BMC Sports Science, Medicine and Rehabilitation

RESEARCH

Open Access

Effects of functional training on skill performance and movement quality among skilled youth male tennis players: A cluster randomized control trial

Wensheng Xiao[1,2], Te Bu[2], Feida Zhao[1], Junlong Zhang[3], Xiaorong Bai[1*] and Soh Kim Geok[3*]

Abstract

Purpose Functional training to improve athletes' technical performance and movement quality is becoming increasingly popular, but few studies have focused on young tennis players. The aims of this study were to compare the effects of 12 weeks of functional training on skilled youth male tennis players' skill performance and movement quality.

Methods Forty skilled youth male tennis players were assigned to the functional training group ($n = 20$) or the control training group ($n = 20$). The control group received a traditional resistance training program by their coach, whereas the functional training group was given Santana's Racket Sports Program. Each group received 60-minute training sessions three times per week for 12 weeks. At baseline (T0), after six weeks (T6), and after 12 weeks (T12), the participants' skill performance was measured according to the International Tennis Federation's protocol, and movement quality was measured according to the functional movement screening assessment recommended by Gray Cook. The data were analyzed via a generalized estimation equation model.

Results The results revealed that there were no significant differences in skill performance or movement quality between the groups at baseline ($p > 0.05$), but there were significant differences in those variables between the groups after 6 weeks of the intervention and 12 weeks of the intervention ($p < 0.05$).

Conclusion These results indicate that the functional training model seems to be more effective than the traditional resistance training model in terms of increasing athletic skill performance and movement quality. The inclusion of functional training as part of an athlete's training routine is highly recommended, as it has proven to be an effective method for improving skill performance and movement quality.

Trial Registration ISRCTN67565717, registered 26/07/2024, retrospectively registered.

Keywords Functional movement, Technical performance, Adolescents, Tennis, Injury risk

*Correspondence:
Xiaorong Bai
03219@zjhu.edu.cn
Soh Kim Geok
kims@upm.edu.my

[1]School of Physical Education, Huzhou University, Huzhou 313000, China
[2]College of Physical Education, Hunan Normal University, Changsha 410000, China
[3]Department of Sports Studies, Faculty of Educational Studies, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia

© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

Introduction

Tennis performance in sports results from the interaction of multiple factors [1], and tennis match results are determined by scoring from the player's attack and opponent's errors [2]. A player's skill or technical engagement in individual tennis bouts (training or match play) has been described through stroke rates (shots hit per minute of play), rally lengths, stroke frequency and stroke location [3, 4]; the ability to master of all these skills by tennis players is one of the factors that enhance their competitive ability, because athletes must adjust and combine the skills they master to perform their best in a game [5]. The most critical and the only thing that is determined by the player in tennis is the contact point when hitting the ball, which helps the players to control the return shot when hitting the opponent's ball so that it lands in the best position. The most critical factors that affect the contact point are the athlete's anticipation of the opponent's shot and their mobility on the tennis court. Athletes need to perform these two skills to ensure that the players have the best position on the court when hitting the ball [5, 6]. Since tennis shots occur while in motion, positioning oneself correctly is crucial. Improper movements could cause the player to become unbalanced and change the players' actions, which would decrease the shot's accuracy [7, 8]. Therefore, the first step of hitting a ball is to find the best contact point, which increases the player's need for better mobility when moving on a tennis court. Additionally, the hitting accuracy, depth, and angle are the key performance metrics when analyzing tennis players' ability to hit the ball [9, 10]. Like all sports, tennis can result in injury if the athlete does not have the necessary competencies [11]. Notably, there is no one-size-fits-all tennis movement model. Instead, players should develop their own strategies on the basis of their unique physical features and abilities. Reasonable movement patterns can increase hitting efficiency, but overly exact imitation can impede individual technical improvement [5].

Due to the highly competitive nature of tennis, athletes and coaches are constantly seeking ways to gain a competitive edge, often focusing on training methods that enhance specific aspects of performance, such as physical fitness, technical skills, tactics, and mental fortitude [12]. Several studies have confirmed the effectiveness of various exercise training methods—such as high-intensity interval training, plyometric training, and resistance training—on improving skill performance and movement quality in young tennis players [13–15]. These approaches have been shown to not only boost athletic performance but also contribute to injury prevention and overall development in the sport. However, there is increasing interest in determining the best overall training methods, especially those that are exercise-based, rather than focusing on training specific muscles and joints in isolation, as these methods may be more effective in improving an athlete's competitive performance. In this context, functional training stands out as a way to prioritize the principle of specificity in a balanced manner to achieve performance development. Compared with training specific muscles, functional training simulates target movements, to better promote improvement in those movements [11, 16]; it is better than traditional resistance training in improving athletes' overall performance and achieves effects [16, 17]. In practice, efficacy is sometimes given precedence over risk, whereas current sports training should place equal focus on injury prevention and training effectiveness [18]. In this sense, professional tennis players are vulnerable to musculoskeletal injuries because of the high pressures they put on their joints during practice and competition [19, 20]. According to injury surveillance statistics from the Association of Tennis Professionals, the overall injury rate is 6.05 injuries per 1000 playing hours, with muscle and tendon injuries accounting for more than 84% of acute and chronic injuries [21]. Sports injuries can be thought of as random events; however, they frequently appear in the movement patterns needed to execute an activity [22, 23]. Players should therefore utilize the kinetic chain as efficiently as possible to reduce the risk of overuse injuries in tennis [22]. This calls for an injury prevention training program that adjusts to dynamic movement patterns [24]. Moreover, the training process is one in which athletes are systematically exposed to stimuli with the objective, adapting to the determinants of performance, enhancing physical abilities and acquiring specific sports skills [25]. Therefore, a dynamic framework must be developed when guiding the training process and should be adjusted on the basis of an athlete's specific situation. The training load is the core element of this dynamic framework [26]. The training load corresponds to the stress that the exercise puts on the body; it comprises internal and external loads, depending primarily on the measurable aspects that occur internally and/or externally to the athlete [27]. However, in performance interventions, the selection of exercise training methods is crucial. Existing studies have confirmed that functional training can significantly improve the skill performance and movement quality of athletes [28–30], but there are no reports on the effects of functional training in young tennis players, and no study has applied functional training to the exercise training process model. Therefore, this study focused on different types of external load exercise to investigate whether functional training can effectively improve the skill performance and movement quality of young male tennis players. Additionally, previous evidence has shown that the duration of functional training varies [31–33], and it is not possible to determine from the existing studies the optimal choice for the duration of functional training interventions for developing the skill performance and movement quality of young tennis players. Therefore, this study compared the effects of different durations of functional training and traditional resistance training on the skill performance and movement quality development of young male tennis players. The hypothesis is that functional training could enhance skill performance and movement quality more than traditional resistance training. We also studied the optimal duration of functional training necessary to improve athletes' skill performance and movement quality.

