UNIVERSITI PUTRA MALAYSIA

DIFFERENCES IN SELECTED FITNESS, TENNIS SKILLS AND FUNCTIONAL MOVEMENT FOLLOWING FUNCTIONAL MOVEMENT TRAINING PROGRAM AMONG YOUNG MALE CHINESE TENNIS PLAYERS

XIAO WENSHENG

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By

XIAO WENSHENG

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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July 2022

Chairman : Professor Soh Kim Geok, PhD
Faculty : Educational Studies

The purpose of this research was to evaluate the effect of a 12-week functional training intervention on selected fitness, tennis skills, and functional movement among Chinese young male tennis players. The group (centers) was used as the unit of randomization, and the training bases of young tennis players were selected from 11 representative teams using the Lottery Method and the same method was used to select the functional training group (FTG) and control group (CTG). Forty-four eligible participants were recruited from both training sites in Zhejiang provinces. Subjects were between the ages of 14-18 years. A Cluster Randomized Controlled Trial study was conducted. Both groups performed for 60 minutes, three times a week (36 sessions). The fitness and tennis skills test procedures followed the International Tennis Federation's recommend test protocol, as well as the functional movement test procedures, following the functional movement screen test protocol. Data collection procedures for the control group (CTG) were collected the same as for the functional training group (FTG). Additionally, those test protocols were used to assess changes in the dependent variables that resulted from intervention at zero, six, and 12 weeks. The Generalized Estimating Equations determined differences between and within the group. The hypotheses of the thesis received significant support. Within-group effects showed significant differences between FTG and CTG for three times time fitness and skills variables ($p<0.05$) except for volley depth between posttest 1 and posttest 2 was not statistically significant in CTG ($p>0.05$). Additionally, for FTG, except for deep squat, in-line lunge, active straight leg raise, trunk stability push-up, and rotary stability was no statistical significance between pretest and posttest 1 ($p>0.05$), for other functional movement variables, the results were significant ($p<0.05$). In the CTG, the results were not significant for other functional movement variables ($p>0.05$), except for the total score, which was signed between pretest and post-test 2,

hurdle step and shoulder mobility were significant between both post-tests. Between-group effects showed that all dependent variables (fitness, skills, and functional movement) were not statistically significant at the pretest ($p>0.05$). There was a statistically significant difference in fitness (wall squat test, left), functional movement (deep squat, trunk stability push-up, rotary stability) at posttest 1 ($p<0.05$), while tennis skills variables had statistically significant differences at posttest 1 ($p<0.05$). Additionally, all dependent variables had significant differences at posttest 2 ($p<0.05$), except for the speed variable ($p>0.05$). The results showed that functional training is more effective than standard training in improving fitness, skills, and functional movement in young tennis players. For skills training, six weeks of functional training had a more significant effect than standard training. This improvement is mainly due to the specific functional training principle that stimulates and facilitates the improvement of the target movement. Therefore, it can be used to replace standard training, as it promotes better improvement in fitness, skills, and functional movement of young male tennis players. Future research is recommended to explore functional training in other sports, and other genders while observing the effects on fitness and skill parameters.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENENTUAN PERBEZAAN KECERGASAN, KEMAHIRAN TENIS DAN PERGERAKAN FUNGSIAN TERPILIH BERIKUTAN PROGRAM LATIHAN PERGERAKAN BERFUNGSI DALAM KALANGAN PEMAIN TENIS LELAKI MUDA CINA

