Effects of 12-Week Combined Circuit Tabata Training (Ctt): Empower the Fitness and Passion of Young Squash Athletes

Efectos del Entrenamiento en Circuito Tabata (Ctt) Combinado de 12 Semanas: Potencia la Forma Física y la Pasión de los Atletas Jóvenes de Squash

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Abstract

The present study aims to investigate the effects of combined circuit tabata training (CTT) on physical fitness and passion of young squash athletes. This experiment randomized control trial (RCT) research was carried out three times a week for 12 weeks. A total of 50 young squash athletes were divided into CTT (n = 25, 18.7 ± 1.06 year, 161 ± 3.74 cm, 58.0 ± 3.03 kg, 22.0 ± 1.06 kg/m2) and control group (CG, n = 25, 18.9 ± 1.04 year, 162 ± 3.50 cm, 59.0 ± 3.49 kg, 22.2 ± 1.04 kg/m2). Pre and post measurements were carried out using the handgrip dynamometer test (HDT), 5m sprint test (5mST), 5-0-5 COD test (505CODT), medicine ball throw test (MBTT), sit and reach test (SRT), yo-yo intermittent recovery test level 1 (YYIRTL1). We observed Time (T) effects for physical fitness on components HDT (p < .001), 5mST (p

Resumen

El presente estudio tiene como objetivo investigar los efectos del entrenamiento tabata en circuito combinado (CTT) sobre la condición física y la pasión de los jóvenes atletas de squash. Esta verdadera investigación experiment de control aleatorio (ECA) se llevó a cabo tres veces por semana durante 12 semanas. Un total de 50 jóvenes atletas de squash se dividieron en CTT (n = 25, 18.7 ± 1.06 años, 161 ± 3.74 cm, 58.0 ± 3.03 kg, 22.0 ± 1.06 kg/m2) y grupo de control (CG, n = 25, 18.9 ± 1.04 años, 162 ± 3.50 cm, 59.0 ± 3.49 kg, 22.2 ± 1.04 kg/m2). Las mediciones previas y posteriores se llevaron a cabo mediante la prueba de dinamómetro de agarre manual (HDT), la prueba de sprint de 5 m (5mST), la prueba de COD 5-0-5 (505CODT), la prueba de lanzamiento de balón medicinal (MBTT), la prueba de sentarse y alcanzar (SRT),

< .001), 505CODT (p < .001), MBTT (p < .001), SRT (p = .006), and YYIRTL1 (p < .001). There were significant differences in group (G), including HDT (p < .001), 5mST (p = .048), 505CODT (p = 0.018), MBTT (p = .005), SRT (p = .004), and YYIRTL1 (p = .001). There was an interaction (I) on the components HDT (p < .001), 5mST (p < .001), 505CODT (p < .001), MBTT (p < .001), YYIRTL1 (p < .001). However, no interaction was reported on SRT (p = .687). In addition, based on %Δ and ES, it shows that CTT group has greater changes in physical fitness and passion from pre-test to post-test compared to CG group. Among young squash athletes, the study revealed that CTT was the key factor in the improvement of physical fitness and passion.

Keywords: Circuit tabata training, Fitness, Passion, Squash.

Prueba de recuperación intermitente yo-yo nivel 1 (YYIRTL1). Observamos efectos del tiempo (T) para la aptitud física en los componentes HDT (p < .001), 5mST (p < .001), 505CODT (p < .001), MBTT (p < .001), SRT (p = .006) y YYIRTL1 (p < .001). Hubo diferencias significativas en el grupo (G), incluyendo HDT (p < .001), 5mST (p = .048), 505CODT (p = .018), MBTT (p = .005), SRT (p = .004) y YYIRTL1 (p = .001). Hubo interacción (I) sobre los componentes HDT (p < .001), 5mST (p < .001), 505CODT (p < .001), MBTT (p < .001), YYIRTL1 (p < .001). Sin embargo, no se informó ninguna interacción con la SRT (p = .687). Además, con base en %Δ y ES, muestra que el grupo CTT tiene mayores cambios en la aptitud física y la pasión desde la prueba previa hasta la prueba posterior en comparación con el grupo CG. Entre los jóvenes atletas de squash, el estudio reveló que el CTT era el factor clave en la mejora de la condición física y la pasión.

Palabras clave: Circuito tabata entrenamiento, Fitness, Pasión, Squash.

Introduction

Squash is a type of competitive sport that has the characteristics of high intensity game, because athletes are required to perform several types of movement skills (e.g., running, accelerations, decelerations, hitting the ball, changing direction) (James et al., 2022). In addition, Squash is considered a racket sport that has a fast level and requires an energy expenditure of 4.933 ± 620 kJ.h−1 (Turner et al., 2021), and the average oxygen consumption during the game is 86-92% from maximum oxygen consumption (VO^{2max}) (Ventura-Comes et al., 2019), therefore athletes need well-developed physical fitness (Ma & Kabala, 2024). Physical fitness consists of many factors (motor abilities) for example: strength, speed, agility, power, flexibility and endurance. Data from previous studies reported that physical fitness is an important factor in competitive sports (Lambrich & Muehlbaue, 2023; Wang et al., 2023), athletes with high physical fitness can maintain good performance during competition (Deng et al., 2023; Eraslan et al., 2021). Likewise in tennis, components of physical fitness such as strength can generates strong shots (Xiao et al., 2022), in badminton it helps athletes change direction quickly (Guo et al., 2021). Meanwhile, poor physical fitness is a major factor that causes fatigue and difficulty to achieve high performance (Gani et al., 2023). In addition, it has been proven based on previous studies that physical fitness is an important aspect for athletes to achieve success in competitive sports (Gonzalez Ortega, 2023; Marin et al., 2023; Rios et al., 2023).