Methods

The study was designed and reported in accordance with the CONSORT declaration [34], and a two-arm cluster-randomized controlled trial was used. The Ethics Committee for research involving human participants of the Universiti Putra Malaysia evaluated and approved the study and approved it (approval number: JKEUPM-2020-283).

Participants

This study's subjects are from Zhejiang Province. They are local junior tennis athletes. This choice was based on the following factors. First, Zhejiang Province is an important site for Chinese youth tennis tournaments, where young tennis players have a certain representativeness. Second, researcher randomly selected two teams (clusters) that are participating in youth tennis competitions in Zhejiang Province because every year, athletes of a certain level are selected from these two training bases to participate in national and provincial youth tennis competitions. Therefore, athletes' competitive ability at the two bases is representative of that of Chinese tennis players [35, 36]. With the help of the tournament staff, the training bases of skilled youth tennis players were selected from 11 representative teams, and a lottery method was used to select the functional training group (FTG) and control training group (CTG).

During the initial sign-up period, the following inclusion and exclusion criteria were implemented in addition to their voluntary participation: (1) The inclusion criteria in the present study were (i) Skilled youth male tennis players (14–18 years old) who had participated in youth tennis competitions in Zhejiang Province. (2) The exclusion criteria were (i) Participants who were injury-free and had no history of sports injuries (i.e., knee, elbow, or shoulder injuries) for at least one year; and (ii) Participants who agreed to follow the experimental design, in which the all subjects received normal technical training, the experimental group had to stop participating in traditional resistance training and only received the functional training intervention, and the control group followed the normal training schedule. (iii) This study did not exclude participants based on their' dominant and backhand grip patterns.

The sample size analysis was calculated via G*Power 3.1. The effect size was calculated on the basis of previous studies (effect size = 0.24) [37]. Considering an alpha = 0.05 and a power of 0.80 the sample size was calculated as $n = 30$ ($n = 15$ for each group). However, Donner et al. (1981) suggested that the designed sample size for presumptuous individual randomization may be magnified by a design effect (DE) to achieve the required statistical performance under a CRCT [38]. Considering the design effect and potential dropout ratio as 20% of the total sample size [5], the final sample size was calculated as 42.75. Since there were two groups in this study, the sample size was rounded up to $n = 44$ young male tennis players.

Intervention procedures

After subject recruitment, the participants were introduced to the intervention process. During this procedure, the maximum repetition method was used to assess the training level and intensity (load level-weight) of each subject. The FTG received a program based on Santana's Racket Sports Program [39], whereas the CTG followed a traditional resistance training program. The study training protocol is summarized in Table 1. During the 12–week intervention, both groups were trained every Monday, Wednesday, and Friday from 4 to 5 p.m. The main exercise period consisted of 2–4 sets of 10–15 repetitions with a rest period of 20–120 s between sets. Researchers collected the participants' training logbooks weekly and encouraged them to adhere to the intervention. The definition of intervention adherence was attendance at 80% of prescribed sessions. Additionally, the FTG selected two physical education students with rich functional training research as coaches who conducted all the intervention sessions, and the control group was managed by two tennis coaches from the experimental site.

Outcome measures procedures

The dependent variables were tested three times; a pretest (T0) was conducted before the intervention, posttest 1 (T6) was conducted after 6 weeks of the intervention, and posttest 2 (T12) was conducted after 12 weeks of the intervention, to observe the differences between the two groups after the three analyses. Training effects were assessed via two tests. First, tennis skill performance was evaluated via the International Tennis Number on Court Assessment (ITN) test battery [9]. The tennis skill performance evaluated in this protocol assess four aspects: groundstroke depth (GD); volley depth (VD); groundstroke accuracy (GA); serve assessment (SA), and the maximum score is 90 for the GD, 72 for the VD, 84

Table 1 Details of the training programs

Duration	Program	Stage 1	Stage 2	Stage 3
Week 1–4	Functional training	MB wood chop Side T plank BP compound row	MB ABC squat BP staggered stance fly BP staggered stance CLA row	Rope circles Vibration blade throw
	Control training	Light jogging Arm circles Wrist flexes Shoulder rotations	Chest press Body-weight squat Push up Sit up Leg curl Knee lifts	Upper body stretch Shoulder stretch Waist stretch Lower body stretch
Week 5–8	Functional training	BP low-to-high chop DB single-arm diagonal fly rotation BP staggered stance CLA compound row	DB lateral reaching lunge T push up DB staggered-stance bent-over single-arm row	X-up SB rollout Rope circles Vibration blade throw
	Control training	Light jogging Arm circles Wrist flexes Shoulder rotations	Shoulder press Roll up Squat jump Push up bicep curl Leg curl Knee lifts	Upper body stretch Shoulder stretch Waist stretch Lower body stretch
Week 9–12	Functional training	DB lateral reaching lunge Skater BP low-to-high chop MB rotational throw: perpendicular	BP high-to-low chop MB overhead side-to-side slam BP swim MB overhead slam BP high-to-low chop MB overhead side-to-side slam	Single-leg CLA anterior reach Rope circles Vibration blade throw
	Control training	Light jogging Arm circles Wrist flexes Shoulder rotations	Chest and shoulder press Roll up Split squat Push up bicep curl Lunge jump Standing calf raise	Upper body stretch Shoulder stretch Waist stretch Lower body stretch