Oleh

XIAO WENSHENG

Julai 2022

Pengerusi : Profesor Soh Kim Geok, PhD
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Tujuan penyelidikan ini adalah untuk menilai kesan intervensi latihan berfungsi selama 12 minggu ke atas kecergasan fizikal yang terpilih, kemahiran tenis dan pergerakan berfungsi dalam kalangan pemain tenis lelaki muda di China. Kumpulan (pusat) digunakan sebagai unit rawak manakala subjek kajian dipilih daripada 11 pasukan dengan menggunakan kaedah “Lottery” dan kaedah yang sama juga digunakan untuk memilih kumpulan latihan berfungsi (FTG) dan kumpulan kawalan (CTG). Empat puluh empat peserta yang layak telah diambil dari kedua-dua pusat latihan di wilayah Zhejiang. Subjek kajian berumur di antara 14-18 tahun. Kajian Percubaan Terkawal Rawak Kluster telah dijalankan. Kedua-dua kumpulan membuat latihan selama 60 minit, tiga kali seminggu (36 sesi). Prosedur ujian kecergasan dan kemahiran tenis adalah mengikut protokol ujian yang disyorkan oleh Persekutuan Tenis Antarabangsa, serta prosedur ujian pergerakan berfungsi mengikut protokol ujian skrin pergerakan berfungsi. Prosedur pengumpulan data untuk kumpulan kawalan (CTG) adalah sama dengan kumpulan latihan berfungsi (FTG). Selain itu, protokol ujian tersebut digunakan untuk menilai perubahan dalam pembolehubah bersandar yang terhasil daripada intervensi pada minggu sifar, minggu keenam dan minggu keduabelas. Persamaan Anggaran Umum menentukan perbezaan antara kumpulan dan dalam kumpulan. Hipotesis kajian menunjukkan sokongan yang signifikan. Kesan dalam kumpulan menunjukkan perbezaan yang signifikan antara FTG dan CTG bagi pembolehubah kecergasan dan kemahiran tiga kali ganda ($p<0.05$) kecuali kedalaman voli antara ujian pasca 1 dan ujian pasca 2 tidak signifikan secara statistik dalam CTG ($p>0.05$). Selain itu, untuk FTG, kecuali untuk deep squat, in-line lunge, active straight leg raise, trunk stability push-up dan rotary stability tidak signifikan secara statistik antara ujian pra dan pasca 1 ($p>0.05$), manakala bagi latihan berfungsi yang lain menunjukkan keputusan yang signifikan ($p<0.05$). CTG menunjukkan bahawa keputusan

untuk jumlah markah (ujian pra dan ujian pasca 2), hurdle step dan fleksibiliti bahu adalah signifikan antara ujian pasca, manakala keputusan untuk latihan fungsi lain adalah tidak signifikan ($p>0.05$). Kesan antara kumpulan menunjukkan bahawa semua pembolehubah (kecergasan fizikal, kemahiran, dan pergerakan berfungsi) adalah tidak signifikan secara statistik ($p>0.05$). Dalam Ujian Pasca 1, terdapat perbezaan yang signifikan secara statistik ($p<0.05$) untuk kecergasan (wall squat test, left), pergerakan berfungsi (deep squat, trunk stability push-up, rotary stability). Semua pembolehubah kemahiran mempunyai perbezaan yang signifikan secara statistik ($p<0.05$) pada ujian pasca 1. Di samping itu, semua pembolehubah bersandar mempunyai perbezaan yang signifikan pada ujian pasca 2 ($p<0.05$), kecuali kelajuan ($p>0.05$). Keputusan menunjukkan bahawa latihan berfungsi adalah lebih berkesan daripada latihan formal dalam meningkatkan kecergasan fizikal, kemahiran, dan pergerakan berfungsi pemain tenis muda. Untuk latihan kemahiran, enam minggu latihan berfungsi menunjukkan kesan yang lebih signifikan berbanding latihan formal. Peningkatan ini disebabkan oleh prinsip latihan berfungsi khusus yang merangsang dan memudahkan peningkatan pergerakan sasaran. Oleh itu, ia boleh digunakan untuk menggantikan latihan standard, kerana ia menggalakkan peningkatan yang lebih baik dalam kecergasan, kemahiran, dan pergerakan fungsi pemain tenis lelaki muda. Penyelidikan masa depan dicadangkan untuk meneroka latihan berfungsi dalam sukan lain, dan jantina serta memerhatikan kesan pada parameter kecergasan dan kemahiran.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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I hereby confirm that:

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This is to confirm that:

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LIST OF ABBREVIATIONS

ITF	International Tennis Federation
WTA	Women's Tennis Association
ATP	Association of Tennis Professionals
USA	United State
NASM	National Academy of Sports Medicine
ACSM	American College of Sports Medicine
FMS	Functional Movement Screen
CMMS	China Market and Media Research
CRCT	Cluster Randomized Controlled Trial
MFT	Multistage Fitness Test
PU	Push-ups
WSTL	Wall Squat Test (left)
WSTR	Wall Squat Test (right)
OMBT	Over Medicine Ball Throw Test
SLJ	Standing Long Jump
THT	The Hexagon Test
PAT	Planned Agility Test
SAR	Sit and Reach
GD	Groundstroke Depth
VD	Volley Depth
GA	Groundstroke Accuracy
SA	Serve Assessment
DS	Deep Squat

HS	Hurdle Step
IIL	In-line Lunge
SM	Shoulder Mobility
ASLR	Active Straight Leg Raise
STPU	Trunk Stability Push-up
RS	Rotary Stability
TS	Total Score
FTG	Functional Training Group
CTG	Control Group
GEE	Generalized Estimating Equations

CHAPTER 1

INTRODUCTION

This chapter mainly elaborates the study background, problem statement, purpose, hypothesis, significance, limitations of the study, delimitations of the study, as well as conceptual and operational definitions of terms.

1.1 Background of the Study

The coach's goal is to enable athletes to achieve their best performance during competitions (Wensheng, 2013). To succeed in a competitive tennis match, coaches must understand the complex process of developing athletic performance (Yu et al., 2020). Results of previous studies have defined the most critical factors affecting tennis performance as speed, endurance, power, strength, agility, flexibility, tennis skills, and movement patterns (Smekal et al., 2001; Kolman et al., 2019; Ulbricht et al., 2013). Additionally, some researchers expressed that future tennis champions should have good (average/better) levels of all these performance factors (Chunlin & Feng, 2008; Jianmei et al., 2010). Lack of knowledge about components of performance level and conditions facilitating players' development has been the main reason affecting athletes' competitive abilities (Chengrun & Zipu, 2021). Mayorga-Vega et al. (2014) concluded that when an athlete's physical fitness is not enough to support the entire game, it first affects the performance of various techniques and quickly leads to the loss of the entire game (Mayorga-Vega et al., 2014). Previous studies showed that tennis players involved in exercise training or sport-specific training improved their competitive ability (Xiaoping et al., 2014; Feng et al., 2019). However, as the sport of tennis continues to change, there is a need to research a variety of exercise training methods to provide players, coaches and managers with information that will help develop efficient and productive tennis performance.

1.1.1 China National Policy to Promotes the Development of Tennis

As a powerhouse for the Olympics, China has been ranked in top three in medals since 2000 (Fei & Chunli, 2021). Although tennis has been an Olympic sport since 1988 (Abrams et al., 2012), Chinese tennis players have won only one gold medal (women's doubles in 2004) and one bronze medal (women's doubles in 2008). Compared with table tennis or badminton, tennis is a disadvantageous event in China (Shoudong, 2012). In order to accelerate the process of building a strong sports nation, the Chinese government will continue to maintain the development of advantaged events, focusing on the development of disadvantaged events (i.e., tennis) as its development goal (Te & Wensheng, 2019). The Chinese government has issued several policies to promote sports

development. Most national policies emphasize science and specificity in athletes' training, and the arrangement of training should be based on the actual needs of athletes (General Office of the State Council, 2016; Ministry Education, PRC and General Office of the State Council, 2017; General Office of the State Council, 2019). The person in charge of Tennis Management Center of the State Sports General Administration pointed out that the understanding of the relationship between the various elements that affect sports performance is unclear, and the scientific level of tennis training is not high. Therefore, the research and innovation of training methods, as well as learning and practice of advanced training concepts, need to be further studied (Jinfang, 2009). Therefore, research on the key factors affecting Chinese tennis performance (i.e., physical fitness, tennis skills, and functional movement) is necessary.

