

EFFECT OF ADDITIONAL CONCURRENT STRENGTH AND REPEATED SPRINT TRAINING ON PHYSICAL PERFORMANCE IN COLLEGIATE BASKETBALL PLAYERS



ผลของการเพิ่มการฝึกความแข็งแรงควบคู่กับการวิ่งด้วยความเร็วสูงสุดแบบซ้ำ ๆ ที่มีต่อ สมรรถภาพทางกายในนักกีฬาบาสเกตบอลระดับวิทยาลัย



ปริญญานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
วิทยาศาสตรมหาบัณฑิต สาขาวิชาวิทยาศาสตร์การกีฬาและการออกกำลังกาย
คณะพลศึกษา มหาวิทยาลัยศรีนครินทรวิโรฒ
ปีการศึกษา 2567
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EFFECT OF ADDITIONAL CONCURRENT STRENGTH AND REPEATED SPRINT TRAINING ON PHYSICAL PERFORMANCE IN COLLEGIATE BASKETBALL PLAYERS



A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of MASTER OF SCIENCE

(Sport and Exercise Science)

Faculty of Physical Education, Srinakharinwirot University

2024

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THE THESIS TITLED

EFFECT OF ADDITIONAL CONCURRENT STRENGTH AND REPEATED SPRINT TRAINING ON PHYSICAL PERFORMANCE IN COLLEGIATE BASKETBALL PLAYERS

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OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE

IN SPORT AND EXERCISE SCIENCE AT SRINAKHARINWIROT UNIVERSITY

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BASKETBALL PLAYERS

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Degree MASTER OF SCIENCE

Academic Year 2024

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This study aims to investigate the effects of additional concurrent strength and repeated sprint training on the physical performance of collegiate basketball players. A matchedgroup design was conducted with 24 male collegiate basketball players (19.75 ± 0.18 years, 181.92 ± 5.11 cm, 79.83 ± 1.30 kg). Participants were assigned to a 6-week training group matched for their 1 repetition maximum (1RM) score: (1) a concurrent strength and repeated sprint training group (CTG, n = 12), or (2) a control group (NTG, n = 12) which underwent their normal basketball training. In the CTG, participants performed the concurrent strength and repeated sprint training twice a week, consisting of 3 sets of 8 repetitions of barbell squats, deadlifts, and power cleans at 80% 1RM. The repeated sprint training program consisted of 3 sets of 6 repetitions of 30-m shuttle run (turn at 15-m) performed at maximum speed, with a 20-second rest between repetitions, and a 5-minute rest between sets. Both groups performed a muscle strength test, countermovement jumps (CMJ), repeated sprint ability (RSA) test (RSA_{best}, RSA_{worst}, RSA_{total time}, RSA_{mean}, RSA_{decrement}), Agility T-Test, 20 m sprint test, and Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1). Both groups showed improvements in muscle strength, agility and CMJ height after training (P < 0.001), but there were no significant differences between groups (P>0.05). The CTG demonstrated significant improvement in RSA_{mean}, RSA_{best}, 20 m sprint time, Yo-Yo IR1 and VO₂ max compared to the NTG group (P<0.001). Concurrent strength and repeated sprint training supplementing normal basketball training with twice a week for 6 weeks induced Improvements in the physical performance of college basketball players. This study highlights the potential benefits of this concurrent strength and repeated sprint training approach during a basketball pre-season.

ACKNOWLEDGEMENTS

My highest respect and sincerest gratitude go to my advisor, Lect. Dr. Krirkwit Phongsri, Ph.D. and my co-advisor, Lect. Dr. Watunyou Khamros, Ph.D. From the initial confusion in selecting my thesis topic, through the meticulous refinement of the research proposal, to overcoming numerous challenges during the research process, and down to every word and sentence in writing my thesis — I could not have done it without your patient guidance. Your rigorous scholarship has kept me diligent in the vast ocean of academia; your profound expertise has illuminated my path forward; your selfless care and encouragement have provided me with warmth in a foreign land. Under your guidance, I have not only acquired professional knowledge but also learned how to pursue scholarship and become an upright person. Your teachings and personal example will forever inspire me to continue exploring the path of academic pursuit. I also extend my heartfelt thanks to all professors in the Department of Sports Science. It is your profound knowledge that has laid a solid professional foundation for me, guiding me through the gates of academia and allowing me to navigate the ocean of knowledge. Each of your classes has served as a key, unlocking doors to different fields of knowledge, and has enabled my growth through exploration.

Above all, I am most grateful to my beloved family. Thank you to my parents and my sister. You are my strongest support, providing endless love and encouragement. No matter what challenges I encountered along the journey, you always encouraged me to move forward bravely. Your selfless love and support have allowed me to pursue my dreams with undivided focus.

I offer a special thanks—a thank-you that crosses mountains and seas—to my dearest girlfriend, Ms. Lu. During these two years of study, time differences and distance tested our relationship, yet they deepened my appreciation for the resilience and preciousness of love. I recall countless late nights when we shared our daily lives across screens, and how I captured the evening glow on campus as gifts for you. Thank you for standing firmly behind me through the challenges of studying abroad.

Finally, I want to thank myself—the one who persevered and worked diligently. This is an ending, but also a new beginning. With a heart brimming with gratitude, I shall continue moving forward!

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CHAPTER 1 INTRODUCTION

Background

Basketball originated in the United States in 1891 (Naismith, 1996), the International Basketball Federation (FIBA) was founded in Geneva, Switzerland, in 1932, men's basketball was listed as an official sport in the Olympic Games in 1936, and women's basketball was awarded the same honor in 1976, and many leagues and tournaments have been produced all over the world such as the FIBA Basketball World Cup, the American professional basketball league (NBA), the Chinese men's professional basketball league (CBA), and many amateur basketball leagues, including the Chinese University Basketball League (CUBAL). In today's college sports arena, basketball has a strong charm and wide influence, and college basketball players devote themselves to training and competing with love and dreams, with high popularity and wide participation on college campuses. Basketball is a comprehensive sport, with high requirements for participants' physical ability, skills, tactical awareness and teamwork ability (Mancha-Triguero et al., 2019), college basketball players not only represent the honor of the school, but also improve their own comprehensive quality.

Basketball games are characteristics by high intensity, high confrontation and intermittency (Stojanovi $\acute{\mathbf{C}}$ et al., 2018). Participants need to be able to sprint and jump quickly and change directions in short periods of time. They also need to engage in team sports, Research shows that high-intensity, short-duration sprints interspersed with short periods of low- to moderate-intensity recovery exercises, such as walking and running, are one of the most effective types of exercise. (Abdelkrim et al., 2007; Dasteridis et al., 2011; Póvoas et al., 2012). Especially in basketball, where participants perform an average of 55 to 105 sprints that can be repeated every 21 to 39 seconds (Abdelkrim et al., 2007; McInnes et al., 1995), maintaining a maximal or near-maximal sprint is a key condition for game performance. And the ability to maintain optimal performance in consecutive sprints is known as repeat sprint ability (RSA). Having good aerobic and anaerobic capacity is also important. Aerobic capacity improves the ability

to perform high-intensity exercises repeatedly and maintain their quality within a limited recovery time. (Abdelkrim et al., 2010; Dupont et al., 2010) there is evidence that suggests that repetitive sprint training in the final stages of the pre-season has an effective role in improving sprint speed, jumping ability, and aerobic capacity of college basketball players (Gantois et al., 2018; Gantois et al., 2019) for extended periods of competition. And strength training plays a vital role in their physical performance in this competitive arena (McGuigan et al., 2012; Strasunskas, 2020). As college basketball competitions continue to improve, so do the intensity and competitiveness of the games. College basketball players need to possess not only outstanding basketball skills but also strong physical fitness to perform well on the court. Strength is an important component of physical fitness that directly impacts an athlete's explosive power, speed, endurance, and stability (Huang et al., 2023). In the fight for rebounds, strong lower limb strength allows participants to jump better (Warneke et al., 2023) and occupy a favorable position; in passing the ball, sufficient upper limb strength can effectively reduce upper limb fatigue, which has a significant negative impact on the grip strength and passing accuracy of basketball players (Ahmed, 2013), and sufficient upper limb strength can allow the participants to complete high-quality passes more accurately; while good core strength ensures participants' body balance and movement coordination during rapid offensive and defensive transitions (Luo et al., 2022). Additionally, strength training can increase bone density, reduce the likelihood of ankle injuries, and enhance athletic performance (Andreoli et al., 2001; Strasunskas, 2020), reducing the risk of injury. Therefore, strength training is essential for advancing in college basketball.

Traditional periodized training is widely used in sports training (Junior, 2020), which is divided into different phases and has its own target focus, and the preparatory phase focuses on the development of basic physical fitness, which has the advantage of being systematic and scientific, but it also has the limitation of being monotonous and unable to satisfy the demand for simultaneous development of multiple physical fitness qualities. With the development of sports science, concurrent training has gained

attention, which is the simultaneous performance of multiple exercises in the same phase, which is attractive to collegiate basketball players who face the dual pressures of academics and training and need multiple fitness qualities for competition, and brings both opportunities and challenges for their fitness training; however, Little research has been conducted on the use of additional concurrent strength and repeated sprint training. Training (Hickson, 1980) this may cause conflict. Some studies suggest that training for strength and endurance simultaneously may lead to interference, leading to a decrease in strength (Häkkinen et al., 2003; Hennessy & Watson, 1994; Hunter et al., 1987) Some studies have also found that adding endurance training has a minimal impact on the benefits of strength training (ALABINIS et al., 2003; McCarthy et al., 1995; McCARTHY et al., 2002; Sillanpää et al., 2008) (Sillanpää et al., 2009)

Therefore, researching the effects of additional simultaneous strength and repeated sprint training on the physical performance of college basketball players is of great practical significance. This study can provide a scientific basis for training college basketball players, help them select more effective training methods, and improve their performance in competitions. At the same time, the study can provide physical education teachers and coaches with a reference to promote the improvement of college basketball training.

Purpose of the study

- 1. To study the effect of concurrent strength and repeated sprint training in addition to a regular training program on physical performance in collegiate basketball players.
- 2. To compare the effects of concurrent strength and repeated sprint training in addition to a regular training program with a regular basketball training program on physical performance in collegiate basketball players.

Importance of the study

- 1. Understanding to the effect of concurrent strength and repeated sprint training in addition to a regular training program on physical performance in collegiate basketball players.
- 2. The results of the research can be applied to maximize the effectiveness of training in developing the physical performance in collegiate basketball players to be ready for competition, which will be beneficial to participants, coaches, those involved in the sports industry, and those interested.

Scope of the study

Study population

The population in this study basketball players, 32 individuals from Lanzhou Modern Vocational College, aged 18-21 years old, with at least two years of basketball practice and competition experience, who were preparing to join the provincial Collegiate University Basketball League at Level 3 (CUBAL)

Study sample

For the purpose of this study, a total of 24 basketball players, selected from population, who have participated once or twice in the provincial basketball league, were purposively randomly sampled by conducting the study

Variables of the study

1. Independent variables

Concurrent strength and repeated sprint training in addition to a regular basketball training program.

2. Dependent variables

Physical performance of collegiate basketball players includes:

- Body composition
- Muscle strength (1 RM)
- Leg explosive power
- Agility
- Repeated sprint ability

- Sprint ability
- Aerobic capacity (VO₂ max)

Definition of specific terms

Body composition

It is the total components that make up the tissues and organs of the body, and the sum of their total is body weight

Muscle strength (1 RM)

It refers to the maximum weight that can be lifted in a single attempt—that is, the maximum weight a person can lift only once under standard conditions. It is commonly used to measure muscle strength levels. For example, during a bench press, if someone can only lift a specific barbell weight once with maximum effort, that weight is their 1RM for the bench press.

Leg explosive power

Refers to the ability of the leg muscles to produce maximum force in a very short period of time. It reflects the level at which the legs can be quickly activated from a resting state to produce a powerful thrust. Leg explosive force is mainly determined by a combination of factors such as the muscle strength of the legs, the speed of muscle contraction and the coordinated control of the nervous system.