Note: BP: bands or pulleys; CLA: contralateral arm; DB: dumbbell; KB: kettlebells; MB: medicine balls; SB: stability balls

for the GA, and 108 for the SA. Second, the functional movement screening assessment recommended by Cook was used to evaluate the participants' movement quality [40, 41]. This screening assessment consists of seven basic movement patterns: 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 each test is scored, on a 4-point scale (0–3); on tests where the left and right sides are measured, the lowest score is used, resulting in a total score of 21 for all seven tests [40, 41]. The seven basic movement patterns can be grouped into three main subscales, which are named advanced movement, mobility and stability [40, 41]; the advanced movements subscale included the DS, HS, and ILL; the mobility subscale includes the ASLR, and SM; and the stability subscale includes the TSPU and RS.

The experimental data of this study originated from field tests instead of laboratory tests. Therefore, to achieve meaningful test results, field trials require considerable reflection and careful management to control for irrelevant foreign variables, which is achieved via the following steps: First, prior to the experiment, an orientation meeting was conducted with the participants to introduce them to and demonstrate the training and measurement processes; Second, the participants were discouraged from engaging in any other types of exercise, seeking outside assistance from professionals, or reading self-improvement literature. Third, every test was given in the same order and at the same time of day, which was from 3 to 6 p.m.; the functional training group finished all their assessments on Saturday, while the traditional training group finished them on Sunday because the research team only had one FMS level-2 certified coach. Fourth, the participants were asked to sleep enough the night before the assessment so that they could actively participate in the test with the right attitude and cooperate with the tester throughout the process.

Statistical analysis

Statistical Software for Social Science (SPSS) version 23 was used for all the statistical analyses.

Independent-sample t-tests were used to analyze the baseline data, and descriptive statistics are presented as the means ± standard deviations. A Generalized estimating equation (GEE) model was used to determine the differences at T0, T6, and T12, a Bonferroni-adjusted significance test was used for post hoc pairwise comparisons, and a percentage was used to calculate the change between T0 and T12. The significance level for the whole procedure was established as $p < 0.05$. Additionally, the effect size (d) of each analysis was established automatically by SPSS and via the commonly used guidelines proposed by Cohen (2009) (d = 0.35 means trivial; d = 0.35 to 0.8 means small; d = 0.8 to 1.5 means moderate; and d > 1.5 means large) to determine the effect size of the intervention [42].

Results

This study screened 57 young tennis players, all of whom were right-handed and had a double-handed backhand. Eight participants did not meet the inclusion criteria (screen failures). One participant refused to participate because of a lack of time, and the guardians or parents of the other four objected to their child participating in this experiment (refer to Fig. 1). The researcher allocated 44 participants who voluntarily participated in this study to the FTG ($n = 22$) or CTG ($n = 22$) and written informed consent (cosigned by the participants and their parents or guardians) was obtained from the participants. Two participants from both groups were eliminated during the study process. Hence, the data analysis included information from a total of 40 participants (more information is available in Fig. 1).

The homogeneity of the demographic characteristics of the two groups was assessed via independent t-tests prior to data analysis. The results (Table 2) revealed that the FTG and CTG groups were not significantly different in terms of age (t = 0.93, $p = 0.36$), height (t = -0.21, $p = 0.84$), weight (t = -0.22, $p = 0.83$), or training background (t = -0.04, $p = 0.97$). In other words, the groups were homogeneous in terms of their demographic characteristics.

As shown in Table 3; Figs. 2 and 3, the results revealed statistically significant differences in skill performance