1.1.2 Core Elements of Tennis Performance

Modern tennis has evolved from essentially technical sport dominated by sport-specific technical skills (Ulbricht et al., 2016) to a dynamic, advanced sport stroke and serve speed and significantly higher physical speed and demands considered movement and explosive movement (Fernandez-Fernandez et al., 2009; Kovacs, 2007a; Faber et al., 2016). Previous research has shown that players typically make 300 to 500 rapid runs during a tennis match and that they spend about 10% to 30% of their time in the game (Hornery et al., 2007; Jinfang, 2009). The actual game exercise time is 15-20 minutes, and a match with two wins in three sets usually takes 1.5-3 hours (Jinfang, 2009). As a result, it is widely believed that players need greater fitness to hit advanced shots and effectively take on better opponents (Fernandez-Fernandez et al., 2009). A tennis player needs a combination of moderate to high aerobic capacity, strength, speed, agility, and other fitness qualities to be successful in the game (Mark Kovacs, 2007).

This successful performance requires a complex interaction of physical fitness components (Fernandez-Fernandez et al., 2009). Underlying these physical fitness components is the learning and performance process of tennis skills (Fernandez-Fernandez et al., 2009). A healthy body structure is the foundation for improved performance in athletes (Fernandez-Fernandez & Ferrauti, 2014a). Furthermore, the ability to efficiently perform multi-joint and multi-plane movements and exploit without compensation is a prerequisite for success in tennis. Therefore, optimized movement patterns have a significant advantage in athletic performance (Ransdell & Murray, 2016; Cook et al., 2014a; Cook, 2010). Experts have recently developed methods to assess and improve functional movement (Ransdell & Murray, 2016). One of those is the functional movement screen developed by Cook et al. (Cook et al., 2014a; Cook et al., 2014b). As a comprehensive test that examines basic movement patterns, it meets a basic expectation for determining general functional performance in an athlete. Based on these findings, a tennis player's physical fitness and tennis technique are key to determining the winning or losing a match. In addition, functional movement is also a crucial factor, especially among players with very similar levels of play

(Page & Coates, 2017; Kovalchik & Reid, 2017). The key to improving these factors lies in the exercise training methods. Therefore, it is vital to pay attention to the research on the exercise training methods of tennis players.

1.2 Problem Statement

Tennis has the second highest global sport popularity after football (Gomes et al., 2013). China has the largest tennis population globally (International Tennis Federation, 2019b). However, the overall performance of Chinese tennis players is not good, especially Chinese male tennis players. Furthermore, compared with table tennis or badminton, tennis is a disadvantaged event in China (Gaoliang & Yong, 2019). Previous studies have found Chinese young tennis players to have certain advantages over international elite tennis players in their comprehensive competitive ability at the age of 12. However, after 14 years of age, their comprehensive advantages gradually weaken. By the age of 16, their overall comprehensive competitive ability lag behind international tennis players, and the gap becomes wider after the age of 18 (Tang, 2005; Zhaoyang, 2009; Fan, 2013). Studies on the analysis of international competition statistics have identified a particular gap between Chinese young tennis players and international elite young players in terms of physical fitness, tennis skills, and functional movement (Zhu et al., 2006; Weiwei, 2016).

Many published studies have shown a substantial connection significant between fitness components, skills, movement patterns, and exercise training interventions (Cureton, 1956; Elbadry, 2014; Fozia et al., 2019). That is to say, the selection of exercise training methods is essential for athletes to obtain, improve, and maintain high-level competitive ability, as well as balancing the development of various physical qualities and movement ability in all parts of the body (Liu et al., 2012; Zhang & Liu, 2016). Therefore, with significant interest from health professionals, different exercise training methods have been tested to find multiple system adaptations that can effectively improve athletic performance. From this point of view, there has been a growing search for ways to improve performance, primarily prioritizing the principle of specificity and developing muscle strength in an integrated and balanced manner, and bringing the other physical fitness components to a sufficient level to meet the athletic needs of the athletes (Xiao et al., 2021). However, for a long time, China has used chiefly technical and tactical training, physical fitness training, and other training methods in athlete training (Yue, 2006; Hongwei, 2011). There are very few exercise training methods aiming to improve physical fitness, skills, and functional movement (Fangyu, 2013; Taotao, 2019). Instead, long-term boring exercise training methods are repeated (Chen & Huang, 2006a). Intensity and volume become the main goals of training; this might be why players are unable to comprehensively improve their physical fitness, tennis skills, and functional movement (Fernandez-Fernandez et al., 2016; Kilit & Arslan, 2019; Santos-rosa et al., 2020). Therefore, exercise training methods must be reformed to incorporate sets of movement patterns to improve the specific skill targets (Jianmei, 2010).