Over the last several decades, passion has also been identified as a factor that is important for athletes (Ogallar-Blanco et al., 2024). Basically, passion can be interpreted as an athlete's ability in gaining strong passion for participating in multiple activities for long term periode (St-Cyr et al., 2021; Uğraş et al., 2024). Based on the literature, "the Dualistic Model of Passion (DMP)" has two dimensions, namely harmonious passion (HP) which is the result of the internalization of autonomous activities into one's identity (Vankakova et al., 2021), HP stimulates a behavior to carry out activities voluntarily or without pressure internal or external (St-Cyr et al., 2023). Meanwhile, obsessive passion (OP) is generated from the internalization of controlled activities into one's identity (Mahdavi-Jafari, 2019), OP creates a certain behavior to engage in activities because of the internal possibilities that control them. Data from previous studies reported that passion provides many positive benefits, for example have an important role in triggering motivation to exercise (Yukhymenko-Lescroart, 2021). Chen et al. (2019), reported that the development of passion in athletes will have a positive impact on reducing burnout. In addition, based on other studies, OP has been shown to be positively related to satisfaction and concentration (Chamorro et al., 2020). Considering the benefits which can be obtained by increasing physical fitness and passion, many studies have documented various types of training to improve physical fitness (Deng et al., 2023), and passion (Castillo et al., 2020).

A combination of circuit tabata training (CTT) becomes a solution and recommendation by researchers (Murawska-Cialowicz et al., 2020). Basically, CTT is an exercise that involves stations (Pieczyńska et al., 2021), each station has a different type of activity (Stojanović et al., 2023). In addition, CTT adopts the concept of high-intensity training carried out for 20-seconds and alternated by 10-second rest periods (Gutiérrez-Arroyo et al., 2023). Based on previous studies, CTT has been proven can be used as a training tool to improve several aspects of athletes, for example it was reported that CTT could be ideal training to induce significant changes in obesity indices and physical fitness (Lee et al., 2021). In addition, other facts reported that CTT induces greater cardiorespiratory and metabolic responses in soccer players (Marín-Pagán et al., 2020). Meanwhile, Mehmood et al. (2022), reported other benefits from the effects of the CTT program for six weeks,

which can reduce body mass index (BMI), body fat (BF) and waist-to-hip ratio (WHR). Research on CTT has been studied previously by several researchers (Andreassen et al., 2019; Ballesta-García et al., 2019; Ho et al., 2024; Marinho et al., 2022; Sperlich et al., 2017; Turri-Silva et al., 2021). However, to the best of our current knowledge there was a lack of previous research on the effects of CTT which was implemented for 12 weeks to improve physical fitness and passion among young squash athletes. Thus, the purpose of the study was to evaluate the effect of CTT training on the physical fitness and passion of young squash players.

Materials and Methods

Participants

There were 60 young male squash athletes from the Department of Physical Education at Makasar State University (Indonesia) were selected based on inclusion criteria: (i) beginner-level athletes, (ii) aged 17-20 years, (iii) not injured. Meanwhile, the exclusion criteria are: (i) got injury in the last 1 month, (ii) more than 21 years old, (iii) elite level athlete, and (iv) currently taking part in a national or international competitive event. Initially, there were 60 athletes involved in this research, but 5 athletes were injured and 5 others took part in national competition.

As a result, only 50 athletes were involved in this research (see Fig.1). When referring to sample (participant) requirements based on G*power analysis (version 3.1.9.4, Kiel University, Germany), with effect size = .25, α err prob = .05, and power (1-β err prob) = .90 (power actual = 0.91%), the result showed that the minimum sample required is 46 athletes, thus the number of 50 athletes involved in this research met the requirement. Participants were allocated into experimental (CTT, *n* = 25, 18.7 ± 1.06 year, 161 ± 3.74 cm, 58.0 ± 3.03 kg, 22.0 ± 1.06 kg/m2), and control (CG, *n* = 25, 18.9 ± 1.04 year, 162 ± 3.50 cm, 59.0 ± 3.49 kg, 22.2 ± 1.04 kg/m2) groups using the Random Group Generator (RGG) application. After participants fully grasp the rules of the study, they are required to sign a consent letter regarding their involvement in the study. This study was approved by the local Ethics Committee of Makasar State University, Indonesia (approval date: UNM-503/LPPM/01/01/2024). All procedures were in accordance with the the latest amendement of the Declaration of Helsinki (Human Studies). Information regarding age, height, weight, and body mass index is presented in Table 1.