Agility

Agility is a combination of physical abilities. It refers to the ability of the human body to respond quickly and accurately to various external stimuli and quickly change the position, direction and movement state of the body.

Repeated sprint ability

Repeated sprint ability refers to the ability to perform full sprints several times in a short period of time. Repeated sprint ability is a kind of physical performance that is of great significance in both sports and daily activities. This ability requires not only a strong initial burst of power for a quick start and high-speed sprint, but also the ability to recover quickly after each sprint for the next one.

Sprint ability

Sprint ability is the ability of the human body to run as fast as possible from the starting point to the finish line over a specific distance of 20 meters

Aerobic capacity (VO₂ max)

 ${
m VO}_2$ max is the maximum amount of oxygen that the body can take in and utilize during strenuous exercise. It is a key indicator of the body's aerobic metabolic capacity and cardiorespiratory fitness. When performing aerobic exercise, the body needs oxygen to produce energy. A higher ${
m VO}_2$ max number indicates that the body is able to utilize more oxygen per unit of time to meet the energy demand of the exercise, which means stronger cardiorespiratory fitness and better aerobic endurance.

Conceptual framework of the study

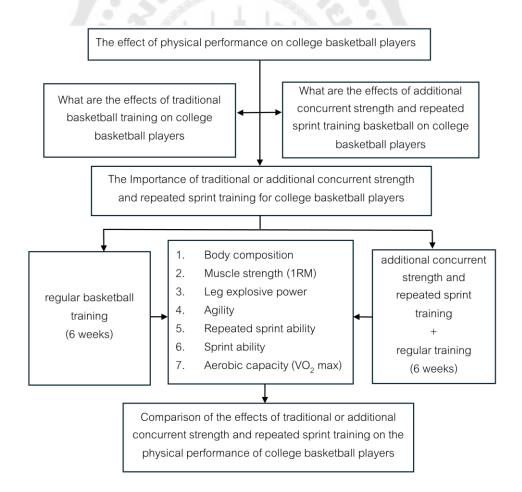


FIGURE 1 Conceptual framework of the study

Research hypothesis

Additional concurrent strength and repeated sprint training will have a better physical performance in collegiate basketball players than traditional basketball training will have in collegiate basketball players



CHAPTER 2 LITERATURE REVIEW

In this study, the researchers have studied the relevant literature and research, Related studies and have been presented below according to the topic:

- Basketball
- Concurrent training
- Strength training
- Repeated sprint training
- Concurrent strength and repeated sprint training

Basketball

Basketball originated in 1891 and was invented by James Naismith, an American physical education teacher (Naismith, 1996). Initially, the rules of the game were relatively simple, and the venues and equipment were relatively crude. With the passage of time, basketball has been developed and perfected, the rules have been gradually refined, and the venues and equipment have been improved. Today, basketball has become one of the most popular sports in the world, with many professional leagues and amateur tournaments. Basketball is played between two teams of 12 players, 5 starters and 7 substitutes, in a readily accessible indoor gymnasium, on a flat, unobstructed, hard-surfaced court, the dimensions of which are 28 meters in length and 15 meters in width, measured from the inside edge of the boundary. The game is divided into four quarters, each lasting ten minutes, with a two-minute break between the first and second quarters (first half), between the third and fourth quarters (second half), and before each decisive quarter, and a 15-minute break in play between the two halves. The goal of each team is to attack the opposing team's basket to score and to prevent the opposing team from scoring during the allotted time. The team that has scored more points in the game at the end of the game time is the winner of the game. Players can play offense and defense by dribbling, passing, and shooting (De Basketball, 2000)

The game of basketball is a high intensity, intermittent sport (Stojanovi $\acute{\mathbf{c}}$ et al., 2018). During the game, players need to constantly perform high-intensity actions such as sprinting, jumping, and confrontation, which requires participants to have a variety of physical qualities, including strength, speed, endurance, and agility. At the same time, it is also necessary to have a good technical level and tactical awareness. Basketball players need to have strong muscle strength and explosive power. The strength of the lower limbs is vital for jumping, starting and changing direction quickly. When grabbing a rebound, the athlete needs to stomp the ground hard and instantly explode with powerful force to get a higher jumping height. Upper body strength, on the other hand, contributes to passing accuracy. The strength of the core muscles is also very important to maintain the stability and balance of the body, which can help the athlete to better control the body and make various technical movements in sports. Explosive strength is also vital for basketball players. Strong explosive power allows players to start and accelerate in an instant, get away from defenders and create better offensive opportunities.

Speed is also vital for basketball players. The modern basketball game is getting faster and faster, and the speed requirement for players is getting higher and higher. Teams with a speed advantage can better adapt to this fast-paced style of play and take the initiative in the game. They can disrupt the opponent's rhythm through quick offensive and defensive transitions to win the game.

In basketball, a game usually lasts 40 minutes or more, and players need to run, move and jump constantly during this time. Good aerobic endurance ensures that players maintain a high level of intensity throughout the game, and that they do not become physically exhausted, which may affect their technical performance. If aerobic endurance is insufficient, players may become fatigued later in the game, resulting in slower speeds and slower reflexes, affecting the team's offensive and defensive efficiency. Players will experience multiple high-intensity sprints and confrontations followed by short rest periods during the game. Players with high aerobic endurance are

able to recover faster and reduce fatigue during rest breaks (Abdelkrim et al., 2010; Dupont et al., 2010).

Concurrent training

Concurrent training, including combining strength and endurance workouts, has been a topic of interest in the field of exercise science. From past research it has been found that using two different forms of training together (Hickson, 1980)this can cause conflict. Leveritt et al. (1999) the benefits and challenges of concurrent strength and endurance training are discussed. Häkkinen et al. (2003) A study was conducted to compare the effects of two training methods on men: simultaneous strength and strength training. The SE group had 11 participants, and the S group had 16 participants. The results showed that RFD increased in the S group (p < 0.01) while remaining unchanged in the SE group. Additionally, RFD increased in Group S, while there was no change in the SE group. Maximum oxygen uptake (VO₂ max) increased by 18.5% (p < 0.001) in the SE group. Hennessy and Watson (1994) A study compared the effects of three preseason training programs. The programs were on endurance, strength, power, and speed. The results showed that strength training alone improved strength, power, and speed. Endurance and upper body strength were improved by S+E training, while lower body strength was weakened. It did not increase strength or speed. Kraemer et al. (1995) research indicates that integrating strength and endurance training can enhance athletic performance and trigger unique physiological adaptations not seen with other training modalities. Glowacki et al. (2004) studied the effects of resistance, endurance, and simultaneous training on training results in men. They found that simultaneous training in young, healthy men does not affect strength development. However, it may hinder the training of maximum aerobic strength. ALABINIS et al. (2003) studied the early changes of concurrently performing endurance and strength training, its methodology 26 male basketball players, divided into 4 groups, 4 days a week, completed a different training program for 7 weeks, the groups were: Strength group (S), Endurance group (E), Strength and Endurance group (S1E), and the control group (C) did not train at all, The maximal oxygen uptake in the S1E group increased more

than in the E group, whereas it decreased in the S group. Strength and vertical jump performance improved in both the S1E and S groups. The S1E group had better posttraining anaerobic capacity than the S group. No improvement in strength, power, or anaerobic capacity was seen in the E and C groups. The final conclusion is that simultaneous endurance and strength training is more effective than endurance and strength training alone in improving athletic performance. McCarthy et al. (1995) studied investigated the effects of combining traditional strength and endurance training three days a week on improving VO₂ max and strength performance simultaneously. Participants were divided into three groups of ten people each. Over a 10-week training period, the strength training group performed eight weight training exercises with four sets of five to seven repetitions per set. The endurance training group engaged in 50 minutes of continuous circuit training at 70% heart rate reserve, and the combined group completed the same training content as the strength and endurance groups in a single session. The 1RM squat improved. It increased 23% for group S and 22% for group C. The bench pre also improved. It increased 18% for both groups. The maximum isometric knee extension torque improved as well. It increased 12% for group S and 7% for group C. The maximum vertical jump improved. It increased 6% for group S and 9% for group C. And lean body mass improved too. It increased 3% for group S and 5% for group C. The training in group E exerted no influence on these variables. Peak oxygen uptake improved in groups E and C. The results show that combined training 3 days per week can significantly improve both VO₂ peak and strength performance. Sillanpää et al. (2008) studied the body composition and physical adaptations of men aged 40 to 65 years during 21 weeks of strength and/or endurance training. Fifty-three men were randomly divided into four groups. The first group was an energy endurance training group (E). The second group was a strength training group (S). The third group was a combined strength and endurance training group (SE). The fourth group was a control group (C). The S and E groups were trained twice a week, while the SE group underwent strength and endurance training twice a week. The thickness of the triceps increased in the S group (22%) and the SE group (20%). The maximum concentric force of the S, SE, and E groups increased significantly (by 22%, 23%, and 7%, respectively), and the maximum oxygen uptake of the E group (11%) and the SE group (11%) increased. The results of the study suggest that a combination of strength and endurance training is more effective than either type of training alone for improving the physical fitness of older men. Sillanpää et al. (2009) Endurance and/or strength training for healthy women aged 39 to 64. Sixty-two participants were randomly assigned to one of four groups: an endurance training group (E), a strength training group (S), a combined strength and endurance training group (SE), or a control group (C). The S group demonstrated a 9 ± 8% rise in leg extension strength, while the SE group exhibited a 12 ± 8% increase (both P < 0.001). In contrast, the E group showed a mere $3 \pm 4\%$ growth (P = 0.036). The isometric bench press strength of the S and SE groups increased by 20% (P < 0.001). Maximum oxygen uptake increased by 23 ± 18% in the E group and by 16 ± 12% in the SE group (both P < 0.001). endurance training, strength training, and the combination of both resulted in the expected training-specific improvements in fitness without interfering with the development of fitness or muscle mass.

Table 1 Concurrent training literature review results

Researcher	Research purpose	Sample	Research results
Sporiš et al., 2011	Examine the impact of strength training regimens on the aerobic and anaerobic capacities of women who play soccer.	24 U-20 female players	Strength training improves an athlete's aerobic and anaerobic capacities.
Alabinis et al., 2003	Studied the early changes of concurrently performing endurance and strength training	26 male basketball players	Research has found that doing both endurance and strength training is more effective.
McCarthy et al., 1995	The study examined whether combining traditional strength and endurance training could improve both VO ₂ max and strength performance simultaneously.	strength training group (S) endurance training group (E) combination group (C)	The results show that combined training 3 days per week can significantly improve both VO ₂ peak and strength performance.