A new approach to athletic training that has recently received more attention in the development of athletes' performance is functional training (Feito et al., 2018). It attempts to train muscles in corresponding multiplanar movements and intergrade multiple joints, dynamic tasks and constant changes on the basis of support to improve the athlete's postural control, reduce energy consumption during movement completion, and improve the power transmission efficiency chain at the end of the movement (Cook, 2010; Michael, 2016). Boyle describes practical training as targeted exercise, which states that "function is essentially purpose" (Michael, 2016). According to a comprehensive review of the literature on the functional training of athletes, functional training has been shown to enhance physical fitness, skills, and functional movement. The latter is based on two systematic reviews. The first is the effect of functional training on fitness, and the other is the effect of functional training on skills and functional movement (Baron et al., 2020; Tomljanović et al., 2011; Sander et al., 2013; Alonso-Fernández et al., 2017; Yildiz & Gelen, 2019; Keiner et al., 2020; Dinc et al., 2017; Kamal, 2016; Kovac et al., 2021; Sebastian, 2018; Bodden et al., 2015; Osipov et al., 2017; Cherepov & Shaikhetdinov, 2016; Oliver & Brezzo, 2009; Elbadry, 2014). Although the importance of functional training to improve fitness, skills, and functional movement among athletes, it is currently limited to research among football players, martial arts players, and handball players. A total of 15 studies were included in the two systematic reviews (duplicate studies were excluded), and six studies reported on football players (Oliver & Brezzo, 2009; Sander et al., 2013; Dinc et al., 2017; Sebastian, 2018; Baron et al., 2020; Keiner et al., 2020), three studies reported on martial arts players (Bodden et al., 2015; Cherepov & Shaikhetdinov, 2016; Osipov et al., 2017), and two studies reported on handball players (Elbadry, 2014; Alonso-Fernández et al., 2017). To date, studies on tennis players are still limited. Only one research study reported about functional training among prepubertal tennis players (aged 9.6±0.7 years), but the study focused on fitness and functional movement instead of tennis skills (Yildiz & Gelen, 2019). As tennis skills are a critical factor that affects tennis players' performance, it needs to be further studied, especially regarding the impacts of functional training on fitness, tennis skills, and functional movement of elite and young players.

Some studies believe that proper exercise training can effectively improve fitness, tennis skills, and functional movement (Chen et al., 2014; Zhou, 2010). Therefore, the identification of factors influencing exercise training on physical fitness, tennis skills, and functional movement should be based on principles and theories that apply to a variety of exercise training. The principle of functional training is the specificity of training, which means that training in a specific activity is the best way to maximize that specific activity's performance (Reilly et al., 2009; Hawley, 2008). In other words, the closer the training is to the desired outcome, the better the outcome will be (Skelton et al., 1995; Giné-Garriga et al., 2010; Cress et al., 1996; Alexander et al., 2001).

Impellizzeri et al. (2019) proposed an exercise training process model in which the exercise training environment is defined as the input variables that are manipulated to generate desired training response (Impellizzeri et al., 2019b). Coaches can improve athlete performance by manipulating frequency (F), intensity (I), time (T), and type (T) to achieve the desired training response. However, based on the results of two systematic reviews, there are currently no study reports on Santana's sport-specific programs. Therefore, this study used Santana's sport-specific programs (racket sports training program) as an intervention in young male tennis players to observe this functional training method on their fitness, tennis skills, and functional movement. Therefore, the exercise training process model can be extended from this study to provide a theoretical framework for the conduct of this study.

1.3 Research Objectives

This study's research objectives are divided into general and specific objectives. These are explained in detail below.

1.3.1 General Research Objective

This study evaluates the effect of functional training on selected fitness, tennis skills, and functional movement among Chinese young male tennis players.