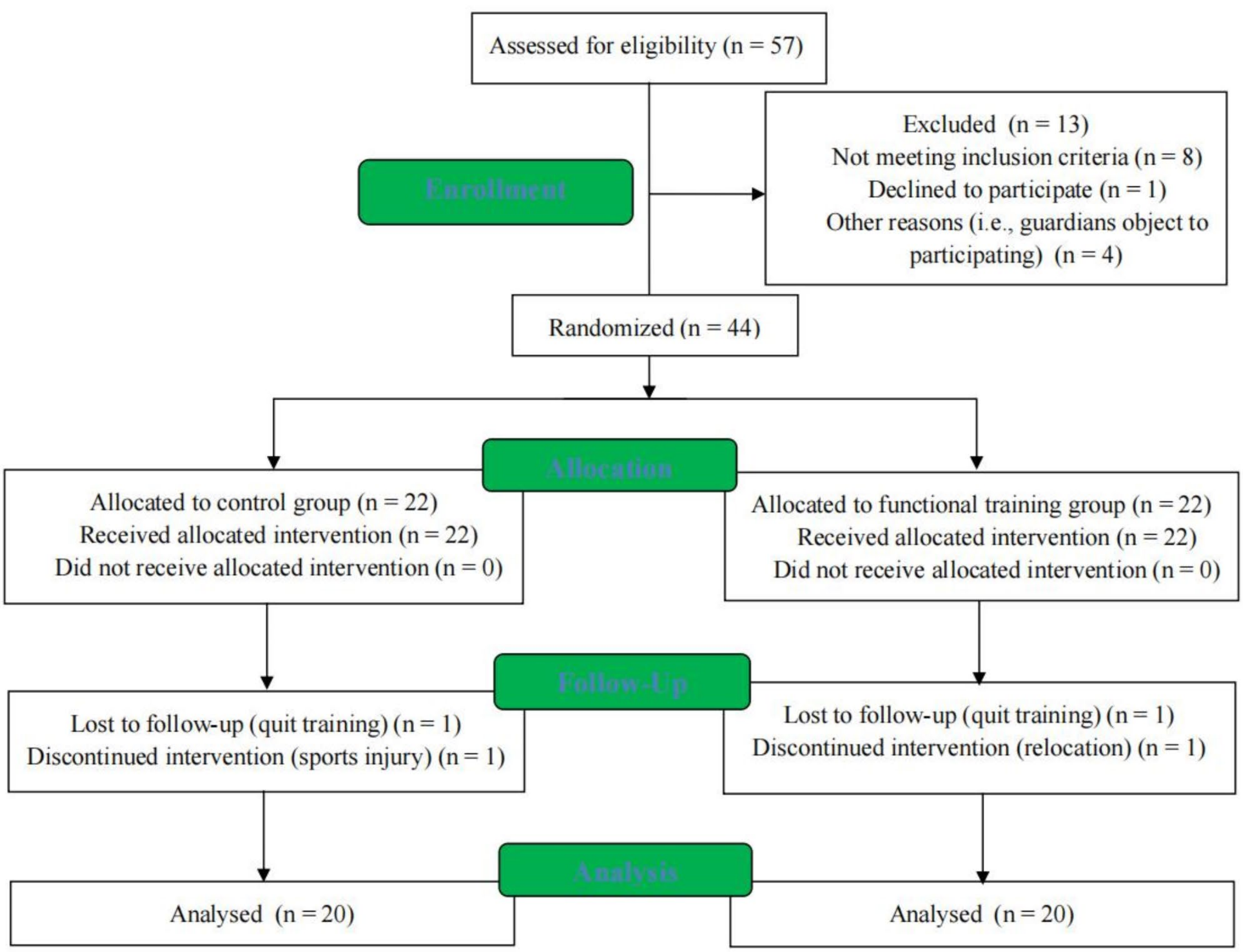

Fig. 1 Participants' flow diagram

Table 2 Participants demographic characteristics

Variables	FTG	CTG	t	*p*
Age (year)	16.65 ± 0.41	16.51 ± 0.57	0.93	0.36
Height (cm)	176.24 ± 2.58	176.41 ± 2.43	-0.21	0.84
Weight (kg)	71.61 ± 2.91	71.82 ± 3.17	-0.22	0.83
Training background (month)	57.90 ± 4.40	57.95 ± 4.23	-0.04	0.97

Note: FTG, functional training group; CTG, control training group

Table 3 Effects of the functional training on skill performance and movement quality

Variables		Time	FTG	CTG	Between Group *p*	Within Group d (T0 vs. T12)		% change (T0 vs. T12)	
						FTG	CTG	FTG	CTG
Skill performance	GD	T0	40.20 (2.14)	39.90 (2.77)	0.694	4.59	3.49	46.0	29.1
		T6	48.15 (2.66) *	44.90 (2.77) *	< 0.001				
		T12	58.70 (5.28) †#	51.50 (3.80) †#	< 0.001				
	VD	T0	32.95 (2.01)	32.00 (2.62)	0.187	2.58	0.59	24.0	4.8
		T6	36.10 (2.66) *	33.05 (2.67) *	< 0.001				
		T12	40.85 (3.83) †#	33.55 (2.65) #	< 0.001				
	GA	T0	38.65 (3.77)	39.10 (2.57)	0.651	4.85	3.39	44.4	24.4
		T6	47.20 (3.94) *	43.85 (3.01) *	0.002				
		T12	55.80 (3.29) †#	48.65 (3.05) †#	< 0.001				
	SA	T0	41.65 (2.62)	41.90 (3.45)	0.791	2.92	1.29	22.7	10.3
		T6	46.50 (3.72) *	43.30 (3.13) *	0.003				
		T12	51.10 (3.75) †#	46.20 (3.24) †#	< 0.001				
Movement quality	Advanced movements subscale	T0	5.85 (0.49)	5.90 (0.45)	0.729	3.08	0.41	36.8	-4.2
		T6	6.65 (0.75) *	5.90 (0.55)	< 0.001				
		T12	8.00 (0.86) †#	5.65 (0.75)	< 0.001				
	Mobility subscale	T0	3.85 (0.75)	3.95 (0.51)	0.611	1.53	0.98	35.1	-12.7
		T6	4.45 (0.76) *	3.85 (0.49)	0.002				
		T12	5.20 (1.01) †#	3.45 (0.51) †#	< 0.001				
	Stability subscale	T0	4.05 (0.61)	3.95 (0.51)	0.562	1.81	0.42	29.6	-5.1
		T6	4.25 (0.44)	3.95 (0.39)	0.020				
		T12	5.25 (0.72) †#	3.75 (0.44)	< 0.001				

Note: FTG, functional training group; CTG, control training group; GD: groundstroke depth; VD: volley depth; GA: groundstroke accuracy; SA: serve assessment; T0: pre-intervention test; T6: after 6-week post-intervention test; T12: after 12-week post-intervention test; * T0 vs. T6, $p < 0.05$; † T6 vs. T12, $p < 0.05$; #T0 vs. T12, $p < 0.05$

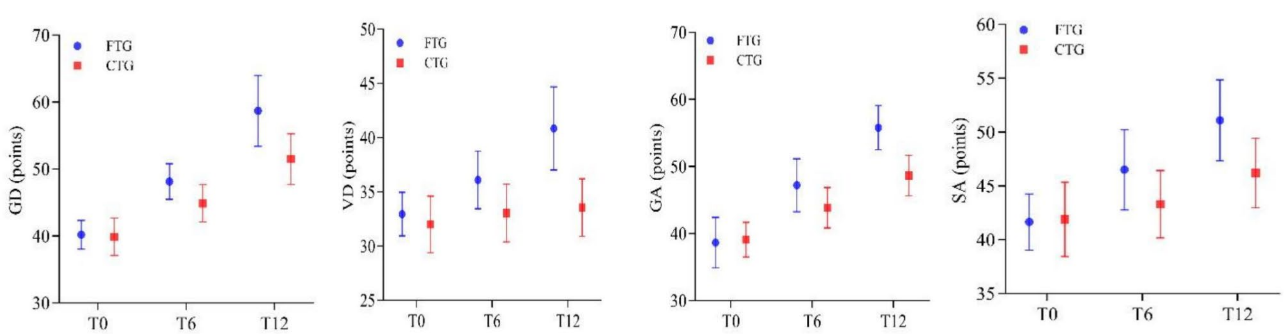

Fig. 2 Effects of 12-week training on the skill performance. Data in blue color represent the functional training group and data in red color represent the traditional training group. FTG, functional training group; CTG, control training group

and movement quality between T0 and T6 ($p < 0.05$), between T0 and T12 ($p < 0.05$), and between T6 and T12 ($p < 0.05$) in the FTG. The functional training intervention was superior to the standard training intervention after a 12-week training period.