Figure 1
CONSORT flow

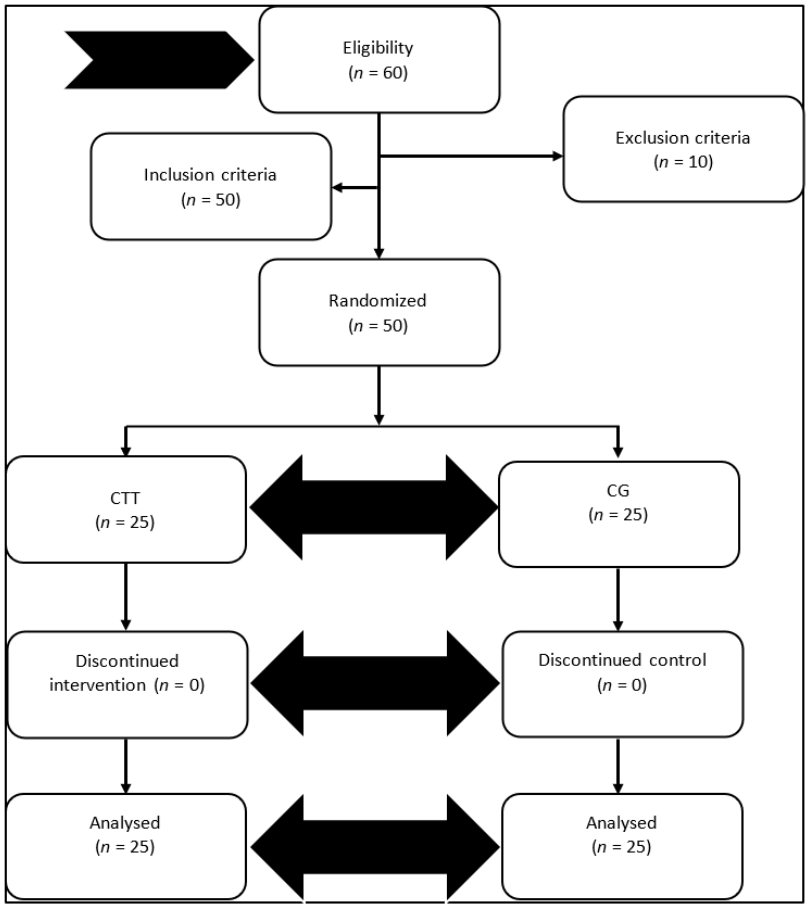


Table 1
Participant Characteristics (mean ± SD)

Group	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)
CTT (*n* = 25)	18.7 ± 1.06	161 ± 3.74	58.0 ± 3.03	22.0 ± 1.06
p	.232	.158	.189	.131
CG (*n* = 25)	18.9 ± 1.04	162 ± 3.50	59.0 ± 3.49	22.2 ± 1.04
p	.311	.243	.269	.144

Note: CTT = Circuit tabata training, CG = Control group, *SD* = Standard deviation, BMI = Body mass index.

Instruments

Physical Fitness

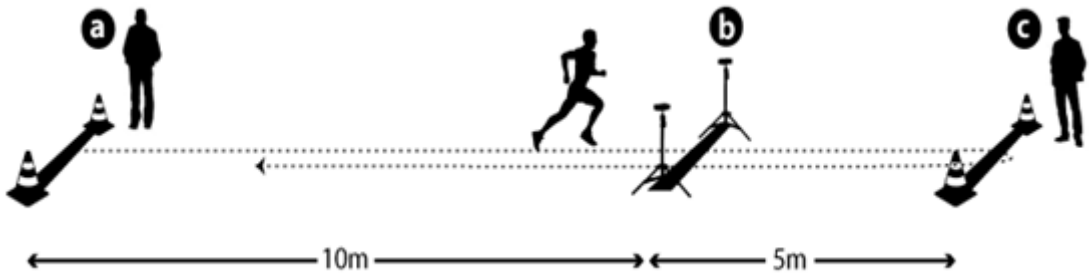
The instrument for measuring the level of physical fitness among athletes consists of several tests:

Strength: Handgrip Dynamometer Test (HDT). The HDT device (Takei Kiki Kogyo, Tokyo, Japan) was used to measure hand grip strength (kg) (Sánchez-Muñoz et al., 2020). Participants stood upright holding the handgrip dynamometer in their right or left hand. On the "Go" signal, participants grip the dynamometer handgrip as tightly as possible. Each participant got three opportunities to carry out this test. The highest score was recorded for statistical analysis.

Speed: 5m Sprint Test (5mST). This instrument was adopted from a previous study to measure running speed levels (James et al., 2022). Participants stood on the start line. On the "Go" signal, participants must run maximally towards the finish line. The distance from the start line to the finish line is 5 m. Each participant got three opportunities and the assessment was carried out by calculating the fastest time (seconds) from these three opportunities.

Agility: 5-0-5 COD Test (505CODT). The 505CODT instrument has been recognized as a valid test for measuring the agility abilities of athletes in several sports that require short-distance acceleration (Guo et al., 2021). Participants stood on the star line. On the "Go" signal, participants ran to cone A then to cone B. From cone B, participants quickly ran to cone C, then turned around and ran back to cone A (see Fig. 2). Participants were given three opportunities. The assessment was carried out by calculating the fastest time (seconds) from these three opportunities.

Figure 2
5-0-5 COD test



Power: Medicine Ball Throw Test (MBTT). MBTT is an accurate instrument for measuring arm power levels (Nuhmani, 2022). Participants stand on a mat holding a medicine ball weighing 6 kg at their chest. On the "Go" signal, participants bend their knees and then threw the medicine ball horizontally using both hands (chest pass) (Belli et al., 2022). Participants were given three opportunities to throw. The farthest throwing was used for the final score (cm) in the analysis result.