1.3.2 Specific Research Objectives

As given above overall objectives, three specific objectives were developed. The definite purposes are listed as follows:

(1) To examine the effects of functional training across pretest, posttest 1, and posttest 2 on selected fitness components in terms of endurance, strength, power, agility, speed, and flexibility among Chinese young male tennis players.

(2) To evaluate the effects of functional training across pretest, posttest 1, and posttest 2 on selected tennis skills parameters in terms of groundstroke depth (GD), volley depth (VD), groundstroke accuracy (GA), and serve assessment (SA) among Chinese young male tennis players.

(3) To examine the effects of functional training across pretest, posttest 1, and posttest 2 on functional movement in terms of deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TSPU), rotary stability (RS), and total score (TS) among Chinese young male tennis players.

1.4 Research Hypotheses

Changes in selected fitness, tennis skills, and functional movement of young male tennis players were evaluated through the following null hypotheses. Following are three main research hypotheses and 18 sub-main research hypotheses.

Hypotheses 1-6 for Objective 1 (selected fitness component**s** were endurance, strength, power, agility, speed, and flexibility).

$H_0$1: There are no significant differences between FTG and CTG on endurance among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$2: There are no significant differences between FTG and CTG on strength among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$3: There are no significant differences between FTG and CTG on power among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$4: There are no significant differences between FTG and CTG on agility among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$5: There are no significant differences between FTG and CTG on speed among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$6: There are no significant differences between FTG and CTG on flexibility among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

Hypotheses 7-10 for Objective 2 (selected tennis skills parameters were were groundstroke depth, volley depth, groundstroke accuracy, and serve assessment).

$H_0$7: There are no significant differences between FTG and CTG on GD among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$8: There are no significant differences between FTG and CTG on VD among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$9: There are no significant differences between FTG and CTG on GA among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$10: There are no significant differences between FTG and CTG on SA among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

Hypotheses 11-18 for Objective 3 (functional movement in terms of deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, rotary stability, and total score).

$H_0$11: There are no significant differences between FTG and CTG on deep squat among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$12: There are no significant differences between FTG and CTG on hurdle step among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$13: There are no significant differences between FTG and CTG on in-line lunge among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$14: There are no significant differences between FTG and CTG on shoulder mobility among Chinese young male tennis players at pretest, posttest 1, and posttest 2

$H_0$15: There are no significant differences between FTG and CTG on active straight leg raise among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$16: There are no significant differences between FTG and CTG on trunk stability push-up among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$17: There are no significant differences between FTG and CTG on rotary stability among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

$H_0$18: There are no significant differences between FTG and CTG on total score among Chinese young male tennis players at pretest, posttest 1, and posttest 2.

1.5 Significance of the Study

Significance of the learning is presented of two parts. First part is the theoretical significance, and the second part is the practical significance. The detailed explanation is as below.

1.5.1 Theoretical Significance

Sports performance is a complex and dynamic process based on the interplay of several factors (Allen & Jones, 2011). However, in tennis, fitness, tennis skills, and functional movement are important factors influencing athletes' performance (Fernandez-Fernandez et al., 2009; Ulbricht et al., 2016; Ransdell & Murray, 2016; Yildiz et al., 2019). Therefore, the importance of proper exercise training for tennis players cannot be underestimated. In addition, intervention studies in exercise have shown positive effects on fitness, skills and functional movement in athletes (Cureton, 1956; Elbadry, 2014; Fozia et al., 2019). From this point of view, the choice of exercise training methods is particularly important. It should

be noted that while functional training is of great significance for improving physical fitness, skills and functional movement of athletes, the current research on this subject is limited to football players, martial arts players, and handball players. Nevertheless, the question remains whether functional training can improve the performance level of young male tennis players. Depending on the exercise training process, this model can be used to understand the relationship between training and individual adaptive responses that can help trainers and scientists better control and optimize the training process for the exercise (Impellizzeri et al., 2019). Functional training is the best way to maximize performance in specific activity's (Hawley, 2008; Reilly et al., 2009). Therefore, this study uses exercise training process model to study the effects of functional training intervention on selected fitness, tennis skills, and functional movement of Chinese young male tennis players; it fills a gap that lack of theoretical applications (Impellizzeri et al., 2019b).