Table 1 (continue)

Researcher	Research purpose	Sample	Research results
Sillanpää et al., 2008	studied the body	endurance training	Concurrent strength
	composition and	group (E, N = 14)	and aerobic training
	physical adaptations	strength training	is more valuable than
	of men aged 40 to 65	group (S, N = 13)	either type of training
	years during 21	combined strength	alone for optimizing
	weeks of strength	and endurance	physical fitness in
	and/or endurance	training group (SE, N	older men.
	training	= 15)	
		control group (C, N =	
		11)	
Sillanpää et al., 2009	A 21-week period of	endurance training	Endurance training,
	endurance and/or	(E)	strength training, and
	strength training was	strength training (S)	the combination of
	performed in healthy	combined strength	both resulted in the
	women aged 39 to	and endurance	expected training-
	64 years to	training (SE)	specific
	investigate the	control (C)	improvements in
	adaptations in body		fitness without
	composition,		interfering with the
	physical fitness, and		development of
	metabolic health		fitness or muscle
			mass

Strength training

Collegiate basketball players, as an important group of basketball players, improving their physical performance is crucial to enhance game performance and athleticism, and strength training as an important part of physical training (McGuigan et al., 2012). Zatsiorsky et al. (2020) pointed out that through strength training can increase the muscular strength of participants, Andersen and Aagaard (2010) in the study found that through strength training can stimulate the growth and hypertrophy of muscle fibers and improve the contraction capacity of muscles. Fischerova et al. (2021) The study examined how combining soccer and strength training affects the strength and performance of female soccer players. Thirty-four players were split into two groups. Each group had 17 players. The experimental group participated in three soccer training sessions and two strength training sessions using 50% of the one-repetition maximum (1RM) load per week. In addition to soccer training using 50%-85% 1RM load, two strength training sessions per week were completed by the experimental group. The experimental results indicated that a six-week short-term soccer training program could significantly improve lower-body strength and jumping parameters in soccer players. During the preparation phase, the program included two strength training sessions per week. Santos and Janeira (2012) in a study of explosive strength indices in adolescent basketball players, twenty-five male adolescents aged 14 to 15 were randomly assigned to an intervention or control group for a 10-week training period. The researchers performed the following tests: squat jumps (SJ), countermovement jumps (CMJ), and Abalakov tests. the hop down, and the seated medicine ball throw (MBT). The results showed that all variables in the EG group significantly improved. In contrast, the SJ, CMJ, and Abalakov test scores decreased significantly in the CG group, while the MBT test scores increased significantly. Both groups performed similarly in the pre-test, while significant differences were observed in all variables in the post-test (p < 0.05). The results showed that a resistance training program during the season can improve vertical jump and MBT performance in young male basketball players. This program should be combined with moderate training volume and intensity. Dasteridis et al. (2011) studied the effects of strength training on sprinting performance. Methods: 27 young male participants were divided into three groups, neuromuscular (NG), hypertrophy (HG) and control (CG). participants in the NG and HG groups trained three times a week for eight weeks. The participants' fastest times in the 30 meters and 60 meters tests were recorded. Analysis of variance (ANOVA) showed that participants in the NG group showed a significant improvement of 8% in their fastest time in the 30 meters run and a significant improvement of 5.9% in their fastest time in the 60 meters run. Similarly, participants in the HG group improved their speed by 6.2% in the 30 meter and 5.2% in the 60 meters, and their fastest times also improved slightly. In contrast, participants in the CG group showed only a slight improvement in their fastest times of 2.1% and 2.4% in the 30 and 60 meters, respectively. The results of the study showed that both neuromuscular and hypertrophic strength training programs were able to improve the participants' sprinting performance. Sporiš et al. (2011) This study investigated the effects of a strength training program on the aerobic and anaerobic capacity of female soccer players. Twenty-four women participated in the study and underwent tests to measure their strength, aerobic capacity, and anaerobic capacity. These tests included a 1RM bench press, a squat, and a leg extension. (LER and LEL for the right and left legs, respectively), and leg flexions (LCR and LCL for the right and left leg bends, respectively). (LER and LEL for left and right legs, respectively) to measure strength, and aerobic and anaerobic capacity were assessed by the VO₂max and 300y round-trip running tests. Positive effects of strength training were determined in all tests, with the greatest impact on the variable right leg curl (LCR), Strength training improved by 10.7%, while variable squatting improved by 9.7%. After 12 weeks, the female soccer players' aerobic capacity increased by 4.3%, while their anaerobic capacity increased by 2.8%. These results demonstrate that 12 weeks of strength training can enhance the aerobic and anaerobic capacities of female soccer players. BalČiŪnas et al. (2006) A study was conducted to investigate how different training regimens affect the strength, speed, skills, and anaerobic capacity of male basketball players aged 15-16 over a four-month period. The athletes were divided into three groups: strength, endurance,

and control. Throughout the contest, the training program was carried out three times per week and comprised the subsequent assessments: The following tests were performed: 20-meter dash, squat jump, count-movement jump, running aerobic sprint assessment (RAST), two-minute shooting evaluation, and single dribbling evaluation. The results showed that both training regimens maintained initial speed and strength values, but only the strength endurance group improved their anaerobic capacity and skills. Basketball involves frequent physical contact, making injuries such as sprains and strains common. (Andreoli et al., 2001; Strasunskas, 2020) found in their study that strength training also enhances the stability of muscles, bones, and joints and reduces the risk of injury.

Table 2 Strength training literature review results

Researcher	Research purpose	Sample	Research results
Sporiš et al., 2011	This study	24 U-20 female	Strength training
	examined the	players	enhances the
	effects of resistance		aerobic and
	training on the		anaerobic
	endurance and		capacities of
	anaerobic capacity		women soccer
	of elite women		players.
	football players.		
Dasteridis et al.,	studied the effects	neuromuscular (NG)	The results of the
2011	of strength training	hypertrophy (HG)	study showed that
	on sprinting	control (CG)	both neuromuscular
	performance		and hypertrophic
			strength training
			programs were able
			to improve the
			participants'
			sprinting
	- Comment		performance
Bal $reve{c}$ i $ar{f u}$ nas et al.,	A study on the	strength endurance	Only the
2006	effects of different	group	participants in the
	training methods on	Endurance group	power endurance
	the strength, speed,	control group	group improved
	skills, and		their anaerobic
	anaerobic capacity		capacity and skills
	of basketball		
	players.		

Repeated sprint training

Repeated sprint training (RST) is a type of training that consists of performing short sprints (≤10 seconds in duration) at maximum effort interspersed with short (≤ 60 seconds) recovery period (Girard et al., 2011). This training pathway appears to be both effective and time-efficient for the physical adaptation of team participants, and it is common in most team and ball sports. Therefore, participants playing these sports may need to be able to recover and reproduce their performance in subsequent sprints. This ability is referred to as repeated sprint ability (RSA). RSA is commonly used as a specific means of performance testing in sports where running is the primary form of exercise (Zagatto et al., 2009). Basketball game is characterized by high intensity, high confrontation and intermittency (Stojanovi $\hat{\mathbf{C}}$ et al., 2018), where participants are required to perform rapid sprints, jumps, changes of direction, etc. in a short period of time, and it can be defined as a sport with a large amount of anaerobic and aerobic capacity (Narazaki et al., 2009). Gantois et al. (2019) The study examined the effects of repetitive sprint training. It focused on anaerobic and aerobic exercise capacity. The study was on basketball players. The study's methodology was as follows: A total of seventeen college students were divided into two groups. One group was the sprint training group. The other group was the control group. The control group only performed conventional training for six weeks before the season. The findings indicated that recurrent sprint training enhanced the optimal sprint time, the suboptimal sprint time, the sprint reduction, the CMJ, and the peak velocity of the incremental test. To sum things up, college basketball players can improve their sprint speed, jumping ability, and aerobic fitness related to neuromuscular mass during the final preseason period by doing repeated sprint training. Kaynak et al. (2017) the study examined the effects of a repetitive sprint training program on the aerobic capacity of college volleyball players. Participants: 18 male volleyball players were split into an experimental group and a control group. Both groups performed a traditional volleyball training program three times a week for six weeks. The experimental group performed a repetitive sprint training session immediately prior to each volleyball training session, Results: After training, the experimental group's maximum oxygen uptake (VO2 max) significantly improved, as did their time to exhaustion. The experimental group also saw significant improvements in both the average sprint time and the fatigue index of their best 20meter sprint time. The results of the study show that training college volleyball players to run faster and longer can make them better at playing volleyball. Fernandez et al. (2012) The study examined the impact of high-intensity interval training (HIIT) and repeated sprint training on various aspects of physical fitness and performance, including aerobic fitness, tennis-specific endurance, linear sprinting ability, RSA, and jumping ability. Subjects were divided into three groups: HIIT, RST, and CON. The results demonstrated the efficacy of RST as a training method, enhancing not only general and tennis-specific aerobic fitness levels but also RSA (Attene et al., 2015; Attene et al., 2016). In basketball, participants perform an average of 55 to 105 sprinting maneuvers, which can be repeated every 21 to 39 seconds (Abdelkrim et al., 2007; McCarthy et al., 1995), and maintaining a maximal or near-maximal sprint is a key requirement for game performance. Taylor et al. (2016) we compared the effects of two types of repeated sprint training programs on soccer fitness. Participants were assigned to either the straight-line (STR) group (n = 8) or the change-of-direction (COD) group (n = 7). Performance metrics covered 5-, 10-, and 20-m sprints, reverse jumps, Illinois agility, and Yo-Yo intermittent recovery test level 1 (YYIRTL1) performance. Improvements in acceleration, speed, and high-intensity running performance in soccer players were shown to result from just two weeks of repetitive sprint training. Implementing repetitive sprint training (RST) was also able to expose participants to maximal sprinting, acceleration, and deceleration, all of which are important components of team sports (Malone et al., 2017; Mendiquchia et al., 2020; Taylor et al., 2017). Repeated sprint training is characterized by low volume and short duration, usually lasting only 10 to 20 minutes at a time. However, because it maximizes training intensity, it is able to trigger adaptive events that ultimately lead to improved athletic performance (Taylor et al., 2015).

Table 3 Repeated sprint training literature review results

Research purpose	Sample	Research results
The study looked at	repetitive sprints	Sprint speed, jumping
how repetitive sprint	training group	ability, and aerobic
training affects the		fitness related to
ability of basketball	control group	neuromuscular mass
players to do		can be effectively
anaerobic and		improved by repeated
aerobic exercise.		sprint training.
studied the effects	experimental	A program of
of a repetitive sprint	group (n = 9)	repeated sprints
training program on	control group	improves both your
aerobic capacity	(n = 9)	aerobic and anaerobic
		capacity.
	The study looked at how repetitive sprint training affects the ability of basketball players to do anaerobic and aerobic exercise. studied the effects of a repetitive sprint training program on	The study looked at how repetitive sprints training group training affects the ability of basketball control group players to do anaerobic and aerobic exercise. studied the effects experimental of a repetitive sprint group (n = 9) training program on control group

Table 3 (continue)

Researcher	Research purpose	Sample	Research results
Fernandez et al.,	The effects of HIIT	HIIT group (n = 11)	Results showed a
2012	and RST on aerobic	RST group (n = 12)	significant time ×
	fitness, tennis-	control group	intervention
	specific endurance,	(CON, n = 9)	interaction on VO ₂
	the focus of the		peak, with a
	investigation was		significant increase
	on linear and		of 4.9% in the RST
	repeated sprint		group (p = 0.010)
	ability (RSA) and		and a significant
	jump ability.		improvement in
			RSA due to RST
Taylor, J. 2016	compared the	straight line (STR)	The results show
	effects of two	repetition training	that just two weeks
	repetitive sprint	group	of repetitive sprint
	training programs	direction (COD)	training was able to
	on soccer fitness	repetition training	stimulate
		group	improvements in
			acceleration,
			Speed. High-
			intensity running is
			another key
			component. in
			soccer players

Concurrent strength and repeated sprint training

Based on existing research, the researcher recommended a combination of strength and sprint training, the researcher reviewed the literature previously studied. Campos-Vazquez et al. (2015) The investigation focused on the impact of integrating repeated sprint training with two distinct muscle strength training methods on the physical performance of young athletes. Researchers randomly assigned twenty-one soccer players to one of two groups: the squat group (SG) or the jump group (TG). It was shown by the results that a 5.28% increase (p \leq 0.05) in the CMJ height was experienced by the SG group. there were no significant changes in the RSA or YYIRT1 values of either group. Thus, performing repetitive sprint training once a week and strength training twice a week does not appear sufficient to stimulate an increase in RSA during the final stage of the season. Whereas (Phongsri, 2017) conducted a 5-week concurrent specific strength and repeated sprint training study with 12 futsal players by performing 2 sets of 3 position strength training at 70% 1RM and jumping over a fence 5 times and then repeated sprint training 7 rounds was found to improve the performance of the futsal players and lead to a stimulus of increased insulin-like growth factor 1. Boer and Van Aswegen (2016) A study was conducted to examine the impact of two distinct training regimens on various physical parameters associated with soccer fitness training. The first regimen involved a repeated sprint training (RST) program, while the second regimen was a combination of training (COM) consisting of RST, aerobic intervals, and continuous aerobic and explosive leg strength training. Forty-six soccer players participated in the study and were assigned to one of three groups: RST, COM, or CON. The players underwent six weeks of training during the preseason. The variables included aerobic capacity, 30-meter sprint, yo-yo interval recovery test 2 (YYIRT2), agility, and explosive power. After six weeks of training, running distance on the YYIRT2 and maximal speed on the VO₂ max test were significantly higher in the RST and COM training groups compared to the CON group and correlated with physical performance in elite soccer. (Fernandez et al., 2015) examined the effects of a repeated sprint and explosive power training program on elite junior tennis players during the

