did not monitor hormonal or biochemical markers, which could have provided deeper insight into physiological adaptations. Finally, while performance metrics were objectively measured, other relevant variables—such as injury rates, player fatigue, or psychological readiness—were not assessed, limiting a holistic evaluation of training efficacy.

Recommendation

The current study provides valuable insights into the effects of circuit strength training on futsal athletes, offering not only directions for future research but also practical guidance for coaches and practitioners.

Based on the findings, coaches are encouraged to incorporate structured circuit strength training programs into regular training regimens, emphasizing lower-body compound movements such as leg extensions and curls, performed at moderate to high intensities (RPE 6–8) three times per week. Such integration can effectively enhance sprint speed, agility, and muscular strength—critical attributes for futsal performance—while also potentially reducing injury risk by promoting muscular balance. Moreover, ensuring inclusive training environments that accommodate diverse athlete profiles may further support equitable performance development across genders.

Nevertheless, several limitations suggest avenues for future research.

First, future research should expand the sample to include participants of different ages, sexes, and competitive levels to improve the generalizability of the findings.

Second, different circuit strength training protocols, such as varying the number of sets, repetitions, and training frequency, should be tested to determine the most effective training prescription.

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