1.5.2 Practical Significance

The main practical significance of this research is divided into two parts. The first part is that coaches, researchers, and managers can also benefit from this study, and the second part is that the study attempts to contribute to the current literature on the application of functional training in different types of athletes.

Firstly, the overarching contribution of this study is for tennis players, coaches, researchers, and managers. This study could help them to find effective exercise training methods to maximize the influence of physical fitness, tennis skills, and functional movement to improve performance among young tennis players. In addition, this study has shown that the 12 weeks, 3 times/week functional training program can significantly improve the selected physical fitness, and functional movement of young male tennis players. While 6/12 weeks, 3 times/week functional training program can significantly improve the skills of young male tennis players. Therefore, future studies can adopt the 12 weeks, 3 times/week functional training program to intervene in the selected physical fitness, and functional movement of athletes, while 6/12 weeks, 3 times/week functional training program to intervene in the tennis skills of athletes.

Secondly, this study attempts to contribute to the current literature on the application of functional training to different types of athletes. To date, most research on functional training has focused on football players (Oliver & Brezzo, 2009; Sander et al., 2013; Dinc et al., 2017; Sebastian, 2018; Baron et al., 2020; Keiner et al., 2020), martial arts players (Bodden et al., 2015; Cherepov & Shaikhetdinov, 2016; Osipov et al., 2017), and handball players (Elbadry, 2014; Alonso-Fernández et al., 2017). However, the results of various studies on the effects of functional training on athlete fitness, skills, and functional movement are encouraging, but there is limed scientific information to determine their potential benefits for fitness, skills, and functional movement. Therefore, research into the benefits of participating in functional training can add to the

current body of research knowledge.

1.6 Limitations of the Study

This study has a few limitations, which is described below.

(1) Based on previous studies, they use demographic as one of the limitations that might have influenced the intervention (Mingmin & Qing, 2013; Xinhui, 2019; Liu & Li, 2021). In order to reduce the impact, the researcher included demographic variables such as age, height, weight, and training background as the co-variates. The Independent T-tests had been conducted, and the results showed that the of the covariate is between 0.360 to 0.971 (age: t=0.926, p=0.360; height: t=-0.208, p=0.836; weight: t=-0.217, p=0.830; training background: t=-0.037, p=0.971). This show that the groups were homogeneous in terms of demographic characteristics. Therefore, that variable has no influence on the effect of this study's intervention.

(2) The speed of the ball is an important measure to assess the level of tennis player. The most advanced way (i.e., Hawk-eye technology and Play Sight) are to use multiple high-speed cameras to calculate the speed (Owens et al., 2003; Zhao et al., 2019). However, high-speed cameras are very expensive and difficult to install, which limits their popularity. In existing studies, International Tennis Number On Court Assessment is the most used to evaluate tennis skills level (Yongsheng, 2017). Therefore, this study uses this test protocol to evaluate the tennis skills level of young male tennis players.

(3) Due to the limitations in objective factors such as the funding of this research project, it was impossible to make uniform arrangements for the participants' diets. However, in this study, the two groups of participants belonged to the southern part of China and no difference in diet. However, the coach advised the participants not to change their usual nutritional habits during the intervention, and the participants agreed when signing they signed the consent form. The coach followed up to check on the students' diet once a week to ensure adherence.

1.7 Delimitations of the Study

The delimitation was encircled in the following aspects.

(1) Different studies have varying definitions of the age stages of teenagers. However, this study defined the age range of participants (aged from 14 to 18 years) based on relevant studies and the setting of Chinese youth tennis events (Xiujuan, 2009). Therefore, only the young tennis players aged 14-18 years were selected in this study. The study found that functional training is specifically suitable for this group, so future studies could focus on athletes

of other ages.