season. Analysis of the effects of twice-weekly explosive strength and repeated sprint training programs on the performance of young elite tennis players during competition. Eight internationally competitive male junior tennis players participated in an eight-week training intervention. Following training, all performance variables improved significantly, except for the RS test and the percentage decrease in maximal aerobic performance. A common assumption is that a training program combining ExpS and RS would be more effective than one using just ExpS or RS. However, the results show that combining these programs is an effective way to improve the RSA and neuromuscular performance of high-level tennis players. Wong et al. (2010) A study was conducted to examine the impact of a combination of muscle strength training and high-intensity interval training on football players before the season. The players were divided into two groups: an experimental group and a control group. Both groups underwent regular football training. The back half-squat and bench press saw a significant increase in 1RM (p ≤ 0.05) due to EGC, all while body weight remained unchanged. In terms of jump height, 10-meter and 30-meter sprints, and the Yo-Yo IR1 test, the EG group showed significantly greater internal improvements than the CG group (p \leq 0.01). These results suggest that combining high-intensity interval running with high-load muscle strength training can improve explosive power and aerobic endurance in football players. Brahim et al. (2021) This study examined how combining muscle strength training with resistance sprint training affects lower-body physical performance in football players. The results were then compared with those of traditional football training. A total of 34 male football players were allocated to either the resistance sprint training group or the control group. The following tests were assessed before and after a six-week training program: Five-meter sprint, 20-meter sprint, squat jump, reverse movement jump, half-back squat with one maximum weight, and football shooting speed. It was concluded that the combination of strength training and horizontal resistance sprint training was more effective than traditional football training in improving football sprinting, jumping ability, and shooting speed. Marques et al. (2015) the study examined how full squat training and full squat plus sprint training affect the sprint

performance of non-athletes over distances ranging from 0 to 30 meters. There were 122 people in all. They were divided into four groups. One group did full squats. One group did full squats and sprints. One group did speed training only. One group was the control group and did not train. Sprint performance exhibited enhancement subsequent to sprint or full sumo squat training alone, and demonstrated a more pronounced augmentation subsequent to full sumo squat plus sprint training. These results suggest that adults involved in recreational activities, a combination of full squat and sprint training is more effective in stimulating sprint performance gains than either training modality alone. Del Vecchio et al. (2019) The effects of strength and sprint training on the physical performance of cyclists were investigated. Twenty-five athletes were assigned to one of 3 groups: CT group, ST group, or CG group. Significant differences in time to exhaustion (TT) were observed between the CT and CG groups after training (p < 0.05). Both the CT and ST groups significantly increased LLLM, and the CT group significantly increased TT (p < 0.05). These results suggest that incorporating strength and sprint exercises into training programs can enhance athletes' sprint performance.

However, these are studies on other sports and no studies have been conducted on basketball; therefore, it is of great relevance to conduct a study on the effects of additional concurrent strength and repeated sprint training on the physical performance of college basketball players. The results of the study can be used to maximize the physical results of college basketball players to prepare them for competition, which will benefit participants, coaches, sports persons, and interested parties.

Table 4 Concurrent strength and repeated sprint training literature review results

Researcher	Research purpose	Sample	Research results
Phongsri. 2017	Effects of concurrent	12 futsal players	Could improve IGF-1
	specific strength		response and
	and repeated sprint		performance of
	training on IGF-1		futsal players
	and physical		
	performance in		
	futsal players		
Campos-Vazquez et	examined the effects	deep squat group	it appears that a
al., 2015	of repetitive sprint	jumping group	combination of one
	training combined		repetitive sprint
	with two different		training session per
	muscular strength		week and two
	training methods		strength training
			sessions per week
			may not be sufficient
			to stimulate an
			increase in RSA
			during the final
			stages of the season

Table 4 (continue)

Researcher	Research purpose	Sample	Research results
Boer, P. 2016	Researchers	RST(COM)	After six weeks of training,
	investigated the	control	running distance on the
	effects of repeated (CON)		YYIRT2 and maximal speed
	sprint training (RST)		on the VO ₂ max test were
	on physical		significantly higher in the
	parameters.		RST and COM training
			groups compared to the
			CON group and correlated
			with physical performance
			in elite soccer
Fernandez et al.,	Examined the effects	Eight	Combining ExpS and RS
2015	of a repetitive sprint	internationally	training programs appears
	and explosive power	competitive	to be an effective training
	training program on	male junior	tool to improve
	elite junior tennis	tennis	neuromuscular performance
	players during the	players	and RSA in elite tennis
	season		players

Table 4 (continue)

Researcher	Research purpose	Sample	Research results
Wong et al., 2010	The impact of	experimental	The results show that it
	muscle strength	group	improves explosive
	and high-intensity	control group	power and aerobic
	interval training on		endurance in football
	the performance of		players.
	football players		
Ben Brahim et al.,	investigated the	resistance sprint	A combination of
2021	effects of combined	training group	strength training and
	muscular strength	(RSTG, $n = 20$)	horizontal and vertical
	and resistance	control group	resistance sprint
	sprint training using	(CONTG, n = 14)	training is more
	a sled and weighted		effective than
	undershirt on the		traditional football
	lower extremity		training in improving
	fitness of U-19 elite		football sprinting,
	soccer players		jumping ability, and
	compared to		shooting speed
	conventional soccer		
	training		

Table 4 (continue)

Researcher	Research purpose	Sample	Research results
Marques et al., 2015	examined the extent	a full squat training	These results
	to which 6 weeks of	group (n = 36)	suggest that for
	full squat versus full	a combined full	adults involved in
	squat plus sprint	squat and sprint	recreational
	running training	training group	activities, a
	shifted sprint	(n = 32)	combination of full
	running	a speed-only	squat and sprint
	performance in non-	training group	training is more
	participants (0 - 10	(n = 34)	effective in
	to 0 - 30 meters)	a no training control	stimulating sprint
		group (n = 20)	performance gains
			than either training
			modality alone
Del Vecchio et al.,	Study examines the	combined strength	It has been
2019	effects of combined	and sprint training	indicated by the
	strength and sprint	group (CT, $n = 9$)	results that the
	training on cyclists'	sprint training group	sprint performance
	performance	(ST, n = 7)	of cyclists can be
		control group (CG,	improved by
		n = 9)	incorporating
			strength and sprint
			training into their
			training.

CHAPTER 3

METHODOLOGY

For this study, the researcher conducted the following steps

- 1. Identification of the total and sample
- 2. Research tools
- 3. Data collection methods
- 4. Research design and procedures
- 5. Statistical analysis

Defining the population and participants

Population used in the study

The population in this study were 32 male basketball players from Lanzhou Modern Vocational College, aged 18-21 years old. They had at least two years of basketball practice and competition experience, and were preparing to join the Level 3 (CUBAL) provincial Collegiate University Basketball League.

Participants

This study recruited 24 male basketball players through purposive random sampling. They have participated in the provincial basketball league once or twice. Sample size was calculated using G*Power software version 3.1.9.2. Effect size was set to 0.60, based on previous research (Phongsri, 2017). Power was set to 0.80%.

1. Inclusion criteria

- 1.1 To samples had at least two years of basketball practice and competition experience, representing the school in the provincial level 3 Collegiate University Basketball League (CUBAL).
- 1.2 Participants have practiced more than six times per week for at least two months.
- 1.3 Participants must be free from any injury that would preclude their involvement in the study.

2. Exclusion criteria

- 2.1 Injured participants
- 2.2 Training for less than two months
- 2.3 Participants with less than 85% attendance

Research tools

Measuring tools

- 1. Portable stadiometer (Seca, mod206 Birmingham United Kingdom)
- 2. Portable scale (Seca, mod762, Birmingham United Kingdom)
- 3. Photocell system (Speed Test 6.0 CEFISE®, São Paulo, Brazil)
- 4. High Jump Trainer (Brand: CSSIT, Origin: China)
- 5. Heart rate monitor (Red mi, Model: M2225B1, Origin: Xiaomi Technology Co. Ltd. China)

Data collection methods

- 1. Contacted the Lanzhou Modern Vocational College to send a letter of request to support the research sample with the head athletic trainer.
- 2. Submitted a letter requesting permission to submit the human subject study to the ethics review committee for review of the research project.
 - 3. Prepared the site, equipment, and documents for the study.
- 4. Explained the details to the volunteers so that they understand and sign a consent form to participate.
 - 5. Explained to volunteers how to perform each step of data collection.
 - 6. Collected age, height, and weight, from the participants
 - 7. Follow the research process and record the data to analyze the results
 - 8. Summarize and analyze the results of the study

Research design and procedures

The design of this study was a randomized controlled trial. Participants consisted of a total of 24 male collegiate basketball players undergoing training. The players were randomly divided into 2 groups consist of normal basketball training group

(control group) (NTG, n=12) and concurrent strength and repeated sprint training supplement regular basketball training group (CTG, n=12). The sample was randomly divided into two groups were using 1RM of barbell squat, with the NTG consisting of participants with 1RM of barbell squat score in the order of 1, 4, 5, 8, 9, 12, 13, 16, 17, 20, 21, and 24, and the other orders as the CTG. This grouping was done in order to prevent differences in sample performance before the experiment began.

The concurrent strength and repeated sprint training supplement regular basketball training group (CTG), in addition to their regular training, performed two sets of strength training and three sets of 6×30-meter repetitive sprint training (RST) twice a week, which were completed in the same training session, with strength training followed by RST training (Murlasits et al., 2018). The normal basketball training group (control group) (NTG) performed only regular basketball training during the six weeks prior to the tournament. At least three research assistant helped to collect the data each time, and all tests were performed in the morning from 07:00 am - 08:30 am ± 30 minutes. The temperature was maintained at 20-25 degrees Celsius during each test. Prior to each test, the sample group abstained from exercise for at least 24 hours prior to the test and from food or energy drinks for 3 hours prior to the test. All samples were tested in an indoor gymnasium measuring 60 m in length and 40 m in width. This study was conducted during the final phase of the basketball preseason where the participants trained for a period of 6 weeks (FIGURE 1). All participants were first familiarized with the testing process during the week prior to the start of the training session, and then the participants underwent assessments across two separate testing occasion, the first being a test of body composition, muscular strength (1RM), agility, and repeated sprint ability (RSA). A 24 hours rest period was implemented between sessions to minimize fatigue related variability and ensure accurate test results. A second session assessed explosive leg strength, acceleration ability, and aerobic capacity (VO₂ max). There was a 20-minute rest and recovery period between tests for each event, and all of these processes were completed within one week prior to the start of training. At the end of the 6 weeks of training, after all participants had rested for 48

hours, the participants were assessed on the same variables across two separate sessions following a protocol consistent with the pretest procedures.

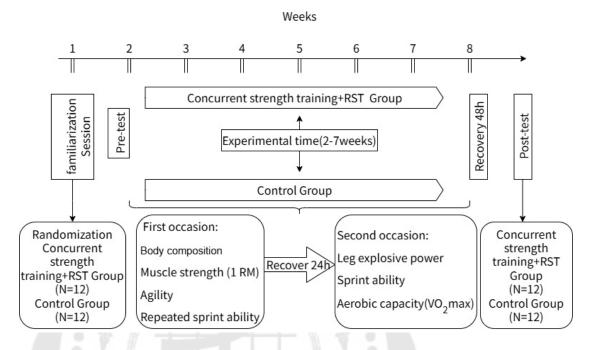


FIGURE 2 Research design and procedures

Standardized warm-up protocol

All participants must perform a standardized 10-minute warm-up routine before testing. This routine includes approximately 2 minutes of static stretching for the leg, back, front, and thigh muscles; 2 minutes of slow jogging; and 3 minutes of dynamic stretching for the same muscle group. The dynamic stretching should be done at approximately 80% to 90% of maximum speed. It should be done back and forth at a speed of 20 meters for two laps. Professional research assistants will supervise and guide participants during the warm-up.

Body composition test

Use an electronic scale (Meiren, Shenzhen, China) to measure baseline weight and height and calculate BMI values, with an accuracy of 50 g, and use a coupled height meter with an accurately of 0.01 cm.