First, regarding skill performance (Fig. 2), from baseline (T0) to week 12 (T12), the following findings were observed: (1) The average increase in the GD in the FTG was 46.0%, significantly increasing from 40.20 ± 2.14 to 58.70 ± 5.28 ($p < 0.05$, d = 4.59), whereas the average

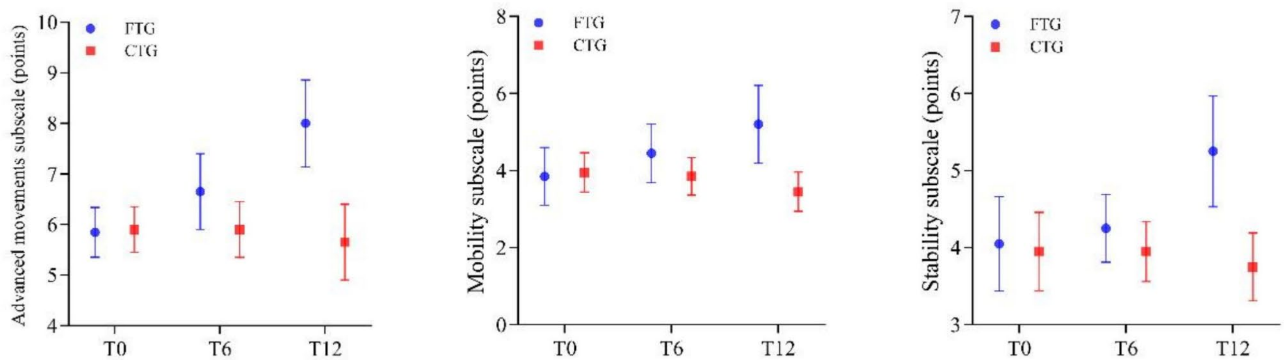

Fig. 3 Effects of 12-week training on the movement quality. Data in blue color represent the functional training group and data in red color represent the traditional training group. FTG, functional training group; CTG, control training group

increase in the GD in the CTG was 29.1%, which was significant increase from 39.90 ± 2.77 to 51.50 ± 3.80 ($p < 0.05$, d = 3.49); there was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$). (2) The mean increase in the VD in the FTG was 24.0%, which represented a change from 32.95 ± 2.01 to 40.85 ± 3.83 ($p < 0.05$, d = 2.58). The average increase in the VD in the CTG was 4.8%, increasing from 32.00 ± 2.62 to 33.55 ± 2.65 ($p < 0.05$, d = 0.59). There was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$). (3) The average increase in the GA in the FTG was 44.4%, which was an increase from 38.65 ± 3.77 to 55.80 ± 3.29 ($p < 0.05$, d = 4.85), and the average increase in the GA in the CTG was 24.4%, increasing from 39.10 ± 2.57 to 48.65 ± 3.05 ($p < 0.05$, d = 3.39), there was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$). (4) The average increase in the SA in the FTG was 22.7%, increasing from 41.65 ± 2.62 to 51.10 ± 3.75 ($p < 0.05$, d = 2.92), and the average increase in the SA in the CTG was 10.3%, increasing from 41.90 ± 3.45 to 46.20 ± 3.24 ($p < 0.05$, d = 1.29); there was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$).

Second, regarding movement quality (Fig. 3), from baseline (T0) to week 12 (T12), the following findings were observed: (1) The average score of the advanced movements subscale in the FTG increased significantly by 36.8%, increasing from 5.85 ± 0.49 to 8.00 ± 0.86 ($p < 0.05$, d = 3.08), whereas the average score of the advanced movements subscale in the CTG decreased by 4.2%, decreasing from 5.90 ± 0.45 to 5.65 ± 0.75 ($p > 0.05$, d = 0.41), and there was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$). (2) The score of the mobility subscale in the FTG significantly increased by 35.1%, increasing from 3.85 ± 0.75 to 5.20 ± 1.01 ($p < 0.05$, d = 1.53). The score of the mobility subscale in the CTG decreased by 12.7%, decreasing from 3.95 ± 0.51 to 3.45 ± 0.51 ($p < 0.05$, d = 0.98). There was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$). (3) The score of the stability subscale in the FTG significantly increased by 29.6%, increasing from 4.05 ± 0.61 to 5.25 ± 0.72 ($p < 0.05$, d = 1.81), whereas that of the CTG decreased by 12.7%, decreasing from 3.95 ± 0.51 to 3.75 ± 0.44 ($p > 0.05$, d = 0.42); there was a significant difference between the two groups after 12 weeks of the intervention ($p < 0.001$).

Discussion

As shown in Table 3; Figs. 2 and 3 and a well-designed functional training program can significantly improve the skill performance and movement quality of young male tennis players. Therefore, the hypothesis that functional training can enhance the skill performance and movement quality of young male tennis players is fully supported by the current data. These findings were expected and are consistent with those of previous studies indicating that functional training can significantly improve the skill performance and movement quality of athletes (badminton, baseball, soccer) in various categories [43–46]. The following discussion presents a more detailed explanation.