Flexibility: Sit and Reach Test (SRT). SRT is an instrument that can be used to measure flexibility of the trunk and hip joints (cm) (Sánchez-Muñoz et al., 2020). Participants removed their shoes and sat on the floor with their legs straight against the box of a sit-and-reach table (Novel Products, Inc., Rockton, Illinois, USA). With their hands on the table, after the "Go" instruction, participants stretched their hands forward as far as possible while pushing the ruler along the measurement scale on the box. Participants were given 3 opportunities. The assessment was carried out by recording the furthest distance.

Endurance: Yo-Yo Intermittent Recovery Test Level 1 (YYIRTL1). YYIRTL1 was used to evaluate the endurance capacity of athletes in meters. This test was conducted as follows: After the audio sounded "beep", participants ran from cone A towards cone B with a distance of 20 m (must be reached before the next beep signal), after reaching cone B, the participants had a recovery period of 10 seconds and run again from cone B to cone A. This activity was carried out continuously until the participant could not run or could not follow the "beep" sound. The running distance (YYIRL1) was recorded for statistical analysis (Villaseca-Vicuña et al., 2021).

Passion

In this study, the Spanish version of the passion measurement tool (Chamarro et al., 2015) was used and translated into the English language, following the International Test Commission's guidelines for cross-cultural-test adaptation of the Hambleton (1993) method to improve its comprehension by the participants. The translated scale evolved from a set of focus-group meetings with university professors. Four male and female academic educators/researchers formed the focus group. The focus group held a discussion and administered a pre-test to a group of students (n = 20) to gauge their understanding of the items in order to identify potential issues relating to issues with the cultural context. This questionnaire has six question items from the harmonious passion (HP) dimension and 6 question items from the obsessive passion (OP) dimension which were adapted to the squash sport. For example, question for HP = "This squash is carried out aligns with my other activities". Meanwhile OP = "I can't live without squash". The 12 question items were scored using a Likert scale from 1 = strongly disagree to 7 = very strongly agree (Vankakova et al., 2021). A high score reflects a great level of passion in squash athletes.

Procedures

This research was carried out between January-March 2024. We adopted a experiment method with a random control trial (RCT) design for 12 weeks. At the first meeting, participants in CTT and CG carried out a physical fitness pre-test (HDT, 5mST, 505CODT, MBTT, SRT, YYIRTL1), and filled out a passion questionnaire (HP, OP). This pre-test activity was directly supervised by five research team members, who were expert in sports training. The second meeting, CTT and CG groups implemented an intervention program for 12 weeks with three meetings a week, namely: Monday, Wednesday, and Saturday. At the last meeting, CTT and CG carried out a physical fitness post-test (HDT, 5mST, 505CODT, MBTT, SRT, YYIRTL1), and filled out a passion questionnaire (HP, OP).

CTT and CG program

Before the CTT and CG intervention program begins, all participants should warm-up for 5 minutes. The duration of CTT was 5 minutes with details of one station work: 20 seconds and rest: 10 seconds, while CG has a training duration of 15 minutes and 1 minute rest for each type of exercise. After the CTT and CG activities were completed, all participants were instructed to cool down for 5 minutes. The CTT and CG programs are presented in Table 2.

Statistic Analysis

Data normality testing was checked using Shapiro-Wilk analysis and homogeneity with Levene's test. Descriptive data was presented as mean ± *SD*. The delta percentage (%Δ) was calculated as follows: %Δ = (posttest–pretest/pretest) × 100. In addition, differences in physical fitness (HDT, 5mST, 505CODT, MBTT, SRT, YYIRTL1), and passion (HP, OP) intervention effects (time [pre-test vs post-test] × group [CTT vs. CG] and interaction [time vs group]) were analyzed with repeated-measures two-way analysis of variance (Menz et al., 2021). Paired student's t tests were chosen to investigate changes in physical fitness and passion variables from the pre-test to post-test. Cohen's (d) was chosen to investigate the effect size (*ES*) selected with the criteria: < 0.2 (trivial), 0.2 – 0.6 (small), 0.6 – 1.2 (moderate), 1.2 – 2.0 (large), and > 2.0 (very large) (Stojanović et al., 2023). Meanwhile, η2p with the criteria: .01 (small), .06 (medium), and .14 (large). All data were analyzed using the Jamovi statistical tool (version 2.3.28). The determined p-value was .05. The reliability of all dependent variables was assessed by calculating intra-class correlation coefficients (ICC).