Muscle strength (1 RM) test

Perform 1RM tests on the barbell squat, deadlift, and power clean, respectively. The researcher instructed the participants to warm up with a weight they could easily perform for 5-10 repetitions, then rest for 1 minute. Participants performed 3-5 repetitions of a weightlifting test with a $10\% \sim 20\%$ increase in weight over the sample weight, and then rested for 2 minutes. The researchers estimated that the participants could lift the maximum weight for 2-3 repetitions by increasing the weight an additional $10\% \sim 20\%$. Starting with the sample weight and resting for 3 minutes, the researchers increased the weight by $10\% \sim 20\%$ until the subject was able to successfully lift the weight in 1 repetition using correct and appropriate technique, this is the maximum weight that can be lifted for each exercise. The National Strength and Conditioning Association (NSCA) tests the maximum lift weight based on prior research. (Shinkle et al., 2012). The reliability of the test method was analyzed by the intra-group correlation coefficient at the level of 0.96-0.97.3.

Leg explosive power test

The counter movement jump (CMJ) test (FIGURE 3), measure leg muscle explosive power, test vertical jumping ability, and assess lower limb explosive power. The requirement is to stand with the feet shoulder-width apart, place the hands in front of the chest and look up, stomp the ground with force, jump as high as possible, keep the body vertical while jumping, and use the lightest force to touch the label at the highest point. After the standard warm-up, each subject performed 3 jumps with 1-minute rest between each jump to achieve optimal jumping performance. The optimal jumping performance was statistically analyzed and tested with reference to a previous study (Ramírez-Campillo et al., 2013).



FIGURE 3 Leg explosive power testing using the CMJ test protocol

Retrieved from: https://pic1.zhimg.com/v296a3bfde56c9a5aac2098da3d811804f

Source: (Ramírez-Campillo et al., 2013)

Agility test

Agility testing using the T-test (FIGURE 4). The agility T-test test involves moving the body forward, sideways, and backward. The researchers placed 10-centimeter-high cones. The test was conducted on an indoor sports field that was 60 meters long and 40 meters wide. The researchers first placed tape on the surfaces of cones A, B, C, and D. A Photocell system (Speed Test 6.0 CEFISE®, São Paulo, Brazil) set the width of 2 meters at point A. After completing the standard warm-up work, the participants started with both feet behind the starting line A, started from 0.5 m away from the starting line, and at a maximum speed sprinted to cone B, touching the bottom of the cone with the right hand. The athlete faces forward and keeps their legs uncrossed. They move to cone C on the left and touch its base with their left hand. Then, they move to cone D on the right and touch its base with their right hand. Next, they move left to cone B and touch its base. Finally, the athlete runs backward as fast as possible to return to line A. if the athlete crosses one foot in front of the other, does not touch the base of the cone and never looks forward, the test is cancelled and repeated if the subject did not perform correctly. The test was performed 2 times with a 2-minute

break between each test. The test duration was calculated to an accuracy of 0.001 seconds. The best score from both tests was statistically analyzed (Pauole et al., 2000).

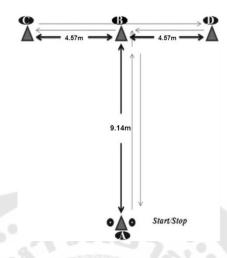


FIGURE 4 Agility testing using the T-test protocol

Source: (Rishiraj et al., 2011)

Repeated sprint ability (RSA) test

The RSA test consisted of a maximum speed sprint over a distance of 20 m, with a total distance of 40 m per lap (20 + 20 m with 180 degree turns), all 6 laps had to be tested, with a 20 second recovery between sprints (FIGURE 5), and the running time of each lap was recorded. Placement of the Photocell system at the start and finish gates. Immediately after the 5-minute warm-up, the athletes underwent a 40-meter maximum speed test. This test was used as the standard for approving the RSA program. To prevent pacing strategies, the athletes were required to give their all in each sprint. The score for the first sprint had to be at least 90% of the maximum speed over 40 meters. As for results, the following indices were identified: RSA best = (the best performance among all sprints), RSA worst = (the worst performance among all sprints), RSA total time = (total time of all sprints), RSA mean = (mean sprint time), and RSA decrement = (percentage decrement in sprint performance). The formula is as follows (Fitzsimons, 1993):

Sprint decrement performance = [100-(Total time/Best time)] ×100

Note: Total time = The total time 6 lap and best time (RSAB) = The best time from 6 laps.

TEST:Repeated sprint ability(RSA)

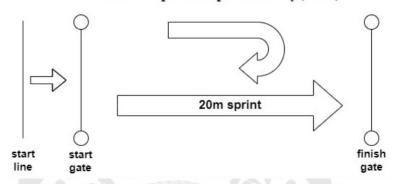


FIGURE 5 Repeated sprint ability testing using the RSA test protocol

Source: (Phongsri, 2017)

Sprint ability test

After the standard warm-up, the test was performed on a 60 m long and 40 m wide indoor sports field with Photocell system (Speed Test 6.0 CEFISE®, São Paulo, Brazil) placed at 10 m and 20 m intervals. Participants began the sprint when ready at the starting line 1 m behind the photocell. A 20 m distance was run at maximum speed (FIGURE 6) and the time (in seconds) required for each 10 and 20 m sprint was recorded to within 0.001 seconds. The researchers advised the participants to perform at their optimum level. The time taken by the subject to pass through each timed gate was recorded each time. The test was administered in 2 rounds with a 2 minutes break between rounds. The optimal time was used for further statistical analysis in this study. The 20 m sprint ability was based on previous basketball research (Delextrat & Cohen, 2009).

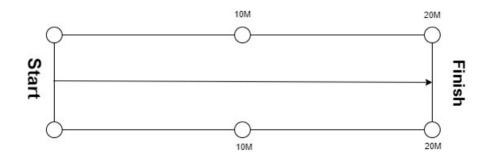
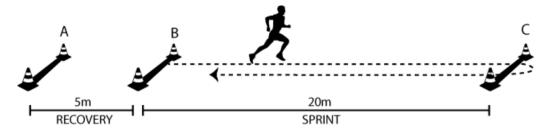


FIGURE 6 Sprint ability performance test

Source: (Sousa et al., 2020)

Aerobic capacity (VO₂ max) test

VO₂ max was tested using the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR 1) on an indoor track 60 meters long and 40 meters wide. The test consists of running between 20-metre laps (180-degree turns) (FIGURE 7), following audio cues to determine the desired running speed. After each 40-metre run, participants were given a 10-second active rest period before running a further 40 meters. The test began with 4 laps at a speed of 10-13 km/h (distance 0-160 m), followed by 7 laps at a speed of 13.5-14 km/h (distance 160-440 m). The test then continued at an additional 0.5 km/h every 8 laps. The maximum test speed was 19 km/h. The total test distance was 3,640 m. During the test, the participants were monitored by warning signals emitted from a low volume loudspeaker. The test was terminated when the subject failed to reach the start line after two consecutive beeps or became exhausted. Total running distance was reported in meters according to the Yo-Yo IR 1 test program used for statistical analysis. Maximal oxygen uptake (VO₂ max) was estimated using the predictive equation developed by (Bangsbo et al., 2008), based on performance in Yo-Yo IR 1. The formula used was: VO₂ $\max (ml \cdot kg^{-1} \cdot min^{-1}) = (distance covered in meters \times 0.0084) + 36.4. Yo-Yo-IR 1 was$ based on a previous study of futsal players (Soares-Caldeira et al., 2014).



Yo-Yo Intermittent Recovery Test

FIGURE 7 Aerobic capacity (VO₂ max) testing using the Yo-Yo IR 1 test protocol

Source: (Soares-Caldeira et al., 2014)

Training program

This study was a 6-week training program during the final phase of the basketball preseason in preparation for the provincial collegiate basketball league (CUBAL). The training program consisted of the coaching staff setting goals for the development of physical fitness, technical and tactical skills. Physical fitness development includes gym and indoor training, strength training, muscular strength development, aerobic and anaerobic endurance, speed and agility skill development. Technical skills include dribbling, turning, breaking, shooting and passing. Tactical training includes zone defense, individual defense, press defense, counterattack, half-court defense, offensive movement, offensive play, defensive play drills and video analysis. Practices are held once a week on Monday, Wednesday and Friday mornings and afternoons. Each session lasts approximately 100-120 minutes and there is no training on Tuesdays, Thursdays, Saturdays or Sundays. Each week, with the exception of Monday and Friday afternoons (Table 5), both teams trained in the same way. After listening to the head coach's training program on Monday and Friday afternoons. The control group trained for about 40 minutes of fitness training and then returned to tactical training and Simulation competition program. The experimental group performed control training for about 60 minutes and then returned to tactical training and Simulation competition program. The control group (regular basketball training team) focused on developing physical and technical skills under the supervision of the team's coach, while the experimental group (control training team) underwent a control training program with additional concurrent strength and repeated sprint training, with training supervised by experienced research assistants, and with the same amount (duration) of training for both the control and experimental groups. The researchers measured each subject's heart rate and perceived exertion score (RPE Borg scale) (FIGURE 8) using a heart rate monitor (Red mi, Model: M2225B1, Origin: Xiao Mi Technology Co. Ltd. China)(Borg et al., 1987) to assess the volume and intensity of training in both groups.



Table 5 The training program design for NTG and CTG

	Мо	nday	Wedn	esday	Fri	day
	AM	PM	AM	РМ	AM	PM
		Fitness				Fitness
NTG		training			Tananassanle	training
(N=12)	Taabaiaal	Tactical	Tankaisal	Clarations	Teamwork	Tactical
	Technical	training	Technical	Shooting	training	training
	training	+ • •	training	training	Video	+
		Simulation			analysis	Simulation
		competition				competition
		Strength		M.C.		Strength
CTG		and RST				and RST
(N=12)		training			Teamwork	training
	Technical	+	Technical	Shooting	training	+
	training	Tactical	training	training	Video	Tactical
		training			analysis	training
		Simulation				Simulation
		competition				competition

Note: shows a one-week training program, which is the same for the first six weeks of the entire season, detailed of the NTG fitness training are in the Appendix A.

Concurrent training programs

Concurrent strength and repeated sprint training

Strength training includes barbell squats, deadlifts and power clean. Perform 3 sets of 6 repetitions of each exercise at 80% of 1RM. Rest 3 minutes between sets. The total strength training duration is approximately 30 minutes. The training program is shown in Table 6. The repeated sprint training program consists of 3 sets of 6 repetitions of straight-line sprinting at maximum speed. 30-meter round trips (15 meters forward and 15 meters backward, with 180 degrees of rotation). There was a 20-second rest between rounds and a 5-minute rest between sets. The total time for the sprint repetitions is approximately 20 minutes, with 15 minutes rest between exercise patterns. Total workout time is approximately 65 minutes.

Table 6 Strength training program

Exercises	Set	Rep	Intensity	Rest interval
	311			
Barbell squat	3	6	80%1RM	3 min
	. 5			
Deadlift	3	6	80%1RM	3 min
		"HW"		
Power clean	3	6	80%1RM	3 min

In experiments with two training programs, researchers exercised and measured heart rate with a heart rate monitor (Red mi, Model: M2225B1, Origin: Xiaomi Technology Co. Ltd. China) after each group until the end of the experiment and measured the rating of perceived exertion (RPE Borg scale) (FIGURE 8)(Borg et al., 1987).

Rating	Descriptor
0	rest
1	very, very easy
2	easy
3	moderate
4	somewhat hard
5	hard
6	
7	very hard
8	
9	
10	maximal

FIGURE 8 RPE Borg scale

Source: (Zamunér et al., 2011)

Diet and exercise control

To prevent side effects of diet and exercise from affecting changes in hormone levels during the experiment, participants were advised to stop exercise and all forms of physical training for at least 48 hours prior to the experiment. Participants were asked to record their food intake for 48 hours. Participants were required to consume the same food prior to both experiments. Participants were also asked to abstain from alcohol and caffeinated beverages, smoking, and alcohol consumption for 48 hours prior to the experiment.

Statistical analysis

1. review and organize the results of each test before and after the experiment, the results of data analysis were presented in the form of mean and standard deviation.

The normality of the distribution of all variables was tested using the Shapiro-Wilk test to

select parametric statistics. If the data distribution of any variable was not normal, a nonparametric statistic was selected.

- 2. Statistical analyses were conducted to examine the interaction effects between group (normal and controlled) and time (pre-training and post-training) on body composition, muscular strength (1RM), leg explosiveness, agility, 20-meter sprint ability, and aerobic fitness (VO_2 max). When significant interactions were identified in the two-way repeated measures analysis of variance (ANOVA), individual differences were further analyzed using Bonferroni post hoc tests.
- 3. G-Power statistical software version 3.1.9.2 (University of Düsseldorf, Düsseldorf, Germany) was used to calculate sample sizes and determine the reliability of test methods. Statistical analyses were performed using intra-group correlation coefficients (ICC), and all statistical data analyzed were determined to be statistically significant at the 0.05 level using the computer software used for statistical analyses (SPSS version 26, IBM, Chicago, Illinois, USA).

CHAPTER 4 RESULTS

Data analysis results presentation

This presentation is divided into two topics: Participant characteristics and physical performance. The specific content of each topic is as follows:

Participants data

The sample group of this study has general physical data and relevant variable performance. All samples were male.

Table 7 Participant characteristics and performance outcomes before training

Variables	CTG (n=12)	NTG (n=12)
variables	Mean ± SD	Mean ± SD
Age (year)	19.75±0.97	19.75±0.87
Height (cm)	181.92±5.11	182.01±4.40
Weight (kg)	79.88±6.65	79.78±6.41
ВМІ	24.12±0.93	24.04±0.97
1RM Barbell Squat (kg)	100.17±12.63	107.08±9.26
1RM Power Clean (kg)	59.67±6.37	59.92±6.22
CMJ (cm)	46.38±1.85	48.44±1.99
RSA _{best} (s)	7.11±0.05	7.13±0.04
$RSA_{worst}(s)$	7.71±0.05	7.73±0.05
RSA total time (s)	44.49±0.26	44.45±0.22
RSA _{mean} (s)	7.41±0.04	7.40±0.04
Yo-Yo IR 1 (m)	1,355.00±91.89	1,289.58±84.70
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	47.77±0.77	47.24±0.72
T-Test (s)	10.21±0.10	10.25±0.05
20 m Sprint (s)	2.79±0.019	2.81±0.02

Physical performance

Effect on muscle strength (1RM) performance

After training, both groups demonstrated significant improvements in muscle strength including barbell squat, deadlift, power clean (P < 0.001) (FIGURE 9). However, no significant differences were observed between groups post-training (Barbell squat: CTG 113.58 \pm 14.20 kg vs. NTG 112.67 \pm 10.18 kg; Deadlift: CTG 133.50 \pm 13.66 kg vs. NTG 124.83 \pm 12.07 kg; Power clean: CTG 66.42 \pm 4.93 kg vs. NTG 64.17 \pm 6.35 kg). All data are shown in Table 8.

Table 8 The results of the mixed analysis of variance statistics of CTG and NTG

			CAPPER TO SERVICE			
Variable	Croup	Pre-test	Post-test	%	Within	Between
Variable Group		(Mean ± SD)	(Mean ± SD)	change	group(p)	group(p)
1RM	CTG	100.17±12.63	113.58±14.20	13.42±2.99	0.001#	
Barbell Squat(kg)	NTG	107.08±9.26	112.67±10.18	5.58±4.23	0.001#	0.533
1RM	CTG	118.75±14.74	133.50±13.66	14.75±2.59	0.001#	
Deadlift(kg)	NTG	118.83±11.55	124.83±12.07	6.00±1.48	0.001#	0.428
1RM Power	CTG	59.67±6.37	66.42±4.93	6.75±3.28	0.001#	
Clean (kg)	NTG	59.92±6.22	64.17±6.35	4.25±1.48	0.001#	0.680

^{*} Significantly different between groups P<0.05

^{*} Significantly different within groups P<0.05

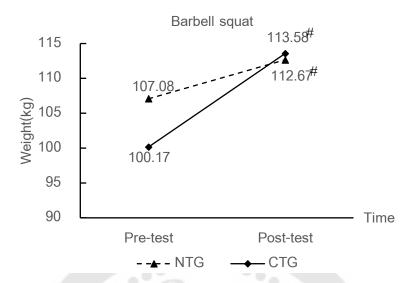


FIGURE 9 Differences in barbell squat post-test within CTG training.

Effect on leg explosive power performance

After training, both groups demonstrated significant improvements in CMJ performance following the training (P < 0.001). However, no significant differences were observed between groups post-training (CMJ: CTG 49.08 ± 1.80 cm vs. NTG 49.90 ± 2.39 cm). All data are shown in Table 9.

Table 9 The results of the mixed analysis of variance statistics of CTG and NTG

Variable Group	Croup	Pre-test	Post-test	%	Within	Between
	Group	(Mean ± SD)	(Mean ± SD)	change	group(p)	group(p)
CMJ (cm)	CTG	46.38±1.85	49.08±1.79	2.70±0.37	0.001#	0.000
	NTG	48.44±1.99	49.90±2.39	1.45±0.79	0.001#	0.092

^{*} Significantly different between groups P<0.05

^{*}Significantly different within groups P<0.05

^{*}Significantly different within groups P<0.05

Effect on repeated sprint ability (RSA) performance

After training, For the RSA $_{\rm best}$, RSA $_{\rm total\ time}$ and RSA $_{\rm mean}$, only the CTG group showed significant within-group improvement (P < 0.001), and comparing post-test was significantly lower than the NTG group (RSA $_{\rm best}$:7.03±0.04 sec vs. 7.11±0.06 sec; RSA $_{\rm total}$ $_{\rm time}$:43.96±0.27 sec vs. 44.52±0.39 sec; RSA $_{\rm mean}$:7.33 ± 0.45 sec vs. 7.42 7.42±0.07 sec) (FIGURE 10, FIGURE 11 and FIGURE 12). For the RSA $_{\rm worst}$, again, significant withingroup improvement was only demonstrated in the CTG group (P < 0.001). however, there were no significant differences between groups after training, For the RSA $_{\rm decrement}$, the NTG group exhibited significant within-group change (P < 0.001), while the CTG group did not. All data are shown in Table 10.

Table 10 The results of the mixed analysis of variance statistics of CTG and NTG

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	% change	Within group(p)	Between group(p)
RSA _{best} (s)	CTG	7.11±0.05	7.03±0.04	0.82±0.01	0.001#	0.001*
No N _{best} (3)	NTG	7.13±0.04	7.11±0.06	0.14±0.03	0.116	0.001
RSA worst (s)	CTG	7.71±0.05	7.67±0.04	0.47±0.01	0.001#	0.098
worst (0)	NTG	7.72±0.05	7.73±0.07	0.01±0.02	0.915	0.000
RSA total time	CTG	44.49±0.26	43.98±0.27	0.51±0.10	0.001#	0.001*
(s)	NTG	44.45±0.22	44.52±0.39	0.08±0.25	0.323	
RSA _{mean} (s)	CTG	7.42±0.04	7.33±0.45	0.87±0.02	0.001#	0.001*
mean (5)	NTG	7.40±0.04	7.42±0.07	0.01±0.04	0.323	
RSA decrement	CTG	4.22±0.07	4.19±0.29	0.02±0.31	0.862	0.181
(%)	NTG	3.92±0.37	4.30±0.18	0.38±0.42	0.009#	

^{*} Significantly different between groups P<0.05

^{*} Significantly different within groups P<0.05

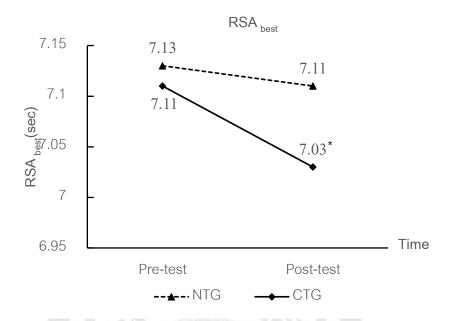


FIGURE 10 Differences in RSA $_{\rm best}$ post-test between CTG vs NTG training.

* Significantly different between groups P<0.05

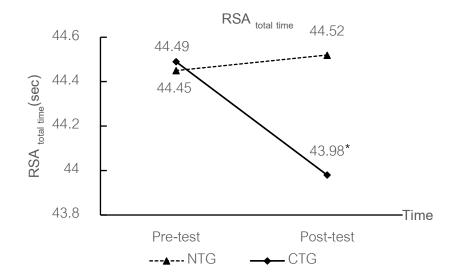


FIGURE 11 Differences in RSA $_{\rm total\ time}$ post-test between CTG vs NTG training.

* Significantly different between groups P<0.05

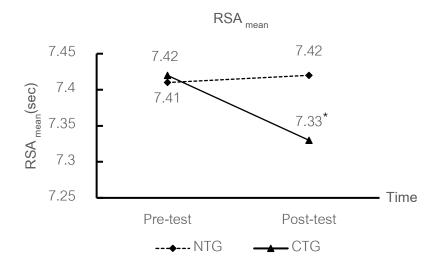


FIGURE 12 Differences in RSA $_{\rm mean}$ post-test between CTG vs NTG training.

Note: NTG; Normal basketball training group (n=12) CTG; Concurrent strength and repeated sprint training group (n=12)

* Significantly different between groups P<0.05

Effect on aerobic capacity (VO₂ max) performance

After training, both groups demonstrated significant improvements in Yo-Yo IR1 performance following the training (P < 0.001). In the post-test, the CTG group showed significantly greater more than the NTG group (1,543.33 ± 89.38 m vs. 1,396.67 1,396.67±89.38 m; P < 0.001) (FIGURE 13). The index of VO₂ max was significantly improved in both groups (P < 0.001). In the post-test, the CTG group performed significantly better than the NTG group (49.37±0.75 ml·kg $^{-1}$ ·min $^{-1}$; P < 0.001). All data are shown in Table 11.

Table 11 The results of the mixed analysis of variance statistics of CTG and NTG

Variable	Croup	Pre-test	Post-test	%	Within	Between
Variable	Group	(Mean ± SD)	(Mean ± SD)	change	group(p)	group(p)
Yo-Yo IR1	CTG	1,355.00±91.89	1,543.33±89.38	188.33±34.59	0.001#	0.001*
(m)	NTG	1,289.58±84.70	1,396.67±89.37	107.08±20.05	0.001#	
VO ₂ max	CTG	47.77±0.77	49.37±0.75	1.60±0.29	0.001#	0.001*
(ml·kg ⁻¹ ·min ⁻¹)	NTG	47.24±0.72	48.13±0.75	0.90±0.17	0.001#	- 0.001*

^{*} Significantly different between groups P<0.05

^{*}Significantly different within groups P<0.05

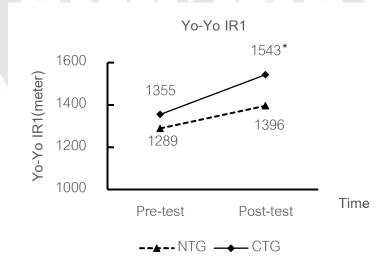


FIGURE 13 Differences in Yo-Yo IR1 post-test between CTG vs. NTG training.

^{*} Significantly different between groups P<0.05

Effect on agility performance

After training, For the T-Test, both groups showed significant within-group improvement (P < 0.001), Nevertheless, the groups did not show any major differences after the training. all data are shown in Table 12.

Table 12 The results of the mixed analysis of variance statistics of CTG and NTG

Variable	Group	Pre-test	Post-test	%	Within	Between
		(Mean ± SD)	(Mean ± SD)	change	group(p)	group(p)
T-Test	CTG	10.21±0.10	10.16±0.09	0.05±0.03	0.001#	0.056
(s)	NTG	10.25±0.05	10.24±0.05	0.02±0.01	0.001#	0.050

^{*} Significantly different between groups P<0.05

Effect on acceleration ability performance

After training, both groups demonstrated significant improvements in 10m,20m Sprint performance following the training (P < 0.001). And both groups had significantly lower post-test scores than the NTG group (10 m Sprint:1.56 \pm 0.02 sec vs. 1.60 \pm 0.02 sec; 20 m Sprint:2.72 \pm 0.02 sec vs. 2.79 \pm 0.02 sec) (FIGURE 14, FIGURE 15). All data are shown in Table 13.