Skill performance

On the basis of previous investigations [47, 48], we hypothesized that functional training, when incorporated into standard tennis training, could enhance skill performance more than standard training. The data, however, seem to suggest otherwise. Over an average length of time, standard training—which is based on a coach's several decades of expertise in coaching tennis sport—is beneficial for promoting the performance of young male tennis players. Consequently, a tennis coach may select any approach to elicit tennis—skill performance, and the outcomes should be equivalent within the time span investigated in this study, even if functional training also showed its efficacy in our group. Moreover, these skill—performance modifications are expected to develop within six to 12 weeks. To the best of our knowledge, this is the first publication to investigate this type of training in this age group of trained individuals. Therefore, the current results are difficult to compare with those of similar studies. However, the conclusion that functional training can significantly improve athletes' skill performance has been confirmed in other types of athletes. Liu et al. (2023) revealed that 3 sessions per week of functional training for 12 weeks improved the accuracy and depth test scores among national—level tennis players [49]. Chen (2023) reported that 8 weeks of functional training with a frequency of 3 sessions per week led to improvements in depth and hitting accuracy test scores among national—level badminton players [43]. Another author reported that 8 weeks of functional training among club basketball players could improve athletes accuracy in shooting skills from outside the three-point arc [50]. In addition, Lee et al. (2023) revealed that 3 sessions per week of functional training for 6 weeks improved the batting speed of collegiate baseball players [44]. These findings demonstrate that functional training regimens might significantly improve athletes' skill performance. One interpretation of the findings of this study is that functional training can enhance an athlete's capacity to regulate their body posture and technical movements, increase the effectiveness of power transmission, and increase their ability to precisely control their motor nerve in relation to the racket [43, 51]. Moreover, an additional plausible rationale could be the functional training specificity principle, which advocates for training in a manner that simulates the intended action to enhance the target movement itself, rather than targeting individual muscle groups [5, 11, 52]. However, workouts that improve muscle strength and durability are used in conventional training. Owing to the unidirectional nature of these workouts, which mainly use the sagittal plane, only the necessary muscles quickly become stronger under high stress. Additionally, functional training is superior to regular training for tennis player performance enhancement since it exercises many axes simultaneously, employing multiple muscle groups and joints.

Movement quality

As expected, a significant improvement in movement quality was observed after the functional training intervention. This finding was not unexpected because functional training attempts to develop muscles in corresponding multiplanar movements and intergrate 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 [52, 53]. When the changes between the different measurements were examined, there was a significant difference between the two groups, with greater improvement observed in the FTG (the advanced movements subscale: 36.8%; the mobility subscale: 35.1%, and the stability subscale: 29.6%). However, there were decreases in these assessments in the CTG (the advanced movements subscale: -4.2%; the mobility subscale: -12.7%; and the stability subscale: -5.1%). This decrease may be due to muscle tension caused by intense exercise loads during rapid body development [11]. If the muscles being used are not exercised in accordance with the principles of functional training, the quality of movement may deteriorate even though individual motor skills may improve. Traditional resistance training is not always multiarticular or multiplanar and therefore may overlook the importance of an athlete's functional limitations and their ability to perform coordinated functional movements accurately [54]. Previous research has validated these findings and demonstrated that functional training can significantly enhance the quality of mobility for various athlete populations [16, 55, 56]. Campa et al. (2018) reported that 20 weeks of a functional training program significantly improved the movement quality of elite male soccer players [57]. Riela et al. (2019) reported that 8 weeks of functional training, three times a week, significantly improved the movement quality of male professional soccer players [45]. Suzuki et al. (2022) reported that 12 weeks (four sessions per week) of functional training greatly improved the movement quality of high school baseball players [46]. Tennis involves multiple muscled groups joints are exercised multiple axes simultaneously, and their explosive movement patterns place a high demand on athletes' movement quality [5]. However, better movement quality can both enhance athletes; performance and successfully prevent sports injuries [5]. Therefore, it is recommended that athletes and coaches exercise according to the functional training principles.

Limitations

This study has several limitations and needs further discussion for future study: First, our study was performed with a particular group of young male tennis players. Therefore, future studies should include other groups (e.g., different age groups, females, elites). Second, the speed of the ball is an important measure for assessing the level of tennis player' performance. The most advanced methods (i.e., Hawk-eye technology and Play Sight) use multiple high-speed cameras to calculate the ball speed. However, high-speed cameras are very expensive and difficult to install, which limits their popularity in research. The International Tennis Federation endorses the ITN as a reliable rating system for tennis. Designed around specific strokes and the sport's unique characteristics, this system offers a more precise evaluation of a player's technical abilities. By assessing players across multiple skill areas, the ITN provides a standardized ranking method that promotes fair competition and aids coaches in customizing training programs to meet individual needs [10]. Therefore, this study used ITN on Court Assessment to evaluate the skill level of the young male tennis players included in this study. Finally, the subjects were from the southern region of China; their diets were essentially the same, with similar caloric intake; we did not regulate or standardize the participants' diets during the study period. The participants agreed and signed informed consent forms after the coach clarified that they did not need to alter their regular eating habits for the duration of the experiment.

Practical implications

The findings of the present study revealed that exercise training can improve athletes' skill performance and movement quality. However, even though functional training is a hot topic of research in the field of exercise training, no study has been published on the effects of functional training on the skill performance and movement quality of young male tennis players. Several studies have shown that functional training can improve athletes' skill performance and movement quality [28–30]. Nonetheless, the findings of this study can assist tennis players, coaches, researchers, and managers in implementing the most effective exercise training methods for improving tennis players' skill performance and movement quality. Additionally, this study demonstrated that Santana's racket-based functional training program can improve the skill performance and movement quality of young tennis players. As a result, coaches, researchers, and managers can apply this functional training program to other racket-based youth athletes, mainly to improve the skill performance and movement quality of athletes in other racket sports.