(2) Although there are many physical fitness and tennis skills variables that can be adopted and tested, this study only selected six physical fitness variables (endurance, power, strength, agility, speed, and flexibility) and four tennis skills variables (groundstroke depth, volley depth, groundstroke accuracy, and serve assessment). Indeed, these variables are more related to general physical fitness and tennis skills levels. Therefore, according to the International Tennis Federation (ITF) physical fitness test program and International Tennis Number (ITN) On Court Assessment test program, the selected variables are the most relevant variables with regards to improving athletes' performance.

(3) A functional training program is critical to improving athlete performance. However, research on the effects of this functional training program on selected fitness, tennis skills, and functional movement in young tennis players remains limited. The racket sports training program in the book "Functional Training" published by Santana was selected as the functional training program for this study (Santana, 2015). This functional training program was selected for experimentation with young male tennis players, but whether the program is applicable to other racket sports (e.g., badminton, table tennis) or tennis players of other genders requires further research.

1.8 Conceptual and Operational Definitions of Terms

During the study, there is a few following terms that are widely used. Some of these terms are used to represent variables.

1.8.1 Young Male Tennis Player

Conceptual Definition: The American Academy of Pediatrics (2017) recommendations for pediatric preventive services identify adolescence as 11 to 21 years (American Academy of Pediatrics, 2017), while the USA Department of Health and Human Services defines adolescents as ages 10 to 19 and young adults as ages 20 to 24 (Coccia et al., 2012).

Operational Definition: The age range of young male tennis players was based on China's General State Sports Administration's Tennis Management Centre of the General Sports Administration of China and the website of the China Tennis Association for the recruitment of young tennis events. In this study, the *young male tennis players* were defined as the age range of 14-18 years old (Xiujuan, 2009) with more than three years of tennis training background, including athletes from youth tennis training bases of sports bureaus at all levels.

1.8.2 Functional Training

Conceptual Definition: *Functional training* regards human movement as a complete chain of exercises instead of repetitive exercises on a single body movement (Cook & Fields, 1997). Starting from the chain link, optimizing the action mode is carried out to reduce energy consumption during the completion of the exercise to a certain extent and improve the transmission efficiency of the power chain when the action is completed (Cook & Fields, 1997).

Operational Definition: *Functional training* is a training method that emphasizes functional and multi-joint movements. It is different from sport-specific training. However, functional training can enhance a particular movement or activity. In this study, the functional training selected Santana's racket sports training program as the intervention program of the experimental group, which included conditioning triplexes (4 weeks), the strength triplexes (4 weeks), power and power endurance triplexes (4 weeks) (Santana, 2015).

1.8.3 Physical Fitness

Conceptual Definition: *Physical Fitness* is the ability to perform daily activities with vigor and agility without getting too tired, while recovering time to appreciate unpredictable interests and emergencies (Singh & Singh, 2017). *Physical fitness* combines health and skill aspects of physical fitness and is essential to the training of a person in sport or play (Parker & Curtner-Smith, 2005). These usually include speed, performance, reaction time, agility, balance, coordination, aerobic resistance, muscle strength, body composition and flexibility (Caspersen et al., 1985; Dalleck & Tischendorf, 2012).

Operational Definition: The corporeal *fitness* of the tennis companies is the essential factor in determining the winner and loser of a match, especially for players with a very close level of competition. The selection of the physical components of this study for young tennis players was mainly based on the ITF fitness testing program. It included endurance, strength, power, agility, speed, and flexibility (International Tennis Federation, 2019a) (International Tennis Federation, 2019a).

1.8.4 Sport Skills

Conceptual Definition: *Sporting skills* are acquired in a sequence of combined movements to produce smooth and effective action to master a particular task (Davis et al., 2011; Van der Fels et al., 2015).

Operational Definition: *Tennis skills* are an essential factor in athletic performance. This study's selection of tennis skills for young tennis players was mainly based on the ITN On Court Assessment, including groundstroke depth, volley depth, groundstroke accuracy, and serve assessment (International Tennis Federation, 2004).

1.8.5 Functional Movement

Conceptual Definition: *Functional movement* is the ability to establish and maintain a balance between mobility and stability in a kinematic chain by operating the underlying model accurately and efficiently (Mills & Mills, 2005).

Operational Definition: This study tested Chinese young male tennis players based on seven fundamental movement patterns.

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