Table 13 The results of the mixed analysis of variance statistics of CTG and NTG

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	% change	Within group(p)	Between group(p)
10 m	CTG	1.62±0.021	1.56±0.02	0.06±0.01	0.001#	0.001*
Sprint(s)	NTG	1.62±0.015	1.60±0.02	0.02±0.01	0.001#	
20 m	CTG	2.79±0.02	2.72±0.02	0.08±0.01	0.001#	0.001*
Sprint(s)	NTG	2.81±0.02	2.79±0.02	0.02±0.01	0.001#	

^{*}Significantly different within groups P<0.05

^{*} Significantly different within groups P<0.05

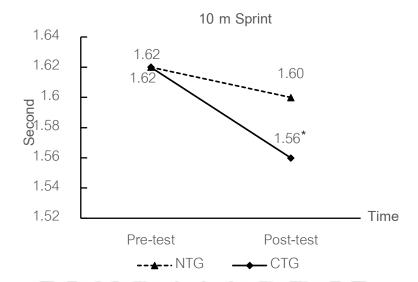


FIGURE 14 Differences in 10 m Sprint post-test between CTG vs. NTG training.

* Significantly different between groups P<0.05

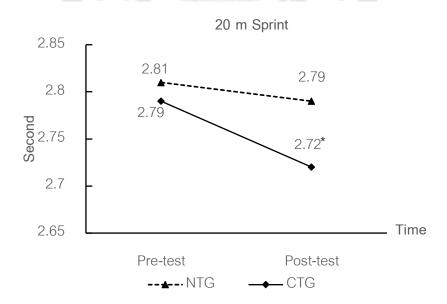


FIGURE 15 Differences in 20 m Sprint post-test between CTG vs. NTG training

^{*} Significantly different between groups P<0.05

* Significantly different between groups P<0.05



CHAPTER 5

DISCUSSION AND CONCLUSION

Basketball games are characterized by high intensity, high confrontation and intermittent nature. Participants need to complete quick sprints, jumps and changes of direction in a short period of time. Studies have shown that in team sports, especially in basketball, participants repeat 55 to 105 sprints every 21 to 39 seconds on average, and maintaining maximum or near-maximum sprint speed is key to performing well in competitions. The capacity to sustain peak performance during successive sprints is termed repeated sprint ability (RSA). Therefore, strength, muscle explosiveness and repeated sprint ability are very important physical qualities for basketball players. This will have a positive impact on game performance. Since participants need time to practice to develop game techniques and tactics, using the above training modes for developing physical qualities in the same training session may have a positive impact on the development of physical qualities, especially when training time is limited. This study will outline the conclusions and discussions of this study in the following order: Brief Summary of the Study, discussion of results, conclusions and suggestions for further research, and practical application of research results

Brief summary of the study

The study's objective was to examine the impact of concurrent training on the physical performance of college basketball players before the season. The researcher collected data and summarized the results as follows

Muscle strength (1RM)

The results showed that after training, both groups showed significant improvements in barbell squat, deadlift and power clean, which were statistically significant.

However, no significant differences were observed between the groups after training. As reflected in the data, the CTG group (strength and repeated sprint training) showed a trend of better improvement.

Leg explosive power

The results showed that both groups showed statistically significant improvements in CMJ performance after training. However, there was no significant difference between the groups after training.

Repeated sprint ability (RSA)

The results showed that for (RSA best, RSA total time and RSA mean, only the CTG group (strength and repeated sprint training) showed significant improvement within the group, which was statistically significant. And the post-test scores were significantly lower than those of the NTG group. For RSA worst, similarly, only the CTG group showed significant changes within the group. However, there was no significant difference between the groups after training. For RSA decrement, the NTG group showed significant changes within the group, while the CTG group did not. The above data reflect that the CTG group (strength and repeated sprint training) has a specific effect on the participants' RSA in pre-season training, helping participants to improve their repeated RSA to the greatest extent.

Aerobic capacity (VO₂ max)

The results showed that after training, the Yo-Yo IR1 scores of both groups were significantly improved, which was statistically significant. In the post-test, the CTG group's scores were significantly better than the NTG group. The data showed that the CTG group (strength and repeated sprint training) was very helpful in improving the aerobic capacity of participants.

Agility

The results showed that the agility T-test showed that the scores of both groups were significantly improved, which was statistically significant. However, there was no significant difference between the groups after training.

Sprint ability

The results showed that after the test, the 10 m and 20 m sprint scores of both groups were significantly improved, which was statistically significant. And the post-test scores of both groups were significantly lower than those of the NTG group. The data showed that the CTG group (strength and repeated sprint training) had a positive effect on improving the participants' short-distance sprinting ability.

Discussion of research results

This study investigated the effects of adding an additional concurrent training program (strength training and repeated sprint training) to a regular pre-season athletic training program for college men's basketball players. The results of the study found that after 6 weeks of preseason training, concurrent strength training and repeated sprint training significantly improved the physical performance of collegiate basketball players, particularly in terms of post-training muscular strength and leg explosiveness. CTG training was more effective than NTG training in improving RSA, 10 m and 20 m sprints, and Yo-Yo IR1. Although both the experimental and control groups improved in other aspects of fitness, the improvements in the experimental group were not statistically significant. However, these data reflect the potential benefits of additional pre-season concurrent training (strength and repeated sprint training).

Muscle strength (1RM)

While the CTG program significantly increased post-training barbell squat, deadlift and Power Clean strength, the change in 1RM was not significantly greater than that achieved in the NTG group over the same period. Our present findings are consistent with Cantrell et al. (2014), who found that sprint interval training combined with strength training increased 1RM. Our findings are also in agreement with (Arslan et al., 2025), who stated that strength training combined with high-intensity interval training (HIIT), and also strength training combined with high-intensity functional training (HIFT), had a positive effect on 1RM strength development. Moreover, our data support previous observations which have shown concurrent strength and endurance training can develop maximum strength (Cantrell et al., 2014; Prieto-González & Sedlacek, 2022;

J. Robineau et al., 2017; Sedano et al., 2013; Suarez-Arrones et al., 2014) compared with non-concurrent training (Petré et al., 2018). The CTG program though is a more effective way to improve both strength and other athletic performance scores. It proved its worth by meeting the goal of concurrently improving strength and other variables of athletic performance. However, in terms of maximal strength (1RM) development, it failed to improve significantly more than the strength-training-only NTG program, which we can explain by the fact that fatigue from energy system interactions limits performance in strength development (Baker et al., 2010), and that concurrent training may lead to mutual conflict between strength and endurance (Häkkinen et al., 2003). Taken together, however, our findings confirm previous studies that have shown the potential effectiveness of incorporating a CTG program into a training program.

Leg explosive power

In the present study, we observed CMJ to be significantly increased following completion of the CTG program, however no significant differences were noted between the two training groups as CMJ performance also improved in the NTG group. Our data is consistent with several studies that have previously indicated this type of program can help increase jumping efficiency (Chen et al., 2024; Kotzamanidis et al., 2005; Sanchez-Sanchez et al., 2019; Sousa et al., 2020), concurrent training also being shown to increase CMJ performance in youth participants (Enright et al., 2015). In contrast, Thomakos et al. (2023) reported that the application of a concurrent training during a pre-season could significantly decrease CMJ height. This disparity in findings may be explained by different training program designs or participants, and/or the total amount of load the participants received from the concurrent training program resulting in varied changes in jump performance. Strength training is able to mobilize more muscle fibers to participate in the bouncing action by stimulating muscle growth and enhancing neural control of muscles, thus effectively enhancing CMJ performance (Andersen & Aagaard, 2010). However, the experimental data showed that the CTG group did not show a statistically significant difference in the magnitude of improvement compared to the NTG group. Given that CMJ growth was strongly correlated with maximal strength growth (Wisløff et al., 2004), this result can be interpreted to mean that although both groups gained gains in maximal strength, there was no significant difference in strength growth between the groups. Therefore, it is logical that there was no statistically significant difference in CMJ intergroup performance between the two groups. Taken together, however, our findings confirm previous studies that have demonstrated the potential effectiveness of incorporating a CTG program into a training program.

Repeated sprint ability (RSA)

We observed a significant shortening of RSA best, RSA worst, RSA mean and RSA total time scores in the CTG group compared to the NTG at the end of the training period. It appears that the CTG program, in which strength training is followed by repeated sprint training programs, can improve several aspects of physical fitness, especially RSA, and aerobic fitness (Cantrell et al., 2014; J. Robineau et al., 2017; Thomakos et al., 2023). These training programs have been shown to have beneficial effects on physical fitness levels (Arazi et al., 2011), although some studies have employed different training durations (Jiuxiang. Gao & Liang. Yu, 2023), which may result in varied outcomes. A study by Suarez-Arrones et al. (2014) also indicating that the intensity pattern of training may have different effects on strength and RSA performance. Therefore, when implementing similar types of training programs, the sequence of training should be considered, as this appears to affect the magnitude of change in physical fitness (Methenitis, 2018). in which RSA best was improved., which was consistent with the findings of (Buchheit et al., 2010), (Gantois et al., 2018), (Gantois et al., 2019) ,(Sanchez-Sanchez et al., 2019); the RSA worst was improved, which was consistent with the results of ((Sanchez-Sanchez et al., 2019), (Gantois et al., 2019); the RSA $_{total\ time}$ was improved, which was consistent with the study of (Gantois et al., 2018); the RSA mean was consistent with the results of the study of (Buchheit et al., 2010), (Gantois et al., 2018), (Sanchez-Sanchez et al., 2019). For the CTG group the end-of-training RSA best, RSA worst, RSA mean and RSA total time scores were significantly shorter for the CTG group compared to the NTG group. This can be explained by the fact that the CTG group's training

program provided a solid power base for sprinting by selecting specific movements such as barbell squat, deadlift, power Clean, which significantly increased lower body explosiveness, speed power, and maximal strength (Nigro & Bartolomei, 2020). Strength gains are directly beneficial to improving single-repetition sprint performance (RSA hest) because it provides more explosive power (Dasteridis et al., 2011). More importantly, strength and repeated sprint training are performed in the same session. Participants perform repeated sprint training (RST) in a non-fully recovered state immediately after strength training, fitting the scenario of a race where they need to sprint at high speed immediately after completing power movements such as confrontations, jumps, and changes of direction (Stojanovi $\acute{\mathbf{c}}$ et al., 2018). This pattern forces the body to maintain sprint speed and optimize the efficiency of running technique under adverse conditions. This enhances the ability to maintain high power output, which benefits RSA worst development, as well as strengthening recovery. This greatly amplifies the stimulation of the anaerobic glycolytic energy supply system as well as the aerobic recovery system, driving the body to produce greater adaptations (Sökmen et al., 2018). Ultimately, the consolidation of the strength base, the increased efficiency of sprint technique, the optimization of power maintenance ability, and the enhancement of recovery collectively contribute to an increase in the overall average of all sprint performances (RSA mean). The reduction in total sprint time (RSA $_{\rm total\ time}$) is the inevitable result of the overall improvement in RSA $_{\rm best}$, RSA $_{\rm worst}$ and RSA $_{\rm mean}$, and is the most direct reflection of the overall improvement in RSA ability. In conclusion, our findings confirm previous studies that have shown that incorporating CTG programs into training programs has a positive impact on RSA performance.

Aerobic capacity (VO₂ max)

The CTG program found that the Yo-Yo IR1 test had a greater positive effect on endurance performance than regular basketball training. This is consistent with the study by (Thomakos et al., 2023) who found that Yo-Yo IR1 distance could be improved over a 4-week training period. The Yo-Yo IR1 test is an aerobic fitness test that has a positive effect on the development of maximal oxygen uptake (VO₂ max), which can

improve endurance in participants (Cantrell et al., 2014), (Arslan et al., 2024) , (Julien Robineau et al., 2017). Petré et al. (2018) especially in a university sample group (Arazi et al., 2011). In addition, a previous study by (Petré et al., 2018) showed that simultaneous HIIT strength and repeated sprint training, combined with strength training, improved VO_2 max more than resistance training alone. The CTG group was significantly better than the regular basketball training NTG group in enhancing performance on endurance as tested by the Yo-Yo IR1 test. This can be explained by the unique advantage of the CTG program strength combined with repeated sprint training, especially strength training first, in stimulating endurance-related physiological adaptations (Jiuxiang Gao & Liang Yu, 2023). The results of the study are consistent with a large body of literature confirming the effectiveness of concurrent strength and repeated spring training in enhancing aerobic capacity.