Conclusions

This study contributes to a growing body of literature on the effects of functional training on improving the skill performance and movement quality of athletes. The results show that functional training can improve the skill performance of young male tennis players more than standard training programs can. Additionally, compared with standard training programs, 6 weeks of functional training had more significant effects on skill performance and movement quality. Collectively, our results suggest that functional training is effective in improving the skill performance of young male tennis players and improving their mobility and stability along the kinetic chain.

Abbreviations

CRCT	Cluster Randomized Controlled Trial
GEE	Generalized Estimating Equation
FTG	Functional Training Group
CTG	Control Group
DE	Design Effect
GD	Groundstroke Depth
VD	Volley Depth
GA	Groundstroke Accuracy
SA	Serve Assessment
DS	Deep Squat
HS	Hurdle Step
ILL	In-line Lunge
SM	Shoulder Mobility
ASLR	Active Straight Leg Raise
TSPU	Trunk Stability Push-up
RS	Rotary Stability

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-025-01085-7.

Supplementary Material 1

Acknowledgements

The authors are gratefully to the study participants, coaches, and testers. The authors thank the assistance of the training base manager.

Author contributions

Conceptualization, XWS, BXR and SKG; methodology, XWS, BXR and SKG; formal analysis, XWS, BXR and FDZ; investigation, XWS, BXR and ZJL; data curation, XWS, BXR, and TB; writing—original draft preparation, XWS, BXR, and SKG; writing—review and editing, SKG and TB. All authors have read and agreed to the published version of the manuscript.

Funding

This study was supported by A Project Supported by the Education Ministry's Youth Fund Project for Humanities and Social Sciences Research of China (Grant No. 24YJC890001), the Scientific Research Fund of Zhejiang Provincial Education Department (Grant No. Y202351082), and the Philosophy and Social Sciences Research Project of Anhui Province (Grant No. AHSKY2022D188).

Data availability

The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate

There are no ethical issues associated with this study, all athletes and their parents were fully informed about the procedure and written informed consent was obtained before testing and intervention. Moreover, this study involving human participants were reviewed and approved by Universiti Putra Malaysia Ethics Committee (protocol number: JKEUPM-2020-283). Additionally, the functional training program was developed at Santana's Racket Sport training program and was also got the permission from the publisher.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 22 July 2024 / Accepted: 17 February 2025
Published online: 08 March 2025