Table 2
CTT and CG program for 12 weeks

Weeks	CTT	Tabata Work:Rest	Music	CG	Duration
	Day: Monday, Wednesday, and Friday Circuit Station			Day: Monday, Wednesday, and Friday	
1-2	Station 1: Jumping Jacks Station 2: Plank Station 3: Push-up Station 4: Dumbbell lateral raise	20 s :10 s perstation	Shape of You (Tabata)	Exercise 1: Sprinting Drills Exercise 2: Push-up Exercise 3: Sit-up Exercise 4: Fartleks	15 minutes
3-4	Station 1: Down-dog toe touch Station 2: Plank Station 3: Shuttle run 10m Station 4: Plank jacks Station 5: Dumbbell lateral raise	20 s :10 s perstation	Poker Face (Tabata)	Exercise 1: Sprinting Drills Exercise 2: Push-up Exercise 3: Sit-up Exercise 4: Fartleks	15 minutes
5-6	Station 1: Side plank Station 2: Plank to push Station 3: Throwing tires Station 4: Mt. climbers Station 5: Dumbbell lateral raise Station 6: Shuttle run 10m	20 s :10 s perstation	Just Dance (Tabata)	Exercise 1: Sprinting Drills Exercise 2: Push-up Exercise 3: Sit-up Exercise 4: Fartleks	15 minutes
7-8	Station 1: Russian twist Station 2: Side plank Station 3: Throwing tires Station 4: Dumbbell lateral raise Station 5: Shuttle run 10m Station 6: Push-ups Station 7: Down-dog toe touch	20 s :10 s perstation	Mi Gente (Tabata)	Exercise 1: Sprinting Drills Exercise 2: Push-up Exercise 3: Sit-up Exercise 4: Fartleks	15 minutes
9-10	Station 1: Side plank Station 2: Plank to push Station 3: Dumbbell lateral raise Station 4: Plank jacks Station 5: Throwing tires	20 s :10 s perstation	Loco Contigo (Tabata)	Exercise 1: Sprinting Drills Exercise 2: Push-up Exercise 3: Sit-up Exercise 4: Fartleks	15 minutes
11-12	Station 1: Russian twist Station 2: Plank Station 3: Down-dog toe touch Station 4: Dumbbell lateral raise Station 5: Throwing tires Station 6: Push-ups Station 7: Shuttle run 10m Station 8: Side plank	20 s :10 s perstation	Despacito (Tabata)	Exercise 1: Sprinting Drills Exercise 2: Push-up Exercise 3: Sit-up Exercise 4: Fartleks	15 minutes

Results

In table 3 presents the reliability and variability on physical fitness and passion variables are in the range of .80 - .94. In addition, the Shapiro-Wilk and Levene's test on all variables in this study had a normal distribution (see Table 4).

Table 3
Reliability and variability of physical fitness and passion

Measures	ICC	95% CI
	Physical fitness	
HDT (kg)	.91	.96 to .99
5mST (s)	.80	.70 to .93
505CODT (s)	.94	.83 to .92
MBTT (cm)	.86	.79 to .97
SRT (cm)	.90	.85 to .94
YYIRTL1 (m)	.87	.88 to .97
	Passion	
HP (score)	.92	.75 to .97
OP (score)	.88	.84 to .86

Note: HDT = handgrip dynamometer test, 5mST =5m sprint test, 505CODT =5-0-5 COD test, MBTT = medicine ball throw test, SRT = sit and reach test, YYIRTL1= yo-yo intermittent recovery test level 1, HP = harmonious passion, OP = obsessive passion, ICC = intraclass correlation coefficient; CI = confidence intervals, SW = Shapiro-Wilk, LT = Levene's test.

Table 4
Shapiro-Wilk and Levene's test of physical fitness and passion

		SW	LT
		p	p
Physical fitness			
HDT (kg)	Pre	.162	.407
	Post	.200	.380
5mST (s)	Pre	.387	.230
	Post	.120	.345
505CODT (s)	Pre	.066	.149
	Post	.176	.281
MBTT (cm)	Pre	.148	.313
	Post	.422	.360
SRT (cm)	Pre	.491	.252
	Post	.344	.169
YYIRTL1 (m)	Pre	.357	.312
	Post	.450	.289
Passion			
HP (score)	Pre	.330	.124
	Post	.316	.344
OP (score)	Pre	.095	.381
	Post	.135	.430

Note: HDT = handgrip dynamometer test, 5mST =5m sprint test, 505CODT =5-0-5 COD test, MBTT = medicine ball throw test, SRT = sit and reach test, YYIRTL1= yo-yo intermittent recovery test level 1, HP = harmonious passion, OP = obsessive passion, SW = Shapiro-Wilk, LT = Levene's test.

Changes in Physical Fitness in CTT and CG

Based on the results of the repeated-measures two-way analysis of variance in table 5, it shows that there is a main effect of time (T) on the physical fitness variable with the HDT component ($F_{1\text{-}48}$ = 162.8, p < .001, η2p = .772), 5mST ($F_{1\text{-}48}$ = 100.0, p < .001, η2p = .676), 505CODT ($F_{1\text{-}48}$ = 26.0, p < .001, η2p = .351), MBTT ($F_{1\text{-}48}$ = 57.8, p < .001, η2p = .546), SRT ($F_{1\text{-}48}$ = 8.35, p = .006, η2p = .148), and YYIRTL1 ($F_{1\text{-}48}$ = 248, p < .001, η2p = .838). We also observed that there was a significant group (G) effect on HDT ($F_{1\text{-}48}$ = 13.6, p < .001, η2p = .221), 5mST ($F_{1\text{-}48}$ = 4.13, p = .048, η2p = .079), 505CODT ($F_{1\text{-}48}$ = 6.03, p = .018, η2p = .112), MBTT ($F_{1\text{-}48}$ = 8.85, p = .005, η2p = .156), SRT ($F_{1\text{-}48}$ = 9.13, p = .004, η2p = .160), and YYIRTL1 ($F_{1\text{-}48}$ = 11.8, p = .001, η2p = .197). In addition, we found that there was an interaction (I) between time (T) x group (G) on the HDT component ($F_{1\text{-}48}$ = 49.5, p < .001, η2p = .508), 5mST ($F_{1\text{-}48}$ = 84.0 p < .001, η2p = .636), 505CODT ($F_{1\text{-}48}$ = 21.9, p < .001, η2p = .313), MBTT ($F_{1\text{-}48}$ = 34.3, p < .001, η2p = .416), YYIRTL1 ($F_{1\text{-}48}$ = 217, p < .001, η2p = .819), but there was no significant interaction for SRT ($F_{1\text{-}48}$ = 0.164, p = .687, η2p = .003).

Based on the results of Paired student's t tests (see Fig. 3) and delta percentage (%Δ), we observed changes in physical fitness (HDT [%Δ = + 33.6, ES = -2.21], 5mST [%Δ = - 16.7, ES = 1.92], 505CODT [%Δ= - 13.1, ES = 0.97], MBTT [%Δ = + 13.8, ES = - 1.35], SRT [%Δ = +1.4, ES = - 0.88], and YYIRTL1 [%Δ = + 27.7, ES = - 3.06]) which was greater in CTT than CG (HDT [%Δ = + 9.4, ES = - 1.28], 5mST [%Δ = - 0.9, ES = 1.28], 505CODT [%Δ = - 0.4, ES = 1.56], MBTT [%Δ= + 2.0, ES = - 1.26], SRT [%Δ = - 0.0, ES = - 0.01], and YYIRTL1 [%Δ = + 0.9, ES = - 1.14]) , as presented in table 5.

Changes in Passion in CTT and CG

Based on the results of the repeated-measures two-way analysis of variance in table 6, it shows that there is a main effect of time (T) on the passion variable with components HP ($F_{1\text{-}48}$ = 676.00, p < .001, η2p = .827), and OP ($F_{1\text{-}48}$ = 248.5, p < .001, η2p = .838). We also observed that there was a significant group (G) effect on HP ($F_{1\text{-}48}$ = 7.29, p = .010, η2p = .132), and OP ($F_{1\text{-}48}$ = 5.36, p = .025, η2p = .100). In addition, we found that there was an interaction (I) between time (T) x group (G) on the HP ($F_{1\text{-}48}$ = 9.21, p = .004, η2p = .161), and OP ($F_{1\text{-}48}$ = 12.8, p < .001, η2p = .210).

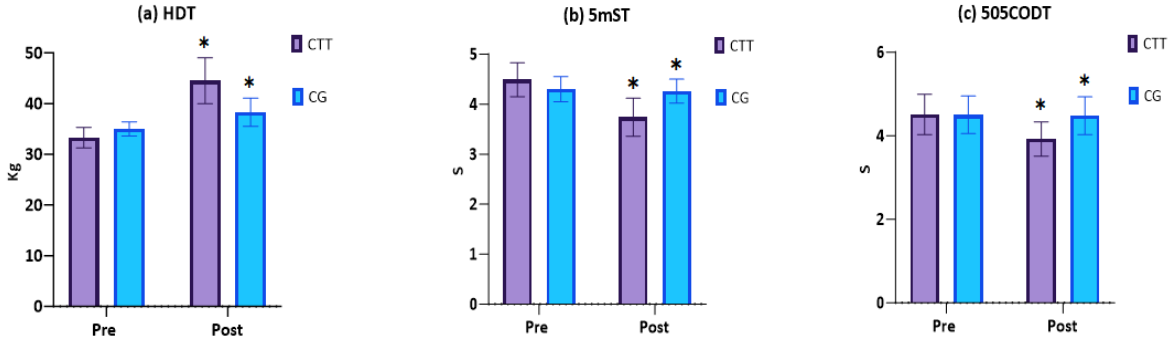
Based on the results of Paired student's t tests (see Fig. 4) and delta percentage (%Δ), we observed changes in passion (HP [%Δ = + 29.0, ES = - 2.24], and OP [%Δ = + 28.4, ES = - 2.69]), which is greater in CTT than CG (HP [%Δ = + 20.4, ES = - 2.09], and OP [%Δ = + 18.1, ES = - 1.76]), as presented in table 6.

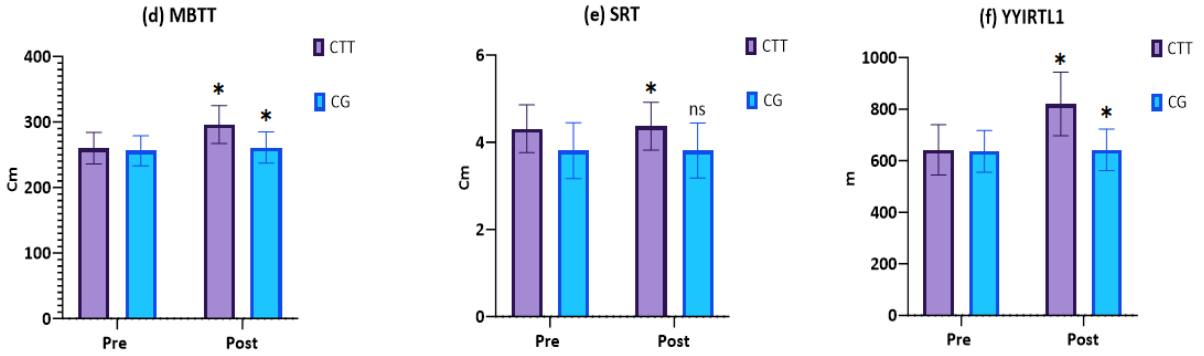
Table 5
Changes in physical fitness between CTT and CG

Outcome measures	CTT (*n* = 25)		%Δ	*ES*	CG (*n* = 25)		%Δ	*ES*	Time (T). Group (G), Interaction (I)
	Pre Mean ± *SD*	Post Mean ± *SD*			Pre Mean ± *SD*	Post Mean ± *SD*			
Physical Fitness									
HDT (kg)	33.3 ± 2.01	44.5 ± 4.52	+33.6	-2.21	35.0 ± 1.40	38.3 ± 2.78	+9.4	-1.28	*T:[$F_{1\text{-}48}$ = 162.8, p < .001, η2p = .772] *G:[$F_{1\text{-}48}$ = 13.6, p < .001, η2p = .221] *I:[$F_{1\text{-}48}$ = 49.5, p < .001, η2p = .508]
5mST (s)	4.49 ± 0.34	3.74 ± 0.38	-16.7	1.92	4.30 ± 0.25	4.26 ± 0.24	-0.9	1.28	*T:[$F_{1\text{-}48}$ = 100.0, p < .001, η2p = .676] *G:[$F_{1\text{-}48}$ = 4.13, p = .048, η2p = .079] *I:[$F_{1\text{-}48}$ = 84.0 p < .001, η2p = .636]
505CODT (s)	4.51 ± 0.48	3.92 ± 0.41	-13.1	0.97	4.50 ± 0.45	4.48 ± 0.45	-0.4	1.56	*T:[$F_{1\text{-}48}$ = 26.0, p < .001, η2p = .351] *G:[$F_{1\text{-}48}$ = 6.03, p = .018, η2p = .112] *I:[$F_{1\text{-}48}$ = 21.9, p < .001, η2p = .313]
MBTT (cm)	260 ± 24.2	296 ± 28.8	+13.8	-1.35	256 ± 22.9	261 ± 23.9	+2.0	-1.26	*T:[$F_{1\text{-}48}$ = 57.8, p < .001, η2p = .546] *G:[$F_{1\text{-}48}$ = 8.85, p = .005, η2p = .156] *I:[$F_{1\text{-}48}$ = 34.3, p < .001, η2p = .416]
SRT (cm)	4.31 ± 0.55	4.37 ± 0.55	+1.4	-0.88	3.81 ± 0.64	3.81 ± 0.63	-0.0	-0.01	*T [$F_{1\text{-}48}$ = 8.35, p = .006, η2p = .148] *G:[$F_{1\text{-}48}$ = 9.13, p = .004, η2p = .160] I:[$F_{1\text{-}48}$ = 0.164, p = .687, η2p = .003]
YYIRTL1 (m)	642 ± 97.4	820 ± 123.1	+27.7	-3.06	636 ± 81.1	642 ± 80.8	+0.9	-1.14	*T:[$F_{1\text{-}48}$ = 248, p < .001, η2p = .838] *G:[$F_{1\text{-}48}$ = 11.8, p = .001, η2p = .197] *I:[$F_{1\text{-}48}$ = 217, p < .001, η2p = .819]

Note: CTT = circuit tabata training, CG = control group, HDT = handgrip dynamometer test, 5mST =5m sprint test, 505CODT =5-0-5 COD test, MBTT = medicine ball throw test, SRT = sit and reach test, YYIRTL1= yo-yo intermittent recovery test level 1, %Δ = change, ES = effect size, η2p = partial eta-square; *****significant values obtained by the two-way ANOVA (p < 0.05).

Figure 3
Changes mean and SD in (a) HDT, (b) 5mST, (c) M505CODT, (d) MBTT, (e) SRT (f) YYIRTL1





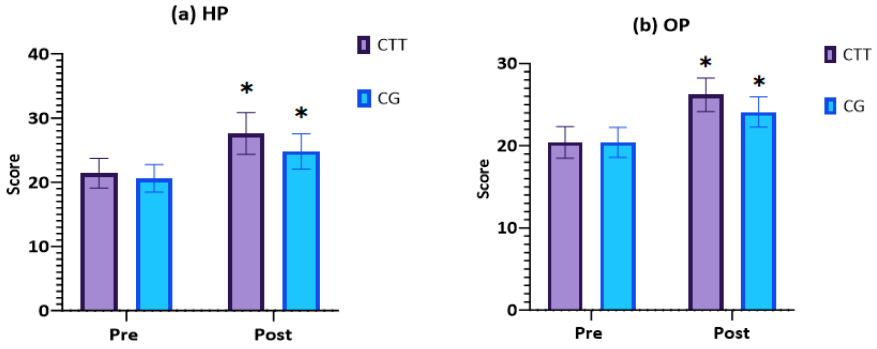
Note: ns = no significance, *significantly different from pre-post at $p < 0.05$.

Table 6
Changes in passion between CTT and CG

Outcome measures	CTT (n = 25)		%Δ	*ES*	CG (n = 25)		%Δ	*ES*	Time (T). Group (G), Interaction (I)
	Pre Mean ± *SD*	Post Mean ± *SD*			Pre Mean ± *SD*	Post Mean ± *SD*			
Passion									
HP (score)	21.4 ± 2.29	27.6 ± 3.25	+29.0	-2.24	20.6 ± 2.16	24.8 ± 2.76	+20.4	-2.09	*T:[$F_{1\text{-}48}$ = 676.00, p < .001, η2p = .827] *G: [$F_{1\text{-}48}$ = 7.29, p = .010, η2p = .132] *I: [$F_{1\text{-}48}$ = 9.21, p = .004, η2p = .161]
OP (score)	20.4 ± 1.93	26.2 ± 2.04	+28.4	-2.69	20.4 ± 1.83	24.1 ± 1.85	+18.1	-1.76	*T:[$F_{1\text{-}48}$ = 248.5, p < .001, η2p = .838] *G:[$F_{1\text{-}48}$ = 5.36, p = .025, η2p = .100] *I:[$F_{1\text{-}48}$ = 12.8, p < .001, η2p = .210]

Note: CTT = circuit tabata training, CG = control group, HP = harmonious passion, OP = obsessive passion, %Δ = change, ES = effect size, η2p = partial eta-square; *significant values obtained by the two-way ANOVA ($p < 0.05$).

Figure 4
Changes mean and SD in (a) HP, (b) OP



Note: *significantly different from pre-post at $p < 0.05$.

Discussion

This present study investigated the effects of CTT on improving the physical fitness and passion of young squash athletes through a 12-week experiment study.

This study has identified several findings. First, CTT is more effective than CG for inducing positive changes in physical fitness related to HDT, 5mST, 505CODT, MBTT, SRT, and YYIRTL1 components in young squash athletes. These results

highlight that the use of a CTT program designed by combining circuits with the tabata protocol has several advantages over CG in cultivating aspects of physical fitness. These results are consistent with previous study which reported that circuit training in combination with the tabata protocol was an ideal exercise to encourage positive changes in physical fitness among students aged 20-23 years at university level (Lee et al., 2021). Another study described similar results, athletes with low physical fitness experienced gradual improvement after following the CTT program for 8 weeks (Gutiérrez-Arroyo et al., 2023). On the other hand, Ho et al. (2024), reported that CTT consistently improved muscle performance in a short time. Similar findings have also been reported by Yunus et al. (2024), in their latest study, which used a true experimental design and 20 teenagers to administer the CTT intervention program, the findings showed that CTT could be an effective alternative training in improving the quality of low physical fitness to a higher level. In addition, other findings have acknowledged that carried out CTT repeatedly with stationary training tasks and high intensity (20:10) was an important tool in developing physical fitness to a higher level (Megahed et al., 2023). Likewise, Ajjimaporn et al. (2019), proved that a high-intensity circuit-based program for 4-weeks was sufficient to improve physical fitness components related to cardiorespiratory endurance. Marinho et al. (2022), supported the results of this study, CTT provided a significant increase in physical performance in men. Finally, in line with our results, Ballesta-García et al. (2019), showed that 12-weeks of CTT training generated a high impact on increasing strength, cardiorespiratory fitness, and gait/dynamic balance compared to CG. Furthermore, to our modeste knowledge, this is the initial study to find out whether CTT is more effective in encouraging positive changes in passion related to HP and OP in athletes than CG. These findings are in line with previous studies which reported that CTT used to increase exercise motivation levels (Wilke et al., 2018). In this research, CTT was proven to be able to influence the level of passion in athletes, this is because CTT has a program with various types of movement tasks which is accompanied with energetic music, so this is the main factor that causes athletes' passion to experience positive changes. Meanwhile, Putri et al. (2020), reported that another benefit provided by the CTT program is an improvement in attention function aspect.

The strength of our research is the positive effect of CTT on increasing physical fitness and passion in young squash athletes. The implications of this research related to the importance of CTT as an effective training method to encourage positive and major changes in physical fitness and passion. Apart from that, the feasibility of CTT causes it simple to implement, and without need to pay expensive costs. Although this research shows that 12 weeks of CTT produced improvements in physical fitness (HDT, 5mST, 505CODT, MBTT, SRT, YYIRTL1) and passion (HP, OP), it still has limitations. First, this study only involved male participants at one university in Indonesia. Therefore, we suggest the future research to involve male and female participants from several universities in Indonesia or other countries, to measure changes more accurately using this CTT for both genders. Moreover, it would be more interesting if future research could compare the effectiveness of CTT against other types of exercise.

Conclusions

We confirm and highlight that CTT can be the main factor causing positive changes in physical fitness (HDT, 5mST, 505CODT, MBTT, SRT, YYIRTL1), and passion (HP, OP) among young squash athletes. Although there are several limitations in this research, the positive results of our research prove that CTT can be used as an appropriate strategy, to provide more empirical evidence about the importance of continuing to investigate the effects of this training program. Moreover, it is expected that CTT can be implemented intensely by athletes and coaches around the world. This research contributes to the development of innovative training methods in squash, so that coaches can apply CTT to athletes continuously and ultimately achieve a high level of physical fitness and passion.

Ethics Committee Statement

This study was approved by the local Ethics Committee of Makasar State University, Indonesia (approval date: UNM-503/LPPM/01/01/2024). All procedures were in accordance with the latest amendment of the Declaration of Helsinki (Human Studies).

Conflict of Interest Statement

All authors confirm there is no conflict of interest.

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Authors' Contribution

Conceptualization I.I., E.S., A.T; Methodology E.S., Z.K., A.K; Software H.H., E.S; Validation E.S., I.I., B.B; Formal Analysis E.S., B.B; Investigation I.I., H.H., E.S; Resources I.I., H.H., S.S; Data Curation E.S; Writing – Original Draft I.I., E.S., Z.K; Writing – Review & Editing E.S., A.T., A.K., Z.K; Visualization I.I., B.B; Supervision E.S; Project Administration I.I., H.H., S.S; Funding Acquisition I.I., H.H., S.S. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Data supporting the findings of this study are available on request from the corresponding author (info@unm.ac.id); Data supporting the findings of this study are available at (Makassar State University repository).

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