Agility

Although the CTG program led to a statistically significant improvement in agility after training, the magnitude of change was not substantially greater than that observed in the NTG group. This finding aligns with the results of a comparative study on concurrent training in adolescent football players reported by (Tarakci & Pinar, 2021). This outcome may be attributed to the multifaceted nature of agility, which depends not only on fundamental physical qualities such as strength, power, and speed, but also on more complex factors including neuromuscular coordination, technical skill, and perceptual decision making. These components are already extensively engaged during sport-specific basketball training (Paul et al., 2016). The present findings support previous research suggesting that the inclusion of CTG programs in training regimens may enhance agility performance.

Sprint ability

The CTG program demonstrated a positive effect in reducing 10-meter and 20-meter sprint times compared to conventional basketball training. The improvements in sprint performance observed in the CTG group may be attributed to several physiological and neuromuscular adaptations associated with concurrent training. In the

context of concurrent training, the resistance training component, particularly when emphasizing explosive movements has been shown to enhance motor unit recruitment, increase the rate of force development (RFD), and improve musculotendinous stiffness. These neuromuscular adaptations collectively contribute to improved acceleration and sprint performance (Wong et al., 2010). Conversely, the aerobic and high-intensity interval training (HIIT) components of concurrent training have been shown to enhance mitochondrial efficiency, increase capillary density, and improve lactate clearance, thereby contributing to greater fatigue resistance during repeated sprint efforts. These adaptations are particularly beneficial in team sports such as basketball, where sprinting is performed repeatedly with short recovery periods. Additionally, concurrent training has been shown to promote favorable shifts in muscle fiber composition, preserving or increasing the proportion of type IIa fibers fast-twitch oxidative fibers that support both power output and fatigue resistance (Sousa et al., 2020). Moreover, neurometabolic adaptations induced by concurrent training may enhance energy system interaction and improve post-activation potentiation, which further supports explosive performance. Finally, improvements in intermuscular coordination and movement efficiency developed through combined training modalities may contribute to better sprint mechanics and running economy (Baena-Raya et al., 2020). Collectively, these mechanisms explain the observed enhancements in short sprint performance following CT interventions.

CONCLUSION

The results of this study indicated that the CTG program, consisting of strength training followed by repeated sprint training twice per week for 6 weeks, can improve aspects of physical performance in college basketball players, particularly in repeated sprint performance and sprint and aerobic capacity. However, although some variables did not differ from the performing routine basketball training, the CTG showed a trend for improvement across several parameters. Therefore, CTG programs may lead to marked improvements in the physical performance of college basketball players during a preseason. The findings of this study provide a scientific basis for the training of college basketball players to assist in the selection of more effective training methods to

enhance physical performance. Concurrently, our data can function as a reference source for sports practitioners and coaches, promoting the enhancement of college basketball training.

Application of the findings

This study found that a CTG training program (including strength training and repeated sprint training twice a week for six weeks) can improve multiple aspects of physical performance in college basketball players. In fact, coaches can use the results of this study to adopt CTG as a time-saving strategy to bridge the gap between general physical training and the intermittent high-intensity training needs of basketball. This can maximize performance while minimizing the risk of injury, ultimately creating stronger, more resilient participants.

Recommendations

The results of this study reveal the effects of a preseason CTG training program (including strength training and repeated sprint training twice a week for six weeks) on multiple aspects of physical performance in college basketball players. However, the researchers believe that further research is needed. The recommendations are as follows:

Sample effect: This study focused on 24 male college basketball players.

Future research should include female participants, different age groups (e.g., adolescents, elite/professional participants), and other team sports (e.g., football, handball) to verify the generalizability of synchronous training (CTG) in the population.

Long-term effects: Extend the intervention period beyond 6 weeks to evaluate the sustainability of performance improvements (e.g., 12-16 weeks) and the potential risk of overtraining in long-term training cycles

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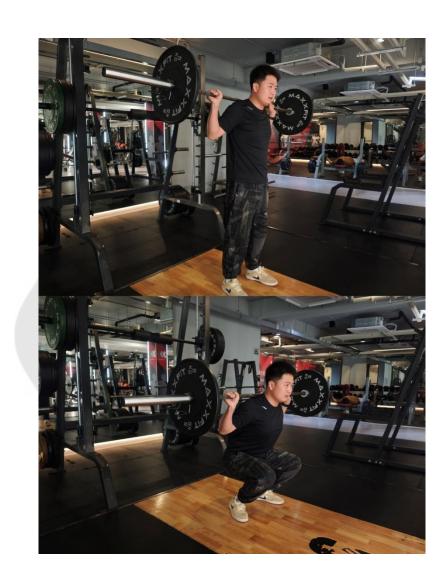


Appendix A NTG fitness training program

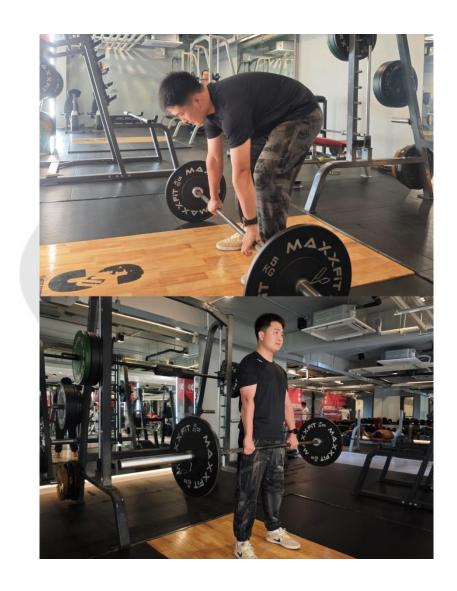
NTG fitness training program

Exercises	Set	Rep	Intensity	Rest interval
Bench press	2	10	60%1RM	3 min
Barbell squat	2	10	60%1RM	3 min
Leg press	2	10	60%1RM	3 min
Barbell buttocks push	2	10	60%1RM	3 min

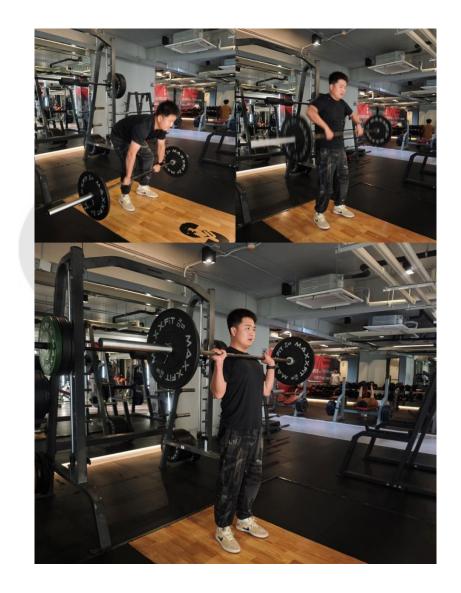
Appendix B
Strength training exercises



Barbell squat

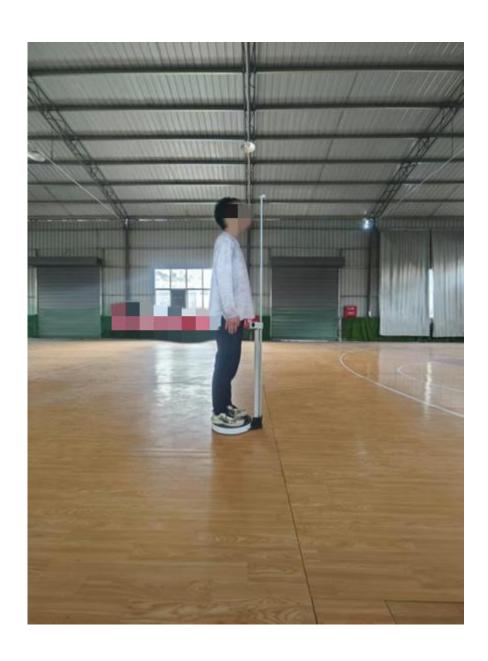


Deadlift



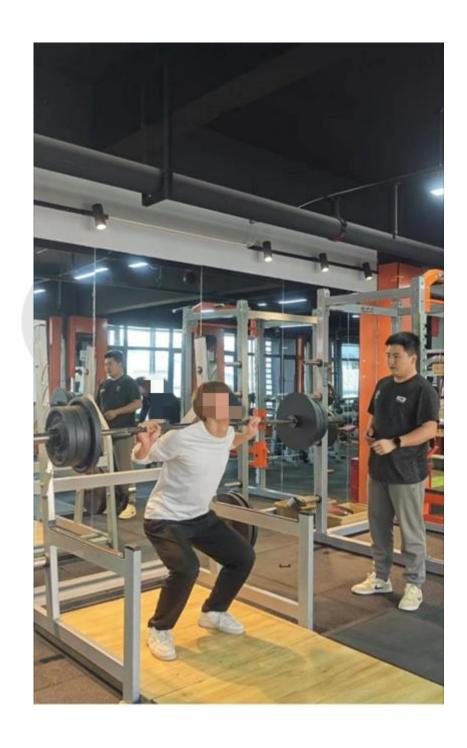
Power clean

Appendix C
Body composition test



Appendix D

Muscle strength (1RM) test



Appendix E
Counter movement jump (CMJ) test









Appendix G
Repeated sprint ability (RSA) test



Appendix H
20 m sprint performance test



Appendix I

Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1)





Appendix J

Human research ethics approval document

Xiamen Institute of Technology Human Research Ethics Committee Approval Certificate Serial number:XIT-2025SS0120001

Project title	Effect of additional concurrent strength and repeated sprint training on physical performance in collegiate basketball players			
Project Source	No have			
Project Leader	Chang Weikang	College	Faculty of Physical Education at srinakharinwirot University	
Review Category	□Apply for animal experiment □Apply for scientific research project ☑ Human movement experiment			

the purpose of the experiment, experimental methods, observation indicators, post-experimental tests,

Overview:Understanding the effects of concurrent strength and repetitive sprint training and regular training on physical performance in college basketball players, the findings can be used to maximize physical performance in college basketball players in preparation for competition.

Ethical Target:24 college basketball players from Lanzhou Modern Vocational College

Experimental:Before the experiment begins, the selected subjects are all voluntary participants, understand the experimental process, ensure that they are fully informed and respect their wishes; inquire and investigate the health status of the subjects to determine the psychological health of the subjects. All subjects have not been subject to any type of threats, coercion, or inducement. The grouping process of the subjects is objective and random. The applicant and relevant researchers have accumulated rich experimental experience in the early stage, and will strictly protect personal privacy and prevent the leakage of relevant information.

The applicant (project leader) promises:

All the contents filled in above are true, if approved, I will carry out the research in strict accordance with the provided program and comply with the ethical code of scientific research and experimentation and related regulations, and voluntarily accept the supervision and inspection by the Academic Committee of the university, and voluntarily accept the corresponding penalties in case of violation of the regulations

Signature of applicant (project leader): Chang Weikang Date: January 10, 2025

Review opinions of the College Academic Committee:

After review by the College's Academic Senate, the project's design specifications, research content and process are in line with the ethical requirements for scientific research experiments promulgated by the state, And abide by the international Declaration of Helsinkh, and it is agreed that the project will be implemented as planned.

> Academic Committee (Seal) Date January 20, 2025

Review Opinions of the Academic Committee of the University:

1. Applicant eligibility:

☑Meet the requirements -Does not meet requirements

2. Experimental methods:

☑appropriate

□Inappropriate

3. Review conclusion:

Øagree

Discuss after modification

Academic Committee (Seal)

Date January 20, 2025

VITA

NAME Chang Weikang

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