References

1. Kolman NS, Kramer TE-GMT. Technical and tactical skills related to performance levels in tennis: A systematic review. J Sports Sci. 2019;37:108–21.
2. Smekal G, Von Duvillard SP, Rihacek C, Pokan R, Hofmann P, Baron R, et al. A physiological profile of tennis match play. Med Sci Sports Exerc. 2001;33:999–1005.
3. Johnson CD, McHugh MP. Performance demands of professional male tennis players. Br J Sports Med. 2006;40:696–9.
4. O'Donoghue P, Ingram B. A notational analysis of elite tennis strategy. J Sports Sci. 2001;19:107–15.
5. Xiao W, Bai X, Geok SK, Yu D, Zhang Y. Effects of a 12-week functional training program on the strength and power of Chinese adolescent tennis players. Children-Basel. 2023;10:635.
6. Zetou E, Vernadakis N, Tsetseli M, Kampas A, Michalopoulou M. The effect of coordination training program on learning tennis skills. Sport J. 2012;15:1–9.
7. Kovacs MS. Tennis physiology. Sport Med. 2007;37:189–98.
8. Kallem Seyyar G, Aras B, Aras O. Trunk control and functionality in children with spastic cerebral palsy. Dev Neurorehabil. 2019;22:120–5.
9. International Tennis Federation. ITN on court assessment. Int Tennis Federation. 2004;:1–23.
10. Morais JE, Kilit B, Arslan E, Soylu Y, Neiva HP. Effects of a 6-week on-court training program on the international tennis number (ITN) and a range of physical fitness characteristics in young tennis players. Front Sport Act Living. 2024;6:1304073.
11. Yildiz S, Pinar S, Gelen E. Effects of 8-week functional vs. traditional training on athletic performance and functional movement on prepubertal tennis players. J Strength Cond Res. 2019;33:651–61.
12. Morais JE, Bragada JA, Silva R, Nevill AM, Nakamura FY, Marinho DA. Analysis of the physiological response in junior tennis players during short-term recovery: Understanding the magnitude of recovery until and after the 25 seconds rule. Int J Sports Sci Coach. 2023;18:1208–16.
13. Saunders PU, Telford RD, Pyne DB, Peltola EM, Cunningham RB, Gore CJ, Hawley JA. Short-term plyometric training improves running economy in highly trained middle and long distance runners. J Strength Cond Res. 2006;20:947–54.
14. Feros SA, Young WB, O'Brien BJ. Efficacy of combined general, special, and specific resistance training on Pace bowling skill in club-standard cricketers. J Strength Cond Res. 2020;34:2596–607.
15. Kilit B, Arslan E. Effects of high-intensity interval training vs. on-court tennis training in young tennis players. J Strength Cond Res. 2019;33:188–96.
16. Kamal S. Effect of functional strength training on performance level of shot put. Sci Mov Heal. 2016;16:98–102.
17. Osipov A, Kudryavtsev M, Gatilov K, Zhavner T, Klimuk Y, Ponomareva E, et al. The use of functional training-Crossfit methods to improve the level of special training of athletes who specialize in combat Sambo. J Phys Educ Sport. 2017;17:2013–8.
18. Keats MR, Emery CA, Finch CF. Are we having fun yet? Fostering adherence to injury preventive exercise recommendations in young athletes. Sport Med. 2012;42:175–84.
19. Girard O, Eicher F, Fourchet F, Micallef JP, Millet GP. Effects of the playing surface on plantar pressures and potential injuries in tennis. Br J Sports Med. 2007;41:733–8.
20. Ellenbecker TS, Pluim B, Vivier S, Sniteman C. Common injuries in tennis players: exercises to address muscular imbalances and reduce injury risk. Strength Cond J. 2009;31:50–8.
21. Porter R. Risk Factors for Injuries in Elite Junior and Professional Tennis Players. 2020.
22. Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. Br J Sports Med. 2012;46:492–8.
23. Moreno-Pérez V, Moreside J, Barbado D, Vera-Garcia FJ. Comparison of shoulder rotation range of motion in professional tennis players with and without history of shoulder pain. Man Ther. 2015;20:313–8.
24. Cooke EV, Tallis RC, Clark A, Pomeroy VM. Efficacy of functional strength training on restoration of lower-limb motor function early after stroke: phase I randomized controlled trial. Neurorehabil Neural Repair. 2010;24:88–96.
25. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. Int J Sports Physiol Perform. 2019;14:270–3.
26. Guoliang W. Training intensity of explosive force with biomechanics. J Shandong Inst Phys Educ Sport. 2007;23:82–3.
27. Drew MK, Finch CF. The relationship between training load and injury, illness and soreness: a systematic and literature review. Sport Med. 2016;46:861–83.
28. Liao T, Duhig SJ, Du G, Luo B, Wang YT. The effect of a functional strength training intervention on movement quality and physical fitness in adolescents. Percept Mot Skills. 2022;129:176–94.
29. Liu Q, Li Y. The effect of functional training on the performance of female handball players' shooting skills. J Sport Sci. 2021;9:35–43.
30. Zirhli O, Demirci N. The influence of functional training on biomotor skills in Girl tennis players aged 10–12. Balt J Heal Phys Act. 2020;12:33–45.
31. Wu C, Cheong M, Wang Y, Wang X, Zhang Q, Li M, et al. Impact of functional training on functional movement and athletic performance in college Dragon boat athletes. Int J Environ Res Public Health. 2023;20:3897.
32. Ju-sik P. The effect of functional training on the physical strength factor of elite Taekwondo athletes. Kinesiology. 2019;4:1–7.
33. Usgu S, Yakut Y, Kudaş S. Effects of functional training on performance in professional basketball players. Turkish J Sport Med. 2020;55:321–31.
34. Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, Devereaux PJ, Altman DG. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. Int J Surg. 2012;10:28–55.
35. Wensheng X. Study on the training model of order form for the young tennis reserve talengs in WenZhou. [Master's dissertation. WenZhou University]. China.; 2016.
36. Cheng C, et al. Comparative study on reserve tennis talents training for teenager in Zhejiang Province. Zhejiang Sport Sci. 2017;39:66–70.
37. Chizewski A, et al. High intensity functional training (HIFT) improves fitness in recruit firefighters. Int J Environ Res Public Health. 2021;18:13400.
38. Donner A, Birkett N, Buck C. Randomization by cluster: sample size requirements and analysis. Am J Epidemiol. 1981;114:906–14.
39. Santana JC. Functional training. Human Kinetics.; 2015.
40. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function—part 1. Int J Sports Phys Ther. 2014;9:396–409.
41. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 2. Int J Sports Phys Ther. 2014;9:396–409.
42. Fröhlich M, Emrich E, Pieter A, Stark R. Outcome effects and effects sizes in sport sciences. Int J Sport Sci Eng. 2009;3:175–9.
43. Chen C. Effect of functional training on hitting quality in badminton players. Rev Bras Med Do Esporte. 2023;29:e20220616-e2022_0616.
44. Lee J, Yang G-S, Lee M. The effects of two types of training on the physical ability of university baseball players. Ann Appl Sport Sci. 2023;11:0–0.
45. Riela LA, Bertollo M. The effectiveness of eight weeks of a movement-based program on functional movement patterns in male professional soccer players. J Phys Educ Sport. 2019;294:1976–83.
46. Suzuki K, Mizoguchi Y, Kimura F, Sawada Y, Akasaka K. Efficacy of injury prevention using functional movement screen training in High-School baseball players: secondary outcomes of a randomized controlled trial. Health Care (Don Mills). 2022;10:2409.
47. Habib. Effect of functional resistance drills with elastic bands on some of physical and Biomechanical variables and kicking accuracy in soccer. Assiut J Sport Sci Arts. 2018;2018:312–32.
48. Alhenawy S. Impact of functional strength exercises on core muscles and the level of technical performance of L-cross skill on rings. J Appl Sport Sci. 2022;12:3–18.
49. Liu B, Yi Y. Effects of functional training on the hitting quality of tennis players. Rev Bras Med Do Esporte. 2023;29.
50. Abood MA, Al Abdullah JS, Al Midhatee SA. Effect of functional exercises on the explosive ability and accuracy of shooting from outside the three-point line in advanced basketball players. Sport Tk-Revista Euroam Ciencias Del Deport. 2022;11:1–11.
51. Kawasaki S, Imai S, Inaoka H, Masuda T, Ishida A, Okawa A, et al. The lower lumbar spine moment and the axial rotational motion of a body during one-handed and double-handed backhand stroke in tennis. Int J Sports Med. 2005;26:617–21.
52. Michael B. New functional training for sports. Journal of Chemical Information and Modeling; 2016.
53. Cook G. Functional movement systems: svreening, assessment and corrective strategies. 2010.
54. Xiao W, Bai X, Soh KG, Zhang Y. Effects of functional training on tennis-specific physical fitness and functional movement screen in junior tennis players. PLoS ONE. 2024;19:1–12.
55. Baron J, Bieniec A, Swinarew AS, Gabryś T, Stanula A. Effect of 12-week functional training intervention on the speed of young footballers. Int J Environ Res Public Health. 2020;17:1–11.

56. Sawczyn M. Effects of a periodized functional strength training program (FST) on functional movement screen (FMS) in physical education students. Phys Educ Students. 2020;24:162–7.
57. Campa F, Spiga F, Toselli S. The effect of a 20-Week corrective exercise program on functional movement patterns in youth elite male soccer players. J Sport Rehabil. 2019;28:746–